DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR

GEOLOGIC ATLAS OF THE UNITED STATES

VAN HORN FOLIO

TEXAS

BY

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GEOLOGIC ATLAS OF THE UNITED STATES.

The Geological Survey is making a geologic atlas of the United States, which is being issued in parts, called folios. Each folio includes topographic and geologic maps of a certain area, together with descriptive text.

THE TOPOGRAPHIC MAP.

The features represented on the topographic map are of three distinct kinds—(1) inequalities of surface, called *relief*, as plains, plateaus, valleys, hills, and mountains; (2) distribution of water, called *drainage*, as streams, lakes, and swamps; (3) the works of man, called *culture*, as roads, railroads, boundaries, villages, and cities.

Relief.—All elevations are measured from mean sea level. The heights of many points are accurately determined, and those of the most important ones are given on the map in figures. It is desirable, however, to give the elevation of all parts of the area mapped, to delineate the outline or form of all slopes, and to indicate their grade or steepness. This is done by lines each of which is drawn through points of equal elevation above mean sea level, the vertical interval represented by each space between lines being the same throughout each map. These lines are called *contour lines* or, more briefly, *contours*, and the uniform vertical distance between each two contours is called the *contour interval*. Contour lines and elevations are printed in brown. The manner in which contour lines express altitude, form, and grade is shown in figure 1.

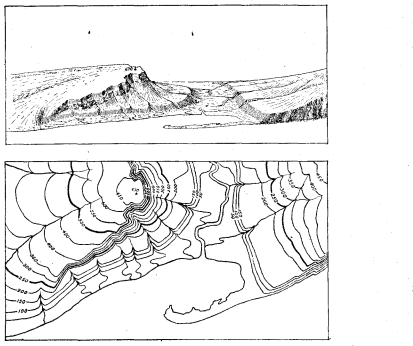


FIGURE 1.—Ideal view and corresponding contour map.

The sketch represents a river valley between two hills. In the foreground is the sea, with a bay that is partly closed by a hooked sand bar. On each side of the valley is a terrace. The terrace on the right merges into a gentle hill slope; that on the left is backed by a steep ascent to a cliff, or scarp, which contrasts with the gradual slope away from its crest. In the map each of these features is indicated, directly beneath its position in the sketch, by contour lines. The map does not include the distant portion of the view. The following notes may help to explain the use of contour lines:

1. A contour line represents a certain height above sea level. In this illustration the contour interval is 50 feet; therefore the contour lines are drawn at 50, 100, 150, and 200 feet, and so on, above mean sea level. Along the contour at 250 feet lie all points of the surface that are 250 feet above the sea—that is, this contour would be the shore line if the sea were to rise 250 feet; along the contour at 200 feet are all points that are 200 feet above the sea; and so on. In the space between any two contours are all points whose elevations are above the lower and below the higher contour. Thus the contour at 150 feet falls just below the edge of the terrace, and that at 200 feet lies above the terrace; therefore all points on the terrace are shown to be more than 150 but less than 200 feet above the sea. The summit of the higher hill is marked 670 (feet above sea level); accordingly the contour at 650 feet surrounds it. In this illustration all the contour lines are numbered, and those for 250 and 500 feet are accentuated by being made heavier. Usually it is not desirable to number all the contour lines. The accentuating and numbering of certain of them—say every fifth one—suffices and the heights of the others may be ascertained by counting up or down from these.

2. Contour lines show or express the forms of slopes. As contours are continuous horizontal lines, they wind smoothly about smooth surfaces, recede into all reentrant angles of ravines, and project in passing around spurs or prominences. These relations of contour curves and angles to forms of the landscape can be seen from the map and sketch.

3. Contour lines show the approximate grade of any slope. The vertical interval between two contours is the same, whether they lie along a cliff or on a gentle slope; but to attain a given height on a gentle slope one must go farther than on a steep slope, and therefore contours are far apart on gentle slopes and near together on steep ones.

A small contour interval is necessary to express the relief of a flat or gently undulating country; a steep or mountainous country can, as a rule, be adequately represented on the same scale by the use of a larger interval. The smallest interval used on the atlas sheets of the Geological Survey is 5 feet. This is in regions like the Mississippi Delta and the Dismal Swamp. For great mountain masses, like those in Colorado, the interval may be 250 feet and for less rugged country contour intervals of 10, 20, 25, 50, and 100 feet are used.

Drainage.—Watercourses are indicated by blue lines. For a perennial stream the line is unbroken, but for an intermittent stream it is broken or dotted. Where a stream sinks and reappears the probable underground course is shown by a broken blue line. Lakes, marshes, and other bodies of water are represented by appropriate conventional signs in blue.

Culture.—The symbols for the works of man and all lettering are printed in black.

Scales.—The area of the United States (exclusive of Alaska and island possessions) is about 3,027,000 square miles. A map of this area, drawn to the scale of 1 mile to the inch would cover 3,027,000 square inches of paper and measure about 240 by 180 feet. Each square mile of ground surface would be represented by a square inch of map surface, and a linear mile on the ground by a linear inch on the map. The scale may be expressed also by a fraction, of which the numerator is a length on the map and the denominator the corresponding length in nature expressed in the same unit. Thus, as there are 63,360 inches in a mile, the scale "1 mile to the inch" is expressed by the fraction $\frac{1}{63,360}$.

Three scales are used on the atlas sheets of the Geological Survey; they are $\frac{1}{250,000}$, $\frac{1}{125,000}$, and $\frac{1}{62,500}$, corresponding approximately to 4 miles, 2 miles, and 1 mile on the ground to an inch on the map. On the scale of $\frac{1}{62,500}$ a square inch of map surface represents about 1 square mile of earth surface; on the scale of $\frac{1}{125,000}$, about 4 square miles; and on the scale of $\frac{1}{250,000}$, about 16 square miles. At the bottom of each atlas sheet the scale is expressed in three ways—by a graduated line representing miles and parts of miles, by a similar line indicating distance in the metric system, and by a fraction.

Atlas sheets and quadrangles.—The map of the United States is being published in atlas sheets of convenient size, which represent areas bounded by parallels and meridians. These areas are called *quadrangles*. Each sheet on the scale of $\frac{1}{250,000}$ represents one square degree—that is, a degree of latitude by a degree of longitude; each sheet on the scale of $\frac{1}{125,000}$ represents one-fourth of a square degree, and each sheet on the scale of $\frac{1}{62,500}$ one-sixteenth of a square degree. The areas of the corresponding quadrangles are about 4000, 1000, and 250 square miles, though they vary with the latitude.

The atlas sheets, being only parts of one map of the United States, are not limited by political boundary lines, such as those of States, counties, and townships. Many of the maps represent areas lying in two or even three States. To each sheet, and to the quadrangle it represents, is given the name of some well-known town or natural feature within its limits, and at the sides and corners of each sheet are printed the names of adjacent quadrangles, if the maps are published.

THE GEOLOGIC MAPS.

The maps representing the geology show, by colors and conventional signs printed on the topographic base map, the distribution of rock masses on the surface of the land and, by means of structure sections, their underground relations, so far as known and in such detail as the scale permits.

KINDS OF ROCKS.

Rocks are of many kinds. On the geologic map they are distinguished as igneous, sedimentary, and metamorphic.

Igneous rocks.—Rocks that have cooled and consolidated from a state of fusion are known as *igneous*. Molten material has from time to time been forced upward in fissures or channels of various shapes and sizes through rocks of all ages to or nearly to the surface. Rocks formed by the consolidation of molten material, or magma, within these channels—that is, below the surface—are called *intrusive*. Where the intrusive rock occupies a fissure with approximately parallel walls it is called a *dike*; where it fills a large and irregular conduit the mass is termed a *stock*. Where molten magma traverses stratified rocks it may be intruded along bedding planes; such masses are called *sills* or *sheets* if comparatively thin, and *laccoliths* if they occupy larger chambers produced by the pressure of the magma. Where inclosed by rock molten material cools slowly, with the result that intrusive rocks are generally of crystalline texture. Where the channels reach the surface the molten material poured out through them is called *lava*, and lavas often build up volcanic mountains. Igneous rocks that have solidified at the surface are called *extrusive* or *effusive*. Lavas generally cool more rapidly than intrusive rocks and as a rule contain, especially in their superficial parts, more or less volcanic glass, produced by rapid chilling. The outer parts of lava flows also are usually porous, owing to the expansion of the gases originally present in the magma. Explosive action, due to these gases, often accompanies volcanic eruptions, causing ejections of dust, ash, lapilli, and larger fragments. These materials, when consolidated, constitute breccias, agglomerates, and tuffs.

Sedimentary rocks.—Rocks composed of the transported fragments or particles of older rocks that have undergone disintegration, of volcanic ejecta deposited in lakes and seas, or of materials deposited in such water bodies by chemical precipitation are termed *sedimentary*.

The chief agent in the transportation of rock débris is water in motion, including rain, streams, and the water of lakes and of the sea. The materials are in large part carried as solid particles, and the deposits are then said to be mechanical. Such are gravel, sand, and clay, which are later consolidated into conglomerate, sandstone, and shale. Some of the materials are carried in solution, and deposits of these are called organic if formed with the aid of life, or chemical if formed without the aid of life. The more important rocks of chemical and organic origin are limestone, chert, gypsum, salt, iron ore, peat, lignite, and coal. Any one of the kinds of deposit named may be separately formed, or the different materials may be intermingled in many ways, producing a great variety of rocks.

Another transporting agent is air in motion, or wind, and a third is ice in motion, or glaciers. The most characteristic of the wind-borne or eolian deposits is loess, a fine-grained earth; the most characteristic of glacial deposits is till, a heterogeneous mixture of bowlders and pebbles with clay or sand.

Sedimentary rocks are usually made up of layers or beds which can be easily separated. These layers are called *strata*, and rocks deposited in such layers are said to be stratified.

The surface of the earth is not immovable; over wide regions it very slowly rises or sinks, with reference to the sea, and shore lines are thereby changed. As a result of upward movement marine sedimentary rocks may become part of the land, and most of our land areas are in fact occupied by rocks originally deposited as sediments in the sea.

Rocks exposed at the surface of the land are acted on by air, water, ice, animals, and plants, especially the low organisms known as bacteria. They gradually disintegrate and the more soluble parts are leached out, the less soluble material being left as a *residual* layer. Water washes this material down the slopes, and it is eventually carried by rivers to the ocean or other bodies of water. Usually its journey is not continuous, but it is temporarily built into river bars and flood plains, where it forms *alluvium*. Alluvial deposits, glacial deposits (collectively known as *drift*), and eolian deposits belong to the *surficial* class, and the residual layer is commonly included with them. Their upper parts, occupied by the roots of plants, constitute soils and subsoils, the soils being usually distinguished by a notable admixture of organic matter.

Metamorphic rocks.—In the course of time, and by various processes, rocks may become greatly changed in composition and in texture. If the new characteristics are more pronounced than the old such rocks are called *metamorphic*. In the process of metamorphism the constituents of a chemical rock may enter into new combinations and certain substances may be lost or new ones added. A complete gradation from the primary to the metamorphic form may exist within a single rock mass. Such changes transform sandstone into quartzite and limestone into marble and modify other rocks in various ways.

From time to time during geologic ages rocks that have been deeply buried and have been subjected to enormous pressures, to slow movement, and to igneous intrusion have been afterward raised and later exposed by erosion. In such rocks the original structures may have been lost entirely and new ones substituted. A system of planes of division, along which the rock splits most readily, may have been developed. This structure is called *cleavage* and may cross the original bedding planes at any angle. The rocks characterized by it are *slates*. Crystals of mica or other minerals may have grown in the rock in such a way as to produce a laminated or foliated structure known as *schistosity*. The rocks characterized by this structure are *schists*.

As a rule, the oldest rocks are most altered and the younger formations have escaped metamorphism, but to this rule there are many important exceptions, especially in regions of igneous activity and complex structure.

FORMATIONS.

For purposes of geologic mapping rocks of all the kinds above described are divided into *formations*. A sedimentary formation contains between its upper and lower limits either rocks of uniform character or rocks more or less uniformly varied in character, as, for example, an alternation of shale and limestone. Where the passage from one kind of rocks to another is gradual it may be necessary to separate two contiguous formations by an arbitrary line, and in some cases the distinction depends almost entirely on the contained fossils. An igneous formation contains one or more bodies of one kind, of similar occurrence, or of like origin. A metamorphic formation may consist of rock of uniform character or of several rocks having common characteristics or origin.

When for scientific or economic reasons it is desirable to recognize and map one or more specially developed parts of a varied formation, such parts are called *members*, or by some other appropriate term, as *lentils*.

AGES OF ROCKS.

Geologic time.—The time during which rocks were made is divided into *periods*. Smaller time divisions are called *epochs*, and still smaller ones *stages*. The age of a rock is expressed by the name of the time interval in which it was formed.

The sedimentary formations deposited during a period are grouped together into a *system*. The principal divisions of a system are called *series*. Any aggregate of formations less than a series is called a *group*.

Inasmuch as sedimentary deposits accumulate successively the younger rest on those that are older, and their relative ages may be determined by observing their positions. In many regions of intense disturbance, however, the beds have been overturned by folding or superposed by faulting, so that it may be difficult to determine their relative ages from their present positions; under such conditions fossils, if present, may indicate which of two or more formations is the oldest.

Many stratified rocks contain *fossils*, the remains or imprints of plants and animals which, at the time the strata were deposited, lived in bodies of water or were washed into them, or were buried in surficial deposits on the land. Such rocks are called fossiliferous. By studying fossils it has been found that the life of each period of the earth's history was to a great extent different from that of other periods. Only the simpler kinds of marine life existed when the oldest fossiliferous rocks were deposited. From time to time more complex kinds developed, and as the simpler ones lived on in modified forms life became more varied. But during each period there lived peculiar forms, which did not exist in earlier times and have not existed since; these are *characteristic types*, and they define the age of any bed of rock in which they are found. Other types passed on from period to period, and thus linked the systems together, forming a chain of life from the time of the oldest fossiliferous rocks to the present. Where two sedimentary formations are remote from each other and it is impossible to observe their relative positions, the characteristic fossil types found in them may determine which was deposited first. Fossil remains in the strata of different areas, provinces, and continents afford the most important means for combining local histories into a general earth history.

It is many places difficult or impossible to determine the age of an igneous formation, but the relative age of such a formation can in general be ascertained by observing whether an associated sedimentary formation of known age is cut by the igneous mass or is deposited upon it. Similarly, the time at which metamorphic rocks were formed from the original masses may be shown by their relations to adjacent formations of known age; but the age recorded on the map is that of the original masses and not that of their metamorphism.

Symbols, colors, and patterns.—Each formation is shown on the map by a distinctive combination of color and pattern and is labeled by a special letter symbol.

Patterns composed of parallel straight lines are used to represent sedimentary formations deposited in the sea, in lakes, or in other bodies of standing water. Patterns of dots and circles represent alluvial, glacial, and eolian formations. Patterns of triangles and rhombs are used for igneous formations. Metamorphic rocks of unknown origin are represented by short dashes irregularly placed; if the rock is schist the dashes may be arranged in wavy lines parallel to the structure planes. Suitable combination patterns are used for metamorphic formations known to be of sedimentary or of igneous origin. The patterns of each class are printed in various colors. With the patterns of parallel lines, colors are used to indicate age, a particular color being assigned to each system.

The symbols consist each of two or more letters. If the age of a formation is known the symbol includes the system symbol, which is a capital letter or monogram; otherwise the symbols are composed of small letters.

The names of the systems and of series that have been given distinctive names, in order from youngest to oldest, with the color and symbol assigned to each system, are given in the subjoined table.

Symbols and colors assigned to the rock systems.

	System.	Series.	Symbol.	Color for sedimentary rocks.
Cenozoic	Quaternary	Recent Pleistocene	Q	Brownish yellow.
	Tertiary	Pliocene Miocene Oligocene Eocene	T	Yellow ocher.
Mesozoic	Cretaceous		K	Olive-green.
	Jurassic		J	Blue-green.
	Triassic		Ꞧ	Peacock-blue.
Paleozoic	Carboniferous	Permian Pennsylvanian Mississippian	C	Blue.
	Devonian		D	Blue-gray.
	Silurian		S	Blue-purple.
	Ordovician		O	Red-purple.
	Cambrian		Є	Brick-red.
	Algonkian		A	Brownish red.
	Archean		Æ	Gray-brown.

SURFACE FORMS.

Hills, valleys, and all other surface forms have been produced by geologic processes. For example, most valleys are the result of erosion by the streams that flow through them (see fig. 1), and the alluvial plains bordering many streams were built up by the streams; waves cut sea cliffs and, in cooperation with currents, build up sand spits and bars. Topographic forms thus constitute part of the record of the history of the earth.

Some forms are inseparably connected with deposition. The hooked spit shown in figure 1 is an illustration. To this class belong beaches, alluvial plains, lava streams, drumlins (smooth oval hills composed of till), and moraines (ridges of drift made at the edges of glaciers). Other forms are produced by erosion. The sea cliff is an illustration; it may be carved from any rock. To this class belong abandoned river channels, glacial furrows, and peneplains. In the making of a stream terrace an alluvial plain is first built and afterward partly eroded away. The shaping of a marine or lacustrine plain is usually a double process, hills being worn away (*degraded*) and valleys being filled up (*aggraded*).

All parts of the land surface are subject to the action of air, water, and ice, which slowly wear them down, and streams carry the waste material to the sea. As the process depends on the flow of water to the sea, it can not be carried below sea level, and the sea is therefore called the *base-level* of erosion. Lakes or large rivers may determine local base-levels for certain regions. When a large tract is for a long time undisturbed by uplift or subsidence it is degraded nearly to base-level, and the fairly even surface thus produced is called a *peneplain*. If the tract is afterward uplifted, the elevated peneplain becomes a record of the former close relation of the tract to base-level.

THE VARIOUS GEOLOGIC SHEETS.

Areal geology map.—The map showing the areas occupied by the various formations is called an *areal geology map*. On the margin is a *legend*, which is the key to the map. To ascertain the meaning of any color or pattern and its letter symbol the reader should look for that color, pattern, and symbol in the legend, where he will find the name and description of the formation. If it is desired to find any particular formation, its name should be sought in the legend and its color and pattern noted; then the areas on the map corresponding in color and pattern may be traced out. The legend is also a partial statement of the geologic history. In it the names of formations are arranged in columnar form, grouped primarily according to origin—sedimentary, igneous, and crystalline of unknown origin—and within each group they are placed in the order of age, so far as known, the youngest at the top.

Economic geology map.—The map representing the distribution of useful minerals and rocks and showing their relations to the topographic features and to the geologic formations is termed the *economic geology map*. The formations that appear on the areal geology map are usually shown on this map by fainter color patterns and the areas of productive formations are emphasized by strong colors. A mine symbol shows the location of each mine or quarry and is accompanied by the name of the principal mineral mined or stone quarried. If there are important mining industries or artesian basins in the area special maps to show these additional economic features are included in the folio.

Structure-section sheet.—In cliffs, canyons, shafts, and other natural and artificial cuttings the relations of different beds to one another may be seen. Any cutting that exhibits those relations is called a *section*, and the same term is applied to a diagram representing the relations. The arrangement of rocks in the earth is the earth's *structure*, and a section exhibiting this arrangement is called a *structure section*.

The geologist is not limited, however, to natural and artificial cuttings for his information concerning the earth's structure. Knowing the manner of formation of rocks and having traced out the relations among the beds on the surface, he can infer their relative positions after they pass beneath the surface and can draw sections representing the structure to a considerable depth. Such a section is illustrated in figure 2.

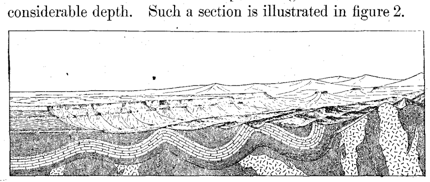


FIGURE 2.—Sketch showing a vertical section at the front and a landscape beyond.

The figure represents a landscape which is cut off sharply in the foreground on a vertical plane, so as to show the underground relations of the rocks. The kinds of rock are indicated by appropriate patterns of lines, dots, and dashes. These patterns admit of much variation, but those shown in figure 3 are used to represent the commoner kinds of rock.

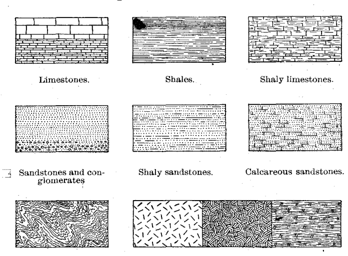


FIGURE 3.—Symbols used in sections to represent different kinds of rocks.

The plateau shown at the left of figure 2 presents toward the lower land an escarpment, or front, which is made up of sandstones, forming the cliffs, and shales, constituting the slopes. The broad belt of lower land is traversed by several ridges, which are seen in the section to correspond to the outcrops of a bed of sandstone that rises to the surface. The upturned edges of this bed form the ridges, and the intermediate valleys follow the outcrops of limestone and calcareous shale.

Where the edges of the strata appear at the surface their thickness can be measured and the angles at which they dip below the surface can be observed. Thus their positions underground can be inferred. The direction of the intersection of a bed with a horizontal plane is called the *strike*. The inclination of the bed to the horizontal plane, measured at right angles to the strike, is called the *dip*.

In many regions the strata are bent into troughs and arches, such as are seen in figure 2. The arches are called *anticlines* and the troughs *synclines*. As the sandstones, shales, and limestones were deposited beneath the sea in nearly flat sheets, the fact that they are now bent and folded is proof that forces have from time to time caused the earth's surface to wrinkle along certain zones. In places the strata are broken across and the parts have slipped past each other. Such breaks are termed *faults*. Two kinds of faults are shown in figure 4.

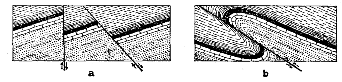


FIGURE 4.—Ideal sections of strata, showing (a) *normal* faults and (b) a *thrust* or *reverse* fault.

At the right of figure 2 the section shows schists that are traversed by igneous rocks. The schists are much contorted and their arrangement underground can not be inferred. Hence that portion of the section delineates what is probably true but is not known by observation or by well-founded inference.

The section also shows three sets of formations, distinguished by their underground relations. The uppermost set, seen at the left, is made up of sandstones and shales, which lie in a horizontal position. These strata were laid down under water but are now high above the sea, forming a plateau, and their change of elevation shows that a portion of the earth's mass has been uplifted. The strata of this set are parallel, a relation which is called *conformable*.

The second set of formations consists of strata that have been folded into arches and troughs. These strata were once continuous, but the crests of the arches have been removed by erosion. The beds, like those of the first set, are conformable.

The horizontal strata of the plateau rest upon the upturned, eroded edges of the beds of the second set shown at the left of the section. The overlying deposits are, from their position, evidently younger than the underlying deposits, and the bending and eroding of the older beds must have occurred between their deposition and the accumulation of the younger beds. The younger rocks are *unconformable* to the older, and the surface of contact is an *unconformity*.

The third set of formations consists of crystalline schists and igneous rocks. At some period of their history the schists were folded or plicated by pressure and traversed by eruptions of molten rock. But the pressure and intrusion of igneous rocks have not affected the overlying strata of the second set. Thus it is evident that a considerable interval elapsed between the formation of the schists and the beginning of deposition of the strata of the second set. During this interval the schists were metamorphosed, they were disturbed by eruptive activity, and they were deeply eroded. The contact between the second and third sets is another unconformity; it marks a time interval between two periods of rock formation.

The section and landscape in figure 2 are ideal, but they illustrate actual relations. The sections on the structure-section sheet are related to the maps as the section in the figure is related to the landscape. The profile of the surface in the section corresponds to the actual slopes of the ground along the section line, and the depth from the surface of any mineral-producing or water-bearing stratum that appears in the section may be measured by using the scale of the map.

Columnar section.—The geologic maps are usually accompanied by a *columnar section*, which contains a concise description of the sedimentary formations that occur in the quadrangle. It presents a summary of the facts relating to the character of the rocks, the thickness of the formations, and the order of accumulation of successive deposits.

The rocks are briefly described, and their characters are indicated in the columnar diagram. The thicknesses of formations are given in figures that state the least and greatest measurements, and the average thickness of each formation is shown in the column, which is drawn to scale. The order of accumulation of the sediments is shown in the columnar arrangement—the oldest being at the bottom, the youngest at the top.

The intervals of time that correspond to events of uplift and degradation and constitute interruptions of deposition are indicated graphically and by the word "unconformity."

GEORGE OTIS SMITH,
Director.

May, 1909.

DESCRIPTION OF THE VAN HORN QUADRANGLE.

By G. B. Richardson.

INTRODUCTION.

GENERAL RELATIONS.

The Van Horn quadrangle is situated in El Paso and Culberson counties, Tex., about 100 miles southeast of El Paso. It is bounded by parallels 31° and 31° 30′ and meridians 104° 30′ and 105° and includes 1019 square miles. This area lies within the Cordilleran region, about midway between Pecos River and the Rio Grande, and forms a part of what is known as trans-Pecos Texas. (See index map, fig. 1.)

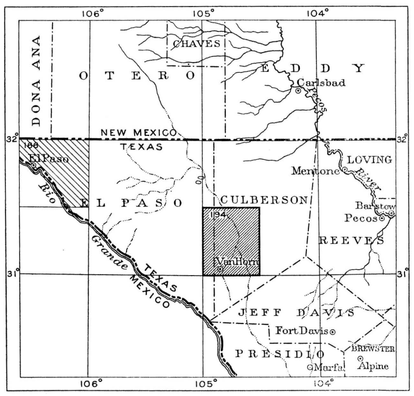


FIGURE 1.—Index map of part of trans-Pecos region, Texas and New Mexico.

The location of the Van Horn quadrangle is shown by the darker ruling. The El Paso folio (No. 166), previously published, is indicated by lighter ruling.

TRANS-PECOS TEXAS.

Characteristic features.—Trans-Pecos Texas, which lies west of Pecos River, is distinctly different from the eastern part of the State in topography, climate, and geology. The surface of the greater part of Texas consists of plains, but trans-Pecos Texas is mountainous, the boundary between the two parts being marked by the northern course of the Pecos. The part of the Cordillera that is included in trans-Pecos Texas is the southern continuation of the central mountainous area of New Mexico, and is characterized by an assemblage of diverse topographic forms which individually resemble features of the Rocky Mountain province on the north, the Basin Range province on the west, and the Mexican Plateau province on the southwest. Topographically the trans-Pecos region forms a transition between these provinces.

Relief.—The trans-Pecos region lies in a belt of comparatively low country that extends across the interior of the continent. Paisano, the highest pass through the Cordilleran range on the Sunset Route of the Southern Pacific system, has an altitude of 5082 feet, and the summit of the Texas & Pacific Railway, which is in the Van Horn quadrangle, has an altitude of 4603 feet. Only two peaks rise higher than 8000 feet above sea level and the lowlands commonly range in height from 3500 to 4500 feet.

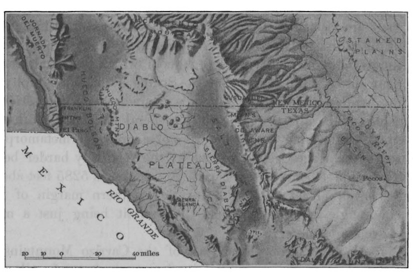


FIGURE 2.—Relief map of part of trans-Pecos region, Texas and New Mexico.

The Van Horn quadrangle lies in the south-central part of the area, including the southeast end of the Sierra Diablo and the west end of the Apache Mountains.

The region is characterized by mountains and intermontane plains having a northwest trend. (See fig. 2.) In general the highlands lack continuity, consisting of isolated peaks, groups of peaks, plateaus, narrow ridges, and broad monoclinal slopes. The intermontane plains are called bolsons, a term of Spanish origin, current in Mexico, which is being introduced into the southwestern part of the United States. Bolsons are aggradation plains that commonly occupy structural basins and have been built up by wash derived from the disintegration of the rocks of adjacent highlands. Their central parts are almost level, but their margins slope up toward the highlands. Some bolsons are closed basins, being entirely surrounded by a rim, but many have outlets, which, however, in this arid climate, are practically free from surface drainage, unless the bolson is crossed by one of the few perennial streams of the region. If the climate were more humid bolson plains would not be formed, for the débris, instead of accumulating, would be carried away by streams.

Climate.—Many of the characteristic features of the trans-Pecos region are due to its arid climate. The annual precipitation on the greater part of the area is only about 15 inches and in places is less than 10 inches. The common type of rainfall is the occasional heavy local summer shower of short duration. Such showers give rise to local torrential floods but yield no permanent run-off, for the short-lived streams that gather in the highlands disappear by absorption and evaporation shortly after reaching the lowlands.

The aridity of the climate is emphasized by the character of the vegetation, which is sparse and of the desert type, so that the general appearance of the country is barren. (See Pls. I to IX, illustration sheet.) Desert growths like yucca, lechuguilla, cacti, sotol, ocotillo, creosote bush, cat's-claw, mesquite, and a variety of bunch grasses are common. Except a few stunted junipers and piñons on some of the highlands there are no trees in the Van Horn quadrangle. Only the highest mountains of the trans-Pecos region, like the Sacramento Mountains in New Mexico, support a forest growth.

Meteorologic records that have been kept for more than 30 years at El Paso indicate the general features of the climate of trans-Pecos Texas. The mean annual precipitation is only 9.8 inches, most of which occurs in heavy local showers and more than half of which falls during July, August, and September. The mean annual temperature is 63.4° F., the mean monthly maximum ranging from 57° in January to 96° in June, and the mean monthly minimum from 31° in January to 69° in July. The average daily range of temperature for the year in a thermometer shelter is about 26° and on exposed rock surfaces is probably more than twice that amount. The mean annual relative humidity is 38.8 per cent and the annual evaporation is about 82 inches. The annual average wind velocity is 10 miles an hour, the maximum figure on record being 78 miles an hour. Velocities of 50 to 60 miles an hour for short periods are not uncommon.

Geology. — The sedimentary rocks of trans-Pecos Texas include representatives of almost all the systems from the Algonkian to the Quaternary and are intruded or overlain, in parts of the area, by a variety of igneous rocks, as stated under the heading "Descriptive geology" (p. 3).

NORTHERN TRANS-PECOS TEXAS.

Across the northern part of trans-Pecos Texas, in the midst of which the Van Horn quadrangle is situated, run three belts of highland separated by parallel belts of lowland, all having a northwest-southeast trend. (See fig. 2.) Named in order from west to east they are the Franklin Mountains, the Hueco Bolson, the Diablo Plateau, Salt Flat, the Guadalupe-Delaware-Apache Mountains, and Toyah Basin (Pecos Valley). An outline geologic map of this strip of country is shown in figure 3.

Franklin Mountains.—The Franklin Mountains are the southern extremity of a broken chain about 10 miles wide and 250 miles long, lying east of the Rio Grande valley and extending from the termination of the main mass of the Rocky Mountains in northern New Mexico southward to El Paso. The main part of the Franklin Range lies entirely in Texas and is 15 miles long and about 3 miles wide, but low outlying hills extend from the range northward a few miles beyond the State boundary. The mountains rise more than 3000 feet above the Rio Grande valley on the west and the Hueco Bolson on the east, culminating in a peak 7152 feet above sea level. The western face of the range is comparatively little eroded and in the main constitutes a dip slope; the eastern face, on the contrary, is much dissected and exposes cross sections of the strata.

The Franklin Mountains are composed chiefly of pre-Cambrian and Paleozoic rocks that strike in general parallel to the trend of the range and dip westward at steep angles. The pre-Cambrian rocks consist of quartzite overlain by rhyolite porphyry. The Paleozoic strata consist of Cambrian sandstone overlain by limestone containing Ordovician, Silurian, and upper Carboniferous (Pennsylvanian) fossils. Devonian time, so far as known, is not represented by sediments, although some relatively thin bedded limestone that overlies the massive Silurian beds may be of Devonian age. The Mississippian and Permian series are absent. Granite of post-Paleozoic age outcrops along the eastern base of the mountains. Faults border the eastern and western margins of the range and other faults cut it internally. The range is a westward-tilted fault block in a mature stage of erosion.

Hueco Bolson.—One of the largest of the intermontane plains of the trans-Pecos region is the Hueco Bolson, which, with its northward and southward continuations, is more than 200 miles long, about half of it lying on each side of the Texas-New Mexico boundary. Its width is irregular, averaging possibly 25 miles. Its greater part lies about 4000 feet above sea level and is bordered by mountains that rise 2000 to 5000 feet higher. On the west are the San Andreas, Organ, and Franklin ranges and others in Mexico; on the east are the Sierra Blanca, Sacramento, Hueco, Finlay, and Quitman mountains. As a whole the lowland is a unit, but it is divided into two distinct parts by a low transverse débris-covered divide a few miles north of the State boundary. The northern part, known as the Tularosa Desert, is a closed basin with no drainage outlet, a large part of its surface being occupied by salt flats and dunes of white gypsiferous sand. The southern part contains practically no salt or gypsum and is crossed by the Rio Grande, which has cut its valley more than 200 feet beneath the general level. Structurally the bolson is a trough occupied by more than 2000 feet of unconsolidated deposits, the upper part of which is proved by fossil bones to be of Pleistocene age, though the lower part may be Tertiary.

Diablo Plateau.—Northeast of the Hueco Bolson is the Diablo Plateau, a flattish-topped upland having an area of

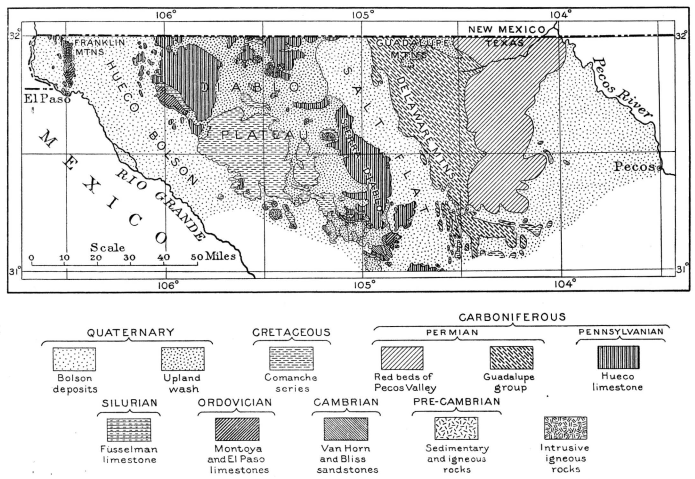


FIGURE 3.—Generalized geologic map of northern trans-Pecos Texas.

about 2500 square miles. A general view of the plateau escarpment from the east is shown in Plate II. The surface includes few broad, flat areas and in general slopes gently eastward in the western part and westward in the eastern part, yet as a whole its plateau character is distinct.

The eroded escarpments of the Diablo Plateau are known by different names. One of them, the Sierra Diablo, at the southeast border of the plateau, bounds an irregular quadrilateral area—on the south by an east-west escarpment 15 miles long, on the east by a north-south escarpment 25 miles long, and on the northeast by a northwest-southeast escarpment 15 miles long. The Sierra Diablo is highest along its eastern escarpment, culminating in a point 6630 feet above sea level. From the crest the general surface slopes gradually westward toward the center of the plateau. North of the Sierra Diablo, near the State boundary, the northeast border of the plateau is marked by the Corundas Mountains and the Sierra Tinaja Pinta, two groups of isolated peaks of igneous rock and lava-capped mesas flanked by Paleozoic and Cretaceous strata. The western border of the plateau, north of the Texas & Pacific Railway, is known as the Finlay Mountains, and farther north, near the State boundary, as the Hueco Mountains, the two areas being separated by an escarpment about 500 feet high and 20 miles long. Southeast of the Diablo Plateau is an area of relatively low hills and ridges known as the Carrizo Mountains.

The plateau is formed of horizontal or gently inclined strata of Carboniferous age, capped in places by Cretaceous sediments, and underlain locally by older Paleozoic strata that outcrop in places on the lower slopes of the escarpments. The crests of the escarpments are at most places formed by massive limestone of Carboniferous age. The strata of the Finlay Mountains are deformed into a rude dome and are extensively intruded by dikes, suggesting that the doming is laccolithic. The Carrizo Mountains are formed chiefly of rocks of pre-Cambrian and early Paleozoic age. The beds have been deformed, the pre-Cambrian strata have been metamorphosed, and the whole complex is overlain unconformably by Cambrian (?), Ordovician, and Carboniferous strata. The plateau area is bordered on both sides by faults separating it from the lowlands, and it is also cut by a number of cross faults.

Salt Flat.—Another large bolson of the trans-Pecos country is known as Salt Flat. It is more than 100 miles long, its average width is about 15 miles, and it has the prevailing northwest-southeast trend. It occupies a structural trough and is a closed basin with no drainage outlet. The lowest point on its floor is less than 3600 feet above sea level, and the lowest point on the divide bounding its drainage area is about 4250 feet above sea level. With adequate rainfall the basin would fill up to that level, forming an enormous lake, and would overflow into the Rio Grande, which 18 miles south of the Van Horn quadrangle, at the mouth of Van Horn Creek, has an elevation of only 3050 feet.

The tributary drainage area of Salt Flat, consisting of more than 8000 square miles, is bounded by the Sacramento Mountains on the north, by the Guadalupe, Delaware, Apache, and Davis mountains on the east, by the Chinati Mountains on the south, and by the Sierra Vieja, the Van Horn and Eagle mountains, and the Diablo Plateau on the west. The main part of the bolson lies north of the Texas & Pacific Railway and extends into New Mexico. South of the railroad it is divided into two parts by the Wylie and Chispa mountains and associated highlands. The western part, known as Ryan Flat, extends almost as far as Marfa and is traversed by the Southern Pacific Railroad. The lowest part of the basin is marshy and is commonly floored with gypsum and near the State boundary contains a salt deposit of local commercial importance, but the greater part is underlain to an unknown depth by gravel, sand, and clay washed in from the adjacent highlands.

Guadalupe and Delaware mountains.—The dominant topographic feature of the eastern Cordilleras in this latitude is the highland mass comprising the Guadalupe, Delaware, and Apache mountains. These mountains extend southward from New Mexico into Texas and separate the lowland of Salt Flat on the west from the Pecos Valley on the east. They form a broad eastward-sloping plateau with a steep scarp rising 1000 to almost 5000 feet above Salt Flat.

The Guadalupe Mountains extend across the State boundary about 45 miles west of Pecos River, where they are 10 miles wide, but they narrow southward, and about 10 miles south of the boundary they terminate abruptly in a precipitous cliff known as Guadalupe Point. El Capitan Peak, one-fourth mile north of Guadalupe Point, rises 8690 feet above sea level and is the highest point in Texas.

The Delaware Mountains are the southern continuation of the Guadalupe Mountains. They extend southeastward uninterruptedly for about 40 miles to Seven-Heart Gap, south of which the upland area is known as the Apache Mountains. The Delaware Mountains constitute a typical cuesta (see fig. 2), with a southwestward-facing scarp 1000 to 2000 feet high, from whose crest the surface slopes gradually northeastward, conforming approximately with the dip of the underlying rocks.

The rocks of the Guadalupe and Delaware mountains consist of sandstone and limestone containing an abundant Carboniferous fauna. These strata outcrop in the escarpment and in a belt 15 miles wide that extends along the eastern slope of the mountains, beyond which, in a gently eastward-sloping plain, they are overlain by bedded gypsum. On the east a narrow range of low hills, capped by gently folded limestone and sandstone, intervenes in places between the gypsum plain and the Pecos Valley. The gypsum and the overlying limestone and sandstone are members of the group of Permian red beds that outcrop in the Pecos Valley and underlie the Llano Estacado.

Pecos Valley.—Pecos River rises in the Rocky Mountains in northern New Mexico, flows southeastward, for the greater part of its course, through the Great Plains province, and empties into the Rio Grande. South of the New Mexico-Texas boundary it meanders through a broad plain known as the Toyah Basin, which extends southward from the State boundary as far as the escarpment of the Stockton Plateau, lying in part between the Llano Estacado on the northeast and the Rustler Hills and the Apache and Davis mountains on the southwest. The basin is underlain by gravel, sand, and clay, in part at least of Quaternary age. West of the Pecos Valley, the altitude of which in this area is between 2500 and 3000 feet, the plain rises to the base of the foothills with a slope of 15 to 30 feet to the mile. Low outlying hills, composed of horizontal limestone and shale of the Comanche series (Lower Cretaceous), rise above the unconsolidated débris at the western border of the basin and in places the underlying Permian red beds are exposed.

TOPOGRAPHY.

General character.—The Van Horn quadrangle includes some of the typical features of the trans-Pecos region. Nearly half of it is occupied by the Salt Flat bolson, which extends across its central part from north to south and which at the southern end of the quadrangle is divided into two branches by the Wylie Mountains. The eastern side of the quadrangle is occupied by the Delaware Mountains and the western end of the Apache Mountains. The western side is occupied by the Sierra Diablo in the north and by the Carrizo Mountains and Beach Mountain in the south. Near the center of the quadrangle the Baylor Mountains project northeastward into Salt Flat.

The altitude of the lowland ranges from 3575 feet above sea level in Salt Lake, the lowest point of the quadrangle, to 4250 feet in places along the base of the mountain scarps. The mountains rise 1000 to 3000 feet higher, the highest being the Sierra Diablo, much of which is more than 6000 feet above sea level. A peak 3½ miles southwest of Figure Two ranch headquarters is the highest in the quadrangle, attaining an altitude of 6630 feet.

The greater part of the lowland surface is nearly level or gently sloping, but the mountainous areas are much dissected and on the whole are rugged, having steep slopes and precipitous scarps. In the Carrizo and Apache mountains the relief is not so pronounced and the topography is more subdued, the continuity of the mountains being broken by rather broadly open and nearly flat-bottomed valleys.

The surface forms of the quadrangle are intimately related to the character and structure of the underlying rocks. The salient features are of structural origin but have been modified by erosion and subaerial deposition. The highlands are areas of relative uplift of consolidated ancient rocks, remnants of larger masses that have been removed by erosion. Salt Flat, on the other hand, is a depressed trough, the floor of which is an aggraded surface composed of unconsolidated deposits derived from the disintegration of the rocks of the highlands and deposited under arid conditions. The lowlands are therefore being built up by the wearing down of the highlands, and the ultimate result, if erosion is not offset by further uplift, will be the reduction of the area to a plain. Several relative uplifts of the highlands and depressions of the intervening lowlands have apparently occurred since the initial post-Cretaceous diastrophism. Some of the resulting escarpments are relatively little eroded; others are more eroded and are evidently older. The present general aspect of the area is a direct consequence of the prevailing aridity.

Salt Flat.—The lowland crossing the middle of the quadrangle from north to south is a part of the Salt Flat bolson. In the northern part of the area it is about 15 miles wide between the Sierra Diablo on the west and the Delaware Mountains on the east. Near the center of the quadrangle its width is reduced to about 5 miles by the Baylor Mountains, which project into it from the southwest. A valley 2 to 3 miles wide, separating the Baylor Mountains from the Sierra Diablo, is a part of the lowland, as is a similar poorly defined valley extending southeastward for a few miles between the Delaware and Apache mountains. South of the Baylor Mountains the lowland is much wider, its width at the south side of the quadrangle, between the Carrizo Mountains on the west and the Apache Mountains on the east, reaching 20 miles.

The central portion of the bolson is in general a nearly level surface underlain by fine-grained wash from the mountains, in part sorted and redeposited by the wind. The surface of the bolson is locally diversified by sand dunes. The lowest part of Salt Flat, in the northern part of the quadrangle, is occupied by an intermittent salt lake that varies in size with the rainfall and is reported to disappear entirely by evaporation in extremely dry seasons.

The marginal slopes of the bolson form a conspicuous zone at the base of the highlands. They are graded but vary in width and declivity and are composed of heterogeneous but generally coarse-grained outwash deposits. West of Salt Lake, at the base of the Sierra Diablo, the slope is little more than a mile wide and in that distance descends 500 feet. On the opposite side of the bolson, at the base of the Delaware Mountains, the slope is more than 6 miles wide and descends only 80 feet to the mile. At the mouths of the larger canyons there are conspicuous alluvial fans, which coalesce with the wash along the base of the highlands. A view of Salt Flat, showing the town of Van Horn, is given in Plate V.

Sierra Diablo.—The northwestern part of the quadrangle is occupied by the Sierra Diablo, the steep eastern escarpment of which, bordered by a fault, extends southward into the quadrangle for 20 miles. The escarpment rises abruptly from the marginal bolson slopes, the crest in many places being less than 2 miles back from the base of the mountains and standing about 3000 feet above Salt Flat. The prominent upper portion of the scarp ranges in height from 250 to more than 500 feet, being nearly vertical in places, and is formed by massive beds of almost flat-lying limestone.

The northern part of the escarpment is highest and most rugged, being carved entirely in limestone. About Apache Peak the escarpment is deeply gashed by several small canyons and by the larger Apache Canyon, which extends well back into the Diablo Plateau. About Victoria Peak the escarpment is also much dissected and is deeply cut by Victoria Canyon. South of Victoria Peak the outline of the crest is more regular and is not so deeply notched by the short canyons that dissect the slope. (See Pl. II.) In that part of the mountains the scarp is lower, and the slope, being formed by homogeneous soft sandstone, is not so steep. Near the high point northwest of the Hall-Canon ranch, the scarp turns abruptly westward and northwestward and passes out of the quadrangle near Bound's ranch. This portion of the escarpment, facing south toward the Carrizo Mountains, is broken by two parallel faults into two minor scarps separated by a platform 2 to 3 miles wide. The lower scarp is 400 to 500 feet and the upper 500 to 800 feet high.

Back from the crest of the escarpment the surface slopes westward to the general level of the Diablo Plateau, conforming to the general westward dip of the underlying limestone. The altitude of the surface decreases from 6500 feet or more along the crest of the Sierra Diablo to 5500 feet or less at the west side of the quadrangle.

Carrizo Mountains.—The southwest corner of the quadrangle, south of the Sierra Diablo, is occupied by the Carrizo Mountains, which lie chiefly in the Van Horn quadrangle but extend westward into the Sierra Blanca quadrangle and southward into the Chispa quadrangle. They consist of irregular groups of hills and low mountains separated by broad, comparatively open valleys. They are traversed by the Texas & Pacific Railway, which reaches its greatest altitude, 4603 feet, where it crosses the divide, about 9 miles west of Van Horn.

The topography of the two parts of the Carrizo Mountains that lie on opposite sides of the railroad is distinctly different owing to differences in the character and structure of the underlying rocks. The area north of the railroad consists mostly of low rounded hills and open valleys developed on relatively soft, homogeneous sandstone, though ridges here and there are formed of steeply dipping, more resistant beds. Next to the railroad is a narrow flat-topped ridge underlain by horizontal limestone, outlying remnants of which form the prominent buttes southwest of Carrizo Spring. The topography of the area south of the railroad is characterized by a series of ridges and valleys that have a general northeast-southwest trend, conforming with the strike of a group of metamorphic rocks, the ridges being formed by the relatively harder beds. The highest point in the Carrizo Mountains is 5285 feet above sea level. Hackett Peak, near the southern margin of the quadrangle, is nearly as high, its summit being just a mile above sea level.

Beach Mountain.—Northeast of the Carrizo Mountains is Beach Mountain, a roughly circular mass about 5 miles in diameter. Beach Mountain is not separated from the Carrizo Mountains by a well-defined valley but is differentiated from them by its greater altitude and more rugged surface, rising rather abruptly 800 to 1000 feet higher than the hills to the west and culminating in a point having an elevation of 5935 feet. Beach Mountain is capped by limestone, which dips in general gently eastward and is much dissected by several deep, narrow, crooked valleys.

Baylor Mountains.—In the central part of the quadrangle is an isolated highland area, trending northeast-southwest and about 10 miles long by 6 miles in greatest width, called the Baylor Mountains. Though lower and less rugged than Beach Mountain, the Baylor Mountains form one of the most striking topographic features of the quadrangle. They jut out into Salt Flat, from which they are separated by faults, rising abruptly 1500 to 2000 feet above the lowland. The highest point, 5566 feet above sea level, is in the southeastern part of the mountains, and the highest summits are in general near the east side of the mass. The mountains are underlain by gently warped limestone, which is dissected by deep, narrow, and crooked valleys descending to the west, north, and east. The southeastern slope is highest, steepest, and least broken by valleys.

Wylie Mountains.—A small irregular highland mass that intervenes between the two branches of Salt Flat at the south side of the quadrangle is called the Wylie Mountains. Only their northern part lies in the Van Horn quadrangle. On the west the Wylie Mountains rise in a fault scarp more than 1000 feet above the western branch of Salt Flat, one peak reaching 5031 feet above sea level. From the crest of the bluff the mountains decrease in altitude eastward and in 5 or 6 miles become low hills surrounded by wash.

Delaware Mountains.—The northeastern part of the quadrangle, as far south as Seven-Heart Gap, is occupied by the Delaware Mountains. They constitute a dissected monocline with a westward-facing escarpment in which are exposed the eroded edges of sandstone and limestone beds that dip eastward, causing the top of the mountains to be a dip slope. The elevation of the crest increases northwestward and ranges from 4874 feet near Seven-Heart Gap to 5870 feet at the northern end of the quadrangle. Accordingly the top of the mountains ranges in height from 1000 to 2000 feet above Salt Flat. East of the rim rock the drainage is down the dip slope and is tributary to Pecos River. The escarpment is dissected by relatively short arroyos, which drain into Salt Flat. The topographic detail differs from place to place, varying with variations in the hardness of the rocks, the softer beds forming slopes and outlying hills and the harder beds generally forming cliffs. Northwest of Seven-Heart Gap a number of small buttes, outliers of the Delaware Mountains, break the surface of the reentrant valley between the Delaware and the Apache mountains. At the northern end of the quadrangle a belt of low foothills, due to a fault block, lies at the base of the mountains.

Apache Mountains.—The southeastern part of the quadrangle is occupied by the western end of the Apache Mountains, a long, narrow, dissected mesa trending northwest-southeast, underlain by massive flat-lying limestone. Its highest point in the quadrangle, 5500 feet, is a summit about 3 miles south of Seven-Heart Gap. The mountains are cut by several broad valleys.

DESCRIPTIVE GEOLOGY.

PREVIOUS GEOLOGIC WORK.

Little has been published on the geology of the Van Horn region. W. H. von Streeruwitz described parts of the area in the four annual reports of the Geological Survey of Texas between 1890 and 1893, but that organization was discontinued before a geologic map or a systematic report on the region was published. E. T. Dumble, director of the Geological Survey of Texas, reviewed the progress of Von Streeruwitz's work in his annual reports, and in 1902 he announced the probable pre-Cambrian age of the fine-textured red sandstone of the Millican formation. R. T. Hill has briefly referred to this general region in a number of publications.[a] The Van Horn quadrangle is included in the region examined by the present writer in 1903.[b]

STRATIGRAPHY.

SEQUENCE OF THE ROCKS.

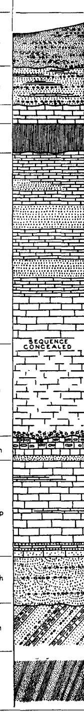
The rocks of the Van Horn quadrangle consist of consolidated and unconsolidated sediments and of a few small igneous masses. The consolidated rocks range in age from Algonkian (?) to Cretaceous, and the unconsolidated are in part at least Quaternary. The general stratigraphy of the quadrangle is outlined in the columnar section. (See fig. 4.)

At the base of the section is a great mass of Algonkian (?) rocks which have been separated into two formations. One, the Carrizo, consists of schists, quartzite, slates, and associated altered igneous rocks, and the other, the Millican, consists of sandstone, conglomerate, and cherty limestone. The stratigraphic relations of these two formations are concealed, but the greater metamorphism which the Carrizo has undergone indicates that it is the older.

The Van Horn sandstone, of probable Cambrian age, lies at a low angle on highly inclined strata of both the Carrizo and the Millican formations. It is composed of several hundred feet of coarse red sandstone and intercalated layers of conglomerate, grading up into a white fine-grained sandstone, which is overlain by the El Paso limestone. Fossils of determinative value have not been found in the sandstone, but the El Paso limestone contains a Lower Ordovician fauna.

The El Paso has a maximum thickness in the Van Horn quadrangle of about 1000 feet and is succeeded, apparently unconformably, by the Montoya limestone, 250 feet thick, which carries an Upper Ordovician fauna.

Uplift and a period of considerable erosion followed the deposition of the Montoya limestone. The Silurian, Devonian, and lower Carboniferous (Mississippian) periods are, so far as known, not represented by sediments, and the next overlying formation, the Hueco limestone of Pennsylvanian age, which with its local basal conglomerate is more than 2500 feet thick, rests unconformably on all of the older formations of the quadrangle. It should be noted that in the absence of fossils it is difficult in all parts of the quadrangle to distinguish the El Paso, Montoya, and Hueco limestones, and that it is quite possible that the delimitation of those formations on the map is not everywhere exact. It is also possible — though no Silurian fossils have been found in the area—that small outlying masses of the Fusselman limestone (Silurian) may be present between limestones carrying Hueco and Montoya faunas.



System.	Series.	Formation.	Symbol.	Columnar section.	Thickness in feet.	Character and distribution.
Quaternary.		Bolson deposits.	Qb		700+	Gravel, sand, and clay in Salt Flat. Unconsolidated impure gypsum at the surface in lowest part of basin.
		UNCONFORMITY				
Cretaceous.	Lower Cretaceous.	Comanche series	Kc		400±	Buff sandstone, with subordinate amount of conglomerate, shale, and limestone. Caps the hills 6 miles west of Van Horn and in the vicinity of Plateau station.
		UNCONFORMITY				
Carboniferous.	Permian	Rustler limestone.	Cr		200±	Fine-grained gray to whitish magnesian limestone in faulted area in eastern part of quadrangle.
		Castile gypsum.	Cc		275±	Massive-bedded gypsum in faulted area in eastern part of quadrangle.
		UNCONFORMITY				
		Delaware Mountain formation.	Cd		2000+	Interbedded gray limestone and buff sandstone in Delaware Mountains; massive white and gray limestone member in Apache Mountains.
		SEQUENCE CONCEALED		SEQUENCE CONCEALED		
	Pennsylvanian.	Hueco limestone.	Ch		2500+	Massive gray limestone with basal conglomerate. In Sierra Diablo, Baylor, Beach, Wylie, and Carrizo mountains.
		UNCONFORMITY				
Ordovician.	Upper Ordovician.	Montoya limestone.	Om		0-250	Massive gray magnesian limestone, in places cherty, and subordinate amount of sandstone at base. In Beach and Baylor mountains.
		UNCONFORMITY (?)				
	Lower Ordovician.	El Paso limestone.	Oep		0-1000	Massive gray magnesian limestone; beds of sandstone in lower part. In Beach and Baylor mountains.
Cambrian ?	Upper Cambrian ?	Van Horn sandstone.	€vh		0-700	Coarse red sandstone with lenses of conglomerate; white sandstone in upper part. Northwest of Van Horn.
		UNCONFORMITY				
Algonkian ?		Millican formation.	Am			Fine red sandstone, cherty limestone, and conglomerate. In northern Carrizo Mountains.
		SEQUENCE CONCEALED				
		Carrizo formation.	Ac			Quartzite, slate, and a variety of schists. In southern Carrizo Mountains.

FIGURE 4.—Generalized columnar section of the rocks of the Van Horn quadrangle.
Scale: 1 inch=1000 feet.

The Hueco is succeeded by about 2000 feet of sandstone and limestone of the Delaware Mountain formation, which contains the Guadalupian fauna, regarded by Girty as of Permian age. Owing to local uplift and erosion, which succeeded the deposition of these rocks, the Delaware Mountain formation is in places unconformably overlain by the Castile gypsum, which in turn is succeeded by the Rustler limestone. Each of the latter formations is about 250 feet thick and both belong to the Permian red beds of Pecos Valley.

SEDIMENTARY ROCKS.

ALGONKIAN (?) SYSTEM.

CARRIZO FORMATION.

Definition.—The Carrizo formation is a complex of quartzite, slate, and a variety of schists, which outcrops in the Carrizo Mountains south of the Texas & Pacific Railway. The name was first used for the formation by Von Streeruwitz.[a]

Distribution and character.—The formation is exposed over about 22 square miles in the southwest corner of the quadrangle, where it forms the southern portion of the Carrizo Mountains. It outcrops in parallel ridges and intervening valleys having a general northeast-southwest trend. The ridges are underlain by harder rocks and the valleys by softer ones, the topographic trend corresponding to the strike.

The formation consists of quartzite, slate, quartz and mica schists, chlorite schists, and metamorphosed igneous rocks. They are prevailingly dull colored and are predominatingly gray, though some are almost black, a few are pale reddish, and others are green. All are fine grained. Foliation, parallel to the strike, is distinctly developed in all the rocks except the quartzite, the minerals being arranged in bands that cause the rocks to be readily cleavable. In places the rocks are traversed, generally parallel to the direction of schistosity, by a number of veins of white quartz, some of which contain large crystals of hematite.

The quartzite, which occurs in layers rarely more than a few feet thick, interbedded with the schists and slate, is composed almost entirely of interlocking grains of quartz. It breaks with a conchoidal fracture and commonly has a vitreous luster. It is relatively massive and is foliated only where containing other minerals besides quartz. Such phases tend to merge into schist.

The slate is extremely fine textured and has a well-developed typical slaty cleavage. Its component minerals are minute and are rarely recognizable, though in places a few grains of quartz may be seen and commonly the slates are made black by graphite.

The quartz and mica schists are composed essentially of quartz and mica, with chlorite, graphite, magnetite, calcite, and feldspar in small amounts as accessory minerals. Quartz predominates in all the varieties, occurring as irregular grains commonly arranged in parallel streaks, the structure being emphasized by scattered bands of relatively coarse texture. Muscovite occurs between the grains of quartz in elongated shreds whose longer dimension is parallel to the schistosity. Different proportions of quartz and mica give rise to the varieties mica schist, quartz-mica schist, and quartz schist, which last grades to almost fine quartzite.

These rocks constitute the great mass of the Carrizo formation. They occur in alternating bands, to which the schistose structure is parallel, and their composition and occurrence clearly show that they are of sedimentary origin. Before metamorphism they were evidently a group of sandstones and shales.

A small part of the Carrizo formation consists of schists which presumably represent igneous sills that were injected in thin layers between the sediments. Of these the chlorite schists are the most conspicuous. Although some may be metamorphosed arkose sandstones, those which were found to extend slightly across the original bedding planes of the adjacent strata are altered basic igneous rocks. The chlorite schists have a pronounced green color and are distinctly foliated though some show an approach to granular texture. They are composed of dominant chlorite in scaly aggregates with more or less quartz, magnetite, and calcite. In the more massive varieties there are remains of plagioclase and pyroxene altering to chlorite, the edges of the minerals being frayed as the result of pressure. Lighter-colored rocks of gray to reddish hue, having the general appearance on casual examination of fine-grained quartz schist, are probably metamorphosed rhyolite. They are dense though slightly laminated and are composed of phenocrysts of quartz and decomposed feldspar, somewhat crushed, embedded in a groundmass of minute grains of quartz and feldspar.

Age and correlation.—The stratigraphic relations of the Carrizo formation to adjacent rocks are in most places concealed by Quaternary deposits, but east of bench mark 4603, on the Texas & Pacific Railway, at the north side of the outcrop and also at the south side of the quadrangle, the formation is seen to be faulted against rocks of Carboniferous and Cretaceous

[a] Notably in Physical geography of the Texas region: U. S. Geol. Survey Top. Atlas, folio 3, 1900.
[b] Texas Univ. Min. Survey Bull. 9, 1904.

[a] Geol. Survey Texas Second Ann. Rept., p. 683, 1891.

ages. In Bass Canyon, 7 miles southwest of Van Horn, immediately south of the quadrangle, an exposed section shows almost horizontal Van Horn sandstone containing pebbles of the underlying rocks lying upon almost vertically tilted schists belonging to the Carrizo formation. The Van Horn sandstone is probably Cambrian, and in view of the marked unconformity at its base and the metamorphism which the Carrizo formation has undergone, there can be no doubt of the pre-Cambrian age of the schists.

Data for exact correlation are lacking, but the Carrizo formation bears a general lithologic resemblance to part of the Llano series of central Texas and to the Pinal schist of Arizona. Except for the presence of quartzite the pre-Cambrian rocks of the El Paso and Van Horn quadrangles bear little resemblance to each other.

MILLICAN FORMATION.

Definition.—The Millican formation, named from Millican's ranch, 10 miles northwest of Van Horn, consists of fine-grained red sandstone, cherty limestone, and conglomerate. The fine-grained red sandstone was called the Diablo sandstone by Von Streeruwitz and the Hazel sandstone by Dumble, but it has been found impracticable to separate it satisfactorily from the cherty limestone and conglomerate.

Distribution.—The formation occupies a considerable area in the southwestern part of the quadrangle, chiefly in the Carrizo Mountains, between the Texas & Pacific Railway and the escarpment of the Sierra Diablo. It outcrops in disconnected areas separated by wash, and its sequence, thickness, and relations are not exposed.

The sandstone occupies most of the undulating hilly district constituting the northern part of the Carrizo Mountains and extends along the lower part of the southeastern escarpment of the Sierra Diablo, where it outcrops conspicuously. A small area of it in the southern Sierra Diablo surrounds Sheep Peak and another peak a mile to the southeast. As the rock is relatively soft it generally underlies an area of subdued relief, and in the Sierra Diablo escarpment it occupies the slopes, above which the Hueco limestone forms a prominent cliff.

The limestone and conglomerate of the Millican formation withstand weathering better than the sandstone and occupy areas of greater relief. They outcrop chiefly in the hills west, south, and southeast of Millican's ranch and in the hill northeast of Grapevine Spring, and they generally form ridges trending with the strike of the strata.

Character.—The sandstone is homogeneous, dark red, and so fine grained that its components can be distinguished in few hand specimens, although in some fragments minute grains of quartz are apparent. Under the microscope it is seen that the texture is characteristically sedimentary and that the rock is composed chiefly of subangular or rounded minute grains of quartz and subordinate feldspar, with some flakes of muscovite and rather abundant interstitial calcite, the minerals being coated with a thin film of red pigment—ferric oxide—that gives the uniform color to the rock. The homogeneity of the rock is so pronounced that bedding planes can rarely be distinguished, and it is practically impossible to determine the thickness of the deposit. At the Hazel mine a decolorized streak in the sandstone shows that there the strike is N. 65°–85° E. and that the beds are nearly vertical.

The limestone is massive and as a rule semicrystalline, though in places it is true granular marble. Generally it is seamed with crumpled layers of chert, which, by withstanding weathering better than the adjacent calcareous material, give the outcrops a characteristic fluted appearance. In places, however, it is practically free from chert. The color is varied; in the marmarized areas it is almost pure white in places and reddish and pink in others. Where chert is more abundant it is apt to be gray. The limestone contains a considerable amount of magnesia. Although the true relations of the members of the Millican formation are difficult to determine, it appears probable, as indicated at several localities (notably on the northern side of the semidetached mountain known as Morris Peak or Tumbledown Mountain, a mile northeast of Grapevine Spring), that the main mass of the limestone overlies the main mass of red sandstone.

The conglomerate consists of angular to rounded fragments of fine red sandstone and cherty limestone, with local subordinate red feldspar porphyry and granite, in a matrix of smaller bits of the same materials bound together by a siliceous, calcareous, or ferruginous cement. The fragments range in diameter from about a foot down to a fraction of an inch. Some have been distinctly flattened by compression to which the rock has been subjected. The conglomerate occurs at different stratigraphic horizons and in various lithologic associations; in places it lies above the cherty limestone, in other places on the red sandstone, and in still others occurs as bands in the fine red sandstone and in the limestone. Northwest of Carrizo Spring a strip of breccia conglomerate lies between the limestone and the red sandstone. The fragments consist preponderantly of limestone adjacent to the limestone and of sandstone adjacent to the sandstone, the relation suggesting fault brecciation.

Relations and age.—Neither the base nor the top of the Millican formation is known. It is distinctly different from the Carrizo formation, but its relations to that formation are concealed by later deposits. It is less metamorphosed than the Carrizo formation and may therefore be presumed to be younger. Along the southern escarpment of the Sierra Diablo a basal conglomerate in the Hueco limestone directly overlies the red sandstone. In other places, as at the north end of Beach Mountain and at the southeast end of the Sierra Diablo, 3 miles northwest of the Hall-Canon ranch, the Van Horn sandstone, containing rounded pebbles of the underlying rocks, lies unconformably on the red sandstone. West of Beach's ranch the Van Horn sandstone, dipping eastward at a low angle, lies on almost vertical conglomerate beds of the Millican formation, thus indicating the pre-Cambrian age of the latter.

CAMBRIAN (?) SYSTEM.

VAN HORN SANDSTONE.

Definition.—The Van Horn sandstone is named from the town of Van Horn, 3 to 6 miles northwest of which it is conspicuously exposed. It consists of sandstone and ranges in thickness from a few feet to about 700 feet.

Distribution and character.—The formation outcrops principally in an area of about 10 square miles in the valley between Beach Mountain and the Texas & Pacific Railway. Most of it is comparatively soft, so that where the overlying rocks have been eroded away it occupies relatively low land. Where capped by massive limestone, as along the west base of Beach Mountain, it forms the slopes of prominent escarpments. Other occurrences are on the north flanks of Beach Mountain, at the south end of Baylor Mountain, and at the southeast corner of the Sierra Diablo.

The sandstone is characteristically coarse grained, in contradistinction to the very fine grained red sandstone of the Millican formation, is cross-bedded, and is banded with thin lenses of conglomerate. In its upper part, however, it is medium to fine grained and is rather more indurated than in the lower part. Its lower part is prevailingly brick-red, but it becomes progressively paler upward and is white or light gray at the top. The conglomerate lenses range in thickness from a few inches to about a foot and are irregularly distributed throughout the lower part of the formation. At the base the pebbles are composed of fragments of the underlying rocks and comprise quartz schist, fine-grained red sandstone, cherty limestone, porphyry, and quartz. The conglomerate in the upper part of the formation consists chiefly of well-rounded quartz pebbles. The sandstone likewise ranges from arkosic—composed of quartz and decomposed feldspar grains—in the lower part to pure quartz sandstone in the upper part.

The following section shows the general character of the formation:

Section of Van Horn sandstone on southwest flank of Beach Mountain.

	Feet.
Limestone, gray (El Paso limestone).	
Sandstone, fine grained, massive, white	25
Sandstone, fine grained, thin bedded, white	30
Sandstone, thin bedded, yellowish	20
Sandstone, thin bedded, varicolored	75
Sandstone, coarse grained, reddish	8
Sandstone, coarse grained, thin bedded, varicolored, mostly white	50
Sandstone, conglomeratic, quartz pebbles, white	5
Sandstone, coarse grained, massive, red	225
Sandstone, coarse grained, with layers of conglomerate, reddish	250
	688

Relations.—The base of the formation is exposed on the north flank of Beach Mountain south of the Hall-Canon ranch, where the coarse red sandstone with a basal conglomerate containing fragments of the underlying rocks rests on an eroded surface of fine-grained red sandstone of the Millican formation; west of Beach's ranch, where the Van Horn sandstone, dipping eastward at a low angle, lies on unevenly eroded, almost vertical beds of the Millican formation; and in Bass Canyon, 7 miles southwest of Van Horn and just outside the quadrangle, where the sandstone with a basal conglomerate lies almost horizontally on highly tilted schists of the Carrizo formation.

Normally the Van Horn sandstone is directly overlain by the El Paso limestone, excellent sections being exposed on the western flank of Beach Mountain (see Pl. IV), where the following measurements were made:

Section of Van Horn sandstone and El Paso limestone southeast of Beach's ranch.

	Ft.	in.
El Paso limestone:		
Limestone, gray, massive, with Beekmantown fossils	100+	
Sandstone, white, fine grained, quartzose	10	
Limestone, gray, with Beekmantown fossils	70	
Shale, greenish to buff, clayey and sandy		2
Van Horn sandstone:		
Sandstone, gray to whitish, fine grained, quartzose, with some lenses of conglomerate containing quartz pebbles	100	
Sandstone, red-brown, coarse grained, arkosic, with layers of conglomerate	150+	

Age.—The upper part of the Van Horn sandstone contains numerous annelid borings and fucoid-like remains, but no diagnostic fossils have been found in the formation and its age is therefore undetermined. However, because of its relations it is provisionally assigned to the Upper Cambrian.

ORDOVICIAN SYSTEM.

In the Van Horn quadrangle the Ordovician system is represented by a considerable thickness of limestone that has been divided into two formations, the El Paso and Montoya limestones. The former is Lower and the latter Upper Ordovician.

EL PASO LIMESTONE.

Definition.—The El Paso limestone is a massive gray magnesian limestone containing a Beekmantown (Lower Ordovician) fauna. It is named from El Paso, Tex., its type locality being in the Franklin Mountains north of that place. Its thickness is about 1000 feet.

Distribution and character.—In the Van Horn quadrangle the El Paso limestone forms the greater part of Beach Mountain. It also occurs in the southern base of the Baylor Mountains and in a few small hills in the valley between the Baylor Mountains and the Sierra Diablo.

The formation is made up of rather homogeneous, massive gray magnesian limestone containing a few irregularly distributed small bits of brownish chert. Lenses of white quartz sandstone from 5 to 50 feet thick occur near the base in some places. A sample of the rock from the southern end of Beach Mountain, analyzed by Chase Palmer, of the United States Geological Survey, contained 19.13 per cent of magnesia. The maximum thickness of the formation in the Van Horn quadrangle is exposed in Beach Mountain, where the following section was measured:

Section of El Paso limestone northeast of Beach's ranch.

	Feet.
Montoya limestone.	
El Paso limestone:	
Limestone, massive, gray to whitish, with Beekmantown fossils	875+
Sandstone, white, quartzose	5
Limestone, gray, massive	10
Sandstone, white, quartzose, fine grained	35
Limestone, gray, thin bedded, with Beekmantown fossils	75
Van Horn sandstone.	

The sandstone near the base of the formation is of irregular occurrence. In some places there are two beds, in others there is none.

Fossils and age.—Although not abundant, fossils are found here and there throughout the formation. Most of the species are undescribed, but all are stated to be of unmistakable types. The more characteristic are: Calathium sp. nov. (coral-like sponge), Maclurea (?) sp. nov. (the small hornlike opercula are very common; the shell itself is of the type of *M. oceana* Billings), and solid siphuncles of an endoceratoid cephalopod, evidently a close ally of *Cameroceras brainardi*. There are also a number of less easily recognized small gastropods. According to E. O. Ulrich the fauna is essentially of Beekmantown age and is of the type prevailing in the upper 1000 feet or so of the Arbuckle limestone in Oklahoma. The formation is provisionally correlated with part of the Ordovician limestone of central Texas and with the Longfellow limestone of the Clifton quadrangle, Ariz.

MONTOYA LIMESTONE.

Definition.—The Montoya is a dark to light gray, massive to thin-bedded magnesian limestone, including locally a bed of sandstone at the base. It contains an abundant Richmond fauna. The name is derived from Montoya, Tex., a station on the Atchison, Topeka & Santa Fe Railway north of El Paso, the type locality being in the Franklin Mountains. The formation is about 250 feet thick.

Distribution and character.—The Montoya limestone outcrops in only a few small areas in the Van Horn quadrangle, chiefly in the northeastern part of Beach Mountain, where it generally caps the summits. It also occupies the upper part of the ridge at the south end of the Baylor Mountains and forms a low hill just south of that ridge.

The basal zone of the formation is characterized by a bed of whitish to gray fine-grained quartzose sandstone, 20 to 30 feet thick, lying between beds of buff conglomeratic sandy limestone. The thickness of the whole is irregular but averages possibly 50 feet. This basal zone apparently marks an unconformity between the El Paso and Montoya limestones, and this is further indicated by a hiatus in the faunas. The next higher zone is a bed, 50 to 60 feet thick, of massive dark-gray magnesian limestone practically free from chert, above which is a massive to thin-bedded light-gray magnesian limestone about 150 feet thick, seamed with layers of chert parallel to the bedding. A sample of limestone from the lower part of the formation in Beach Mountain contained 16.22 per cent and one from the upper part in the Baylor Mountains contained 17.10 per cent of magnesia, according to analyses by Chase Palmer.

Fossils and age.—The Montoya limestone carries an abundant fauna, especially in the upper cherty beds. The following species from the Van Horn quadrangle have been identified by E. O. Ulrich:

Receptaculites sp.	Orthis whitfieldi.
Columnaria thomii.	Dinorthis subquadrata.
Rhombotrypa quadrata.	Dinorthis proavita.
Streptelasma.	Rhynchotrema capax.
Plectambonites saxea.	Rhynchotrema neenah.

In the El Paso folio the Montoya limestone, on the authority of E. O. Ulrich, was described as containing two distinct faunas, one identified as Galena and the other as Richmond. A recent study of the collections from the El Paso and Van Horn quadrangles and of the type section in the Franklin Mountains by Edwin Kirk, of the United States Geological Survey, shows that the entire formation is of Richmond age, with which conclusion Mr. Ulrich now agrees.

This fauna has a widespread distribution. It occurs in the Bighorn dolomite of Wyoming, the Fish Haven dolomite of northeastern Utah, the Fremont limestone of Colorado, and elsewhere.

CARBONIFEROUS SYSTEM.

The greater part of the exposed consolidated rocks in the Van Horn quadrangle belongs to the Pennsylvanian and Permian series of the Carboniferous system. The beds are divided into the Hueco limestone, Delaware Mountain formation, Castile gypsum, and Rustler limestone. The Hueco limestone is Pennsylvanian and the other three formations are referred to the Permian. The Castile gypsum and overlying Rustler limestone are parts of the group of red beds of the Pecos Valley. In the Van Horn quadrangle these formations outcrop at the southern end of the Delaware Mountains in a fault block separated from their main occurrences a few miles to the east.

PENNSYLVANIAN SERIES.

HUECO LIMESTONE.

Definition.—The Hueco limestone is a phase of the Hueco formation which is widely distributed in the trans-Pecos region. Its name is derived from the Hueco Mountains in the El Paso quadrangle. In several areas the formation consists mainly of limestone, but in others, notably in the Sacramento Mountains, N. Mex., it comprises also considerable sandstone and shale, including red beds, and in many places a basal conglomerate. In Texas the Hueco is at least 5000 feet thick, of which about 2500 feet are exposed in the Van Horn quadrangle.

Distribution and character.—The Hueco limestone outcrops conspicuously in the Sierra Diablo, where it forms the entire escarpment north of Victoria Peak and the crest of the escarpment south of that peak; it also underlies the surface of a large part of the Diablo Plateau. It forms nearly the whole mass of the Baylor and Wylie mountains, makes up a large part of the ridge lying north of the railroad west of Van Horn, and occurs in small outlying hills here and there in the western half of the quadrangle. Some of the cliffs it forms are shown in Plates II, VI, and VII.

In the Van Horn quadrangle the Hueco formation consists almost wholly of limestone, but in some places it includes thin beds of dark clay shale, gray quartzose sandstone, and a basal conglomerate. The limestone ranges from massive to thin bedded, the transition being well shown in some of the cliffs along the escarpment of the Sierra Diablo. In some areas bedding planes are scarcely distinguishable, but in others the limestone is distinctly thin bedded and laminated. The limestone is typically nonmagnesian, an analysis by Chase Palmer of a specimen from an outcrop east of bench mark 4603, on the Texas & Pacific Railway, showing only 0.96 per cent of magnesia, thus agreeing with two analyses of the Hueco limestone in the El Paso quadrangle, each of which showed less than 1 per cent of magnesia. On the other hand, a specimen from the top of the Sierra Diablo, 4 miles southwest of the mouth of Apache Canyon, contained 10.69 per cent of magnesia.

The conglomerate is very irregularly distributed, being in places 150 feet thick and in other places absent. The pebbles, which range in diameter from a fraction of an inch to several inches, are rounded fragments of the underlying rocks.

Relations.—The Hueco lies with pronounced unconformity on the older rocks. In places there is a marked discordance of dip between the Hueco and the underlying beds. In the three outlying hills capped by the formation 6 miles northwest of Van Horn the basal conglomerate is well exposed, lying almost horizontally on Van Horn sandstone that dips 2°–30° E. (See fig. 5, *a*, and Pl. I.)

Plate VIII shows the Hueco resting on Van Horn sandstone in Threemile Mountain and, across the valley to the north, the El Paso limestone resting on the Van Horn.

At the south end of the Baylor Mountains the unconformity at the base of the formation is also plainly evident. The limestone, with a basal conglomerate containing among a varied assortment of pebbles rounded fragments of the fossiliferous El Paso limestone, lies in places on an eroded surface of Van Horn sandstone and near by on El Paso limestone. (See fig. 5, *b*.)

Along the southern escarpment of the Sierra Diablo the unconformity is clearly shown, as the Hueco limestone, with its basal conglomerate containing pebbles of the underlying rocks, rests on an eroded surface of the Millican formation.

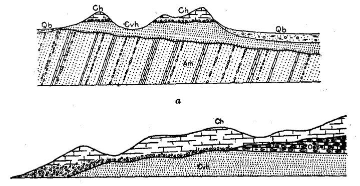


FIGURE 5.—Sections showing unconformity at base of Hueco limestone.

a, Section along line J-J on areal-geology map, 6 miles northwest of Van Horn; *b*, section at south end of Baylor Mountains.
Am, Millican formation; Cvh, Van Horn sandstone; Oep, El Paso limestone; Ch, Hueco limestone; Qb, bolson deposits.
Horizontal scale, 1 inch=approximately half a mile.
Vertical scale, 1 inch=approximately 1800 feet.

The stratigraphic top of the formation is not exposed in or near the Van Horn quadrangle. In a number of localities on the Diablo Plateau an eroded surface of the limestone is directly overlain by Cretaceous strata, outlying remnants of which also lie on the Hueco limestone north of the railroad in the Carrizo Mountains.

Fossils.—Numerous fossils have been found in the Hueco limestone. They are for the most part silicified, so that they can be readily separated from the matrix by etching. Among the many fossils collected, the following from the Sierra Diablo and the Wylie Mountains, identified and in part collected by G. H. Girty, are representative:

Fossils from the Hueco limestone near the top of the Sierra Diablo escarpment, 4 miles southwest of Figure Two ranch headquarters:

Lithostrotion? sp.	Pugnax aff. utah.
Fistulipora sp.	Enteletes aff. hemiplicatus.
Stenopora? sp.	Spirifer aff. cameratus.
Productus occidentalis?	Squamularia aff. guadalupensis.
Productus ivesi?	Composita subtilita.
Productus sp.	

Fossils from the Hueco limestone about 2300 feet below the preceding lot, near the base of the Sierra Diablo escarpment, 3 miles southwest of Figure Two ranch headquarters:

Fusulina cylindrica.	Ambocœlia sp.
Fusulina elongata.	Composita subtilita.
Schwagerina? sp.	Cliothyridina? sp.
Textularia sp.	Pleurotomaria sp.
Echinocrinus trudifer.	Soleniscus sp.
Stenopora sp.	Omphalotrochus sp.
Chonetes n. sp.	Euomphalus n. sp.
Productus semireticulatus.	Griffithides sp.
Schizophoria sp.	

Fossils from the Hueco limestone at the eastern base of the Wylie Mountains:

Fusulina cylindrica.	Camarophoria? sp.
Fusulina elongata.	Spirifer aff. cameratus.
Lophophyllum? sp.	Composita subtilita.
Productus semireticulatus.	Euomphalus sp.
Meekella aff. striaticostata.	

Fossils from the Hueco limestone at the western base of the Wylie Mountains:

Fusulina cylindrica.	Composita subtilita.
Echinocrinus trudifer.	Composita mexicana.
Echinocrinus cratis?	Soleniscus? sp.
Pugnax aff. osagensis.	Plagioglypta canna.
Productus semireticulatus.	Bellerophon aff. crassus.
Productus aff. cancrini.	Omphalotrochus sp.
Dielasma bovidens.	Euomphalus sp.

Age and correlation.—In regard to the age and correlation of the Hueco limestone G. H. Girty says:

The Hueco formation is Pennsylvanian in age, but, owing to the peculiar Asiatic facies which its fossils share with most of the Carboniferous faunas of the West, it is impossible at present to indicate its exact position in the typical Pennsylvanian section.

Collections of fossils made at different points in the Hueco formation are likely to show different facies. This difference is not always due to difference in horizon, but in general the lower faunas of the Hueco seem to be more or less differentiated from the upper, although no definite boundary is established. Thus the paleontologic evidence suggests that certain horizons at the base of the Hueco in the Hueco Mountains may be lacking in the Van Horn quadrangle.

Faunas more or less closely similar to the Hueco are widely distributed through the Cordilleran region. Such faunas have been found in the Kaibab limestone of the Aubrey group of Arizona, in the Manzano group of New Mexico, and in the upper part of the Naco limestone of Arizona, and those formations are tentatively correlated with the Hueco.

PERMIAN SERIES.

SUBDIVISIONS.

The formations assigned to the Permian in the Van Horn quadrangle are the Delaware Mountain formation, the Castile gypsum, and the Rustler limestone. The Delaware Mountain formation and the overlying Capitan limestone (not recognized in this area) constitute the Guadalupe group and contain the unique Guadalupian fauna described by G. H. Girty,[a] which is strikingly different from that of the underlying Hueco formation. For this reason and because of certain resemblances between its fauna and the late Paleozoic faunas of Asia and Europe, the Delaware Mountain formation is classified with the Permian.

[a] The Guadalupian fauna: U. S. Geol. Survey Prof. Paper 58, 1908.

DELAWARE MOUNTAIN FORMATION.

Definition.—The Delaware Mountain formation is a mass of sandstone and limestone having a thickness of at least 2200 feet. Its base is concealed by the Quaternary deposits of Salt Flat, and at the type location, in the Guadalupe Mountains, it is overlain by the Capitan limestone, but in the Delaware Mountains, from which the name is derived, it is overlain by the Castile gypsum.

Distribution and character.—The formation makes up the whole of the Delaware Mountains and of the Apache Mountains, except in the valley extending northwest from Seven-Heart Gap. It also forms the low hills at the base of the Delaware Mountains in the north part of the quadrangle.

In the part of the Delaware Mountains north of the Van Horn quadrangle the formation is prevailingly sandy and contains only thin beds and lenses of limestone. Southward the sandstone decreases and the limestone increases in amount, and in the southern part of the mountains the formation consists of gray limestone with subordinate beds and lenses of sandstone. In the Apache Mountains the rocks are entirely limestone and are separated from the main mass of the formation by a fault.

The sandstone is quartzose, massive to thin bedded, and buff to brownish. The limestone in the Delaware Mountains is both thick and thin bedded, prevailingly gray, and contains but little chert. In the Apache Mountains the limestone is massive, fine grained, and whitish or gray. Three analyses indicate that the limestone of the Delaware Mountain formation is practically nonmagnesian. A sample from the crest of a ridge in the Delaware Mountains near bench mark 5870 shows 0.32 per cent of magnesia; from a hill west of Jones's ranch, 0.45 per cent; and from the Apache Mountains a mile northeast of bench mark 3899, 0.29 per cent.

The following section measured on the western scarp of the Delaware Mountains at the north end of the quadrangle, west of bench mark 5870, shows the general character of the formation:

Partial section of the Delaware Mountain formation at the north end of the Delaware Mountains.

	Feet.
Limestone, thin bedded, drab, with interbedded shaly sandstone and calcareous shale	400
Sandstone, massive, buff, quartzose; weathers brownish	1000
Sandstone, massive, and thin bedded (layers range from 10 feet to fraction of inch), buff, quartzose; weathers brownish	150
Limestone, thin bedded, drab	20
Sandstone, massive, buff, quartzose	30
	1600

From the top of the section, at bench mark 5870, eastward to beyond the limit of the quadrangle the mountains are capped by limestone forming a dip slope.

Fossils and age.—The following fossils, constituting a part of the Guadalupian fauna, were identified and collected in part by G. H. Girty. The first two lots were collected in the Delaware Mountains and the last two in the Apache Mountains.

Fossils from the vicinity of bench mark 5870, Delaware Mountains:

Fusulina elongata.	Rhynchonella indentata.
Lindstrœmia permiana.	Camarophoria sp.
Lioclema shumardi.	Spirifer sp.
Fistulipora grandis var. guadalupensis.	Hustedia meekana var. trigonalis.
	Aviculipecten sp.
Echinocrinus sp.	Edmondia sp.
Meekella sp.	Parallelodon? sp.
Chonetes n. sp.	Plagioglypta canna.
Productus walcottianus.	Pleurotomaria delawarensis.
Productus guadalupensis.	Naticopsis sp.
Productus signatus.	Holopea? sp.

Fossils from a locality 2 miles north of Seven-Heart Gap, at a level 25 to 50 feet below the Castile gypsum:

Sponge.	Productus pileolus?
Heterocœlia n. sp.	Aulosteges guadalupensis?
Lindstrœmia permiana?	Richthofenia permiana.
Cladopora tubulata?	Pugnax osagensis.
Cladopora spinulata.	Spiriferina hilli?
Domopora ocellata?	Martinia rhomboidalis.
Domopora terminalis.	Squamularia guadalupensis.
Acanthocladia guadalupensis.	Composita sp.
Fistulipora grandis var. guadalupensis.	Hustedia meekana.
	Hustedia papillata?
Derbya sp.	Parallelodon n. sp.

Fossils from a locality 1½ miles southeast of Jones's ranch:

Cystothalamia nodulifera.	Composita subtilita?
Amblysiphonella?	Aviculipecten sp.
Lindstrœmia? sp.	Myalina? sp.
Lioclema? sp.	Edmondia sp.
Fistulipora sp.	Sedgwickia sp.
Meekella skenoides.	Pteria richardsoni.
Derbya sp.	Protrete texana.
Chonetes hillanus.	Parallelodon multistriatus?
Productus popei.	Parallelodon politus.
Productus subhorridus var. rugatulus.	Pleurophorus? sp.
	Schizodus sp.
Richthofenia permiana.	Warthia sp.
Enteletes sp.	Murchisonia? sp.
Dielasma sp.	Sphærodoma? sp.
Pugnax shumardiana.	Soleniscus sp.
Rhynchonella longæva?	Euomphalus n. sp.
Spirifer sp.	Pseudomelania? sp.
Martinia sp.	Anisopyge perannulata.

Fossils from the west base of the mountain 1½ miles northeast of bench mark 3899:

Guadalupia cylindrica.	Rhynchonella indentata.
Virgula neptunea.	Heterelasma shumardianum.
Fenestella sp.	Dielasma sp.
Productus semireticulatus var. capitanensis.	Spirifer mexicanus.
Productus pileolus.	Composita emarginata.
Pugnax sp.	Anisopyge perannulata.

CASTILE GYPSUM.

Definition.—The Castile formation, consisting of massive gypsum, is named from Castile Spring, which is situated about 25 miles northeast of the Van Horn quadrangle. The main mass of the formation occupies several hundred square miles between the eastern base of the Delaware Mountains and the Rustler Hills.

Distribution and character.—The Castile gypsum occupies a few square miles at the east side of the quadrangle in the valley between the Delaware Mountains and the Apache Mountains. The gypsum is a massive white granular variety. A characteristic sample analyzed qualitatively by W. T. Schaller shows it to be of no unusual composition. On the surface the gypsum is generally disintegrated and earthy and commonly weathers gray with rough solution surfaces. In the Van Horn quadrangle the thickness of the formation is about 275 feet.

Relations and age.—Throughout its extent in Texas the Castile gypsum apparently lies unconformably on the Delaware Mountain formation. Because of its occurrence as part of the red beds of the Pecos Valley, which are generally recognized as of Permian age, this formation is here included in the Permian series.

RUSTLER LIMESTONE.

Definition.—The Rustler formation is about 200 feet thick and consists of fine-grained gray to whitish magnesian limestone and associated sandstone. It is named from the Rustler Hills in eastern Culberson County, Tex. The sandstone beds are lenticular and not persistent, and in the Van Horn quadrangle the formation consists entirely of limestone.

Distribution and character.—The Rustler limestone caps a few hills in the valley occupied by the Castile gypsum between the Delaware Mountains and the Apache Mountains. The rock is fine-grained gray to whitish magnesian limestone. A sample analyzed by W. T. Schaller had the following composition:

Analysis of Rustler limestone.

Insoluble	6.48
Alumina and iron	1.77
Lime	28.39
Magnesia	18.77
Ignition	44.00
	99.36

Relations.—The fact that the Rustler limestone was deposited directly upon the Castile gypsum shows that the conditions of sedimentation had changed and that marine waters had gained free access to the more or less inclosed basin in which the gypsum was deposited. But no evidence has been found of considerable unconformity.

Fossils and age.—Fossils are extremely rare in the Rustler limestone. None have been found in the Van Horn quadrangle, but a few were obtained in the Rustler Hills, concerning which G. H. Girty reports as follows:

> Two forms are included in this collection, one of them suggesting by its shape a small Myalina, the other being perhaps Schizodus and having the general shape of *S. harei*. The former is a diminutive shell which might be a Modiola or even a member of some aviculoid genus.

Neither the Castile gypsum nor the Rustler limestone can be traced far beyond their type localities. They are typical members of the red beds of the Pecos Valley, which consist of lenses of gypsum and limestone interbedded with red sandstone and shale. In one of these lenses of limestone in the red beds of the Pecos Valley south of Lakewood, N. Mex., J. W. Beede in 1909[a] collected fossils which he correlates with those of the Quartermaster formation and those of the Whitehorse sandstone member of the Woodward formation. These formations are parts of the well-known Permian red beds of northern Texas and Oklahoma.[b]

CRETACEOUS SYSTEM.

COMANCHE SERIES (LOWER CRETACEOUS).

Definition.—The Cretaceous strata in the Van Horn quadrangle are outlying remnants of the great mass of Lower Cretaceous rocks in central Texas, where the Comanche series has its typical development. The series is divided into three groups—the Trinity at the base, the Fredericksburg in the middle, and the Washita at the top. In trans-Pecos Texas generally all three groups are represented, the Trinity group is well developed south of the Texas & Pacific Railway, but only the Fredericksburg and Washita groups are known north of that line. Both the Fredericksburg and the Washita are represented and have been mapped in areas contiguous to the Van Horn region, but in the quadrangle itself the meager fossil collections indicate no more than Lower Cretaceous age, and accordingly the groups have not been there differentiated.

Distribution and character.—In the Van Horn quadrangle rocks in two general areas are assigned to the Comanche series. One area is 7 miles west of Van Horn, where the beds cap the hills immediately north of the railroad; the other is in the southeast part of the quadrangle, both north and south of the railroad, where the beds occur in several isolated areas.

West of Van Horn about 400 feet of Comanche strata lie unconformably on the Hueco limestone. At the base of the Cretaceous is a bed of conglomerate about 10 feet thick containing pebbles of quartz, schist, and limestone up to 2 inches in diameter in a sandy matrix. This is overlain by 10 to 20 feet of fine-grained drab limestone that weathers yellowish and reddish, above which is about 375 feet of massive, somewhat indurated, brown to gray quartz sandstone irregularly banded with thin beds of quartz conglomerate. The stratigraphy is varied by the local occurrence of lenses of limestone and shale in the prevailing sandstone. Fossils are rare. A few undetermined gastropods have been found in the limestone, and fragments of oyster shells and an imperfect Exogyra were obtained in the basal conglomerate.

In the area east of Plateau the beds in several detached hills, surrounded by Quaternary deposits and capped by conglomerate and sandstone, are tentatively mapped as Comanche, but as no fossils have been found in them their age is undetermined. The conglomerate is in places 25 feet thick and is composed of pebbles of quartz, quartzite, and chert embedded in a brownish and reddish sandy matrix. The overlying sandstone is gray to buff and is generally fine grained, although in places it contains lenses of conglomerate.

Northeast of the Wylie Mountains there are a few small areas of conglomerate, which are surrounded by the unconsolidated deposits of Salt Flat. The pebbles, which are rounded and are 2 inches or less in diameter, consist of quartz, quartzite, and chert, embedded in coarse rust-colored sand. The age of the conglomerate is not known, but it is thought to be Comanche.

QUATERNARY SYSTEM.

GENERAL CHARACTER AND AGE.

The Salt Flat bolson and other lowland areas of the quadrangle are occupied by unconsolidated deposits of unknown but considerable thickness. The greater part of this material consists of outwash, but in the lowest part of the Salt Flat, in the vicinity of Salt Lake, a deposit of unconsolidated gypsum covers a considerable area. Part of this material is of Recent age and part no doubt is Pleistocene, being similar to the bolson deposits from which fossils have been obtained in the vicinity of El Paso. The basal bolson deposits may be Tertiary.

UNCONSOLIDATED GYPSUM.

An area of about 80 square miles in the lowest part of Salt Flat, extending from the north end of the Baylor Mountains beyond the northern margin of the quadrangle, is covered with gypsum of Quaternary age. The surface of the central part of Salt Flat is broadly undulating and is divided into a number of irregular small basins underlain by gypsum separated by ridges of wind-blown gypsiferous sand. Local accumulations of gypsum east of Figure Two ranch occur in sand dunes, some of them 20 to 30 feet high.

The gypsum is generally fine grained, impure, and earthy, and is of dull grayish hue due to admixture of sand and silt. In places, however, considerable areas are covered with rather loosely consolidated pure-white gypsum. The thickness of the deposit is not known. Shallow wells in the vicinity of Figure Two ranch headquarters show thicknesses ranging from 2 to 20 feet and in other parts of Salt Flat it is reported that wells 40 or 50 feet deep have not gone through the material.

The gypsum was apparently formed by evaporation of underground water brought to the surface by capillary action, the supply of gypsum being drawn from material more or less disseminated in the bolson deposits. Presumably it was originally derived partly from the gypsum beds of Pennsylvanian age, intercalated with the red beds of the Hueco formation in the Sacramento Mountains of New Mexico, at the northwest end of Salt Flat, and partly from the Castile gypsum.

BOLSON DEPOSITS.

The surface of Salt Flat and of all the lowland areas, outside of the gypsum belt, is occupied by unconsolidated débris derived from the disintegration of the rocks of the adjacent highlands. The deposits cover a large part of the quadrangle and underlie Salt Flat to a considerable depth. The material extends in graded slopes up the mountain sides for several hundred feet above the lowlands. Material derived from the disintegrated rocks accumulates at the base of the mountains and is rudely sorted and washed toward the lowlands, chiefly by the torrential streams characteristic of the region. This débris merges with the alluvial fans that head up in the canyons and form about the larger arroyos. The base of the highlands accordingly is fringed with a great mass of alluvium. Near the mountains the gradient is steep, the slope becoming less and less until it merges into the almost level floor of the lowlands. Torrential streams are the chief transporting agent for the coarse débris, but a slow gravity creep aids, and the wind does important work in shifting the finer material. Coarse débris abounds near the mountains, and finer deposits constitute the surface of the lowlands.

The composition of the material differs with the character of the rocks in the adjacent highlands. The limestone areas are bordered by an outwash slope of limestone gravel, cemented into indurated masses by lime, ranging from thin films to a deposit of almost pure calcium carbonate several inches in thickness, known as caliche. Caliche is not specially abundant in this region, but in places it is conspicuous. For instance, a low bench along the road east of the mouth of Victoria Canyon is formed by a thin bed of it. The deposit is formed by the precipitation of calcium carbonate, in some places from surface water and in other places from ground water brought to the surface by capillarity.

Along the base of the Delaware Mountains, where there is considerable sandstone, a long belt of sand forms the eastern base of Salt Flat. Sand is abundant also in the southeast corner of the quadrangle. In the vicinity of Van Horn a great body of reddish sand, with intercalated clay, is derived from the Van Horn sandstone.

Of the composition and arrangement of the unconsolidated deposits beneath the surface of Salt Flat nothing is definitely known, for although a number of wells have been sunk satisfactory records of the drilling have not been kept. It is probable that in the upper several hundred feet the deposits that have been accumulated under the present arid conditions are various and of lenticular form. But possibly the lower deposits, which may have accumulated in a lake, were sorted and are more regular in their occurrence. The thickness of the unconsolidated material is not known; the deepest wells are those at Van Horn, which show a depth of 600 feet near the margin of the basin. The deposits may attain a thickness of 1000 feet or more in the main part of Salt Flat.

IGNEOUS ROCKS.

In the Van Horn quadrangle igneous rocks are of very minor occurrence. They include only a few small stocks and dikes, some of which are indicated on the map but the smallest of which can not be shown on the scale used. In the pre-Cambrian area it is impracticable to separate the metamorphic rocks of igneous origin from the sedimentary schists.

Little direct evidence as to the age of the igneous rocks is obtainable in the quadrangle. Presumably they are to be referred either to the pre-Cambrian or to the Tertiary, as these were the two main periods of igneous activity in the trans-Pecos region. In the Carrizo Mountains the metamorphosed igneous rocks doubtless antedate the deposition of the Van Horn sandstone, and most if not all of the unmetamorphosed intrusives probably were associated with the orogenic movements of Tertiary time.

The most conspicuous bodies of igneous rock in the quadrangle are diabase dikes in the Carrizo formation 5 to 6 miles southwest of Van Horn. One of these forms a prominent ridge more than 2 miles long. It cuts the pre-Cambrian rocks and extends parallel to their general strike, in this respect being similar to the metamorphosed igneous rocks included in the Carrizo formation. The diabase differs from the more ancient igneous rocks, however, in being distinctly massive. It is greenish-black, dense, and so fine grained that the component minerals are not generally distinguishable in hand specimens. It is distinctly granular with a tendency toward ophitic texture and consists of feldspar and pyroxene in about equal amounts, with secondary chlorite and zoisite and subordinate magnetite. The feldspar ranges from calcic oligoclase to sodic andesine and the pyroxene is augite.

Diabase of similar appearance outcrops in an isolated hill surrounded by wash in the extreme southwest corner of the quadrangle. Its occurrence is in line with a fault which brings the Hueco limestone in contact with the Carrizo formation. The diabase is an extremely hard and massive rock which weathers dull brown but on fresh surfaces is normally greenish-black mottled with specks of gray. The texture is medium granular and the rock is composed of plagioclase feldspar, ranging from calcic andesine to sodic labradorite and augite in about equal amounts. The Millican formation is intruded by several dikes similar to those which cut the Carrizo formation. Their topographic occurrence, however, is less distinctly marked, and their surface exposures are much decomposed.

A mile southeast of the Texas & Pacific Railway pumping station in the Carrizo Mountains near the western border of the quadrangle a low hill almost surrounded by wash is composed

[a] Beede, J. W., The correlation of the Guadalupian and the Kansas sections: Am. Jour. Sci., 4th ser., vol 30, pp. 135–136, 1910.

[b] Richardson, G. B., Stratigraphy of the Upper Carboniferous in west Texas and southeast New Mexico: Am. Jour. Sci., 4th ser., vol. 29, pp. 330–337, 1909.

of rhyolite. The surface is greatly weathered, but fresh exposures show a dense fine-grained grayish to reddish rock composed of small phenocrysts of quartz and of orthoclase and albite intergrown as microperthite in a groundmass consisting of minute grains of interlocked quartz and feldspar, carrying specks of iron oxide. The phenocrysts are much broken and the rock shows evidence of having been subjected to pressure. It is similar to some of the altered rhyolite occurring in the schists south of the railroad.

Two masses of igneous rocks are intruded into the Hueco limestone in the escarpment of the Sierra Diablo southwest of Figure Two ranch headquarters. The southernmost of these masses is important because it has metamorphosed the adjacent limestone into a valuable marble (p. 9). The intrusive rock is dioritic, in which differentiation apparently has taken place, but its relations are obscured by débris. The central mass is coarse grained and gray, but along the periphery a somewhat finer grained darker facies is developed. The inner portion is quartz diorite that approaches granodiorite in composition, being composed of plagioclase, biotite, and hornblende, with subordinate orthoclase and quartz. The outer portion is diorite, being composed of more calcic plagioclase (chiefly andesine) and augite, with no quartz.

STRUCTURE.

TRANS-PECOS REGION.

The dominant structure of the trans-Pecos region is expressed in the northwestward to northward trend of the highlands and intervening lowlands. The highlands are areas of relative uplift and the lowlands are troughs of corresponding depression. The chief movements of the rocks have been vertical, and the main structural features are normal faults. Most of the highland areas are bounded by faults that strike in general with the main trend of the region, though some cut this transversely. In general, the strata either lie nearly flat in the plateaus or are inclined at greater or less angles that form, according to the degree of dip, narrow mountain ridges or broad monoclinal slopes. In places masses of igneous rock have domed and tilted the strata through which they have been intruded.

The major faults apparently were initiated with the Tertiary continental emergence and developed between then and the late Tertiary or early Quaternary uplift. During Mesozoic and Paleozoic time there was in general comparatively little disturbance of the strata in trans-Pecos Texas north of the Texas & Pacific Railway, although there is evidence of a number of regional uplifts and subsidences and of slight local pre-Pennsylvanian tilting (p. 5). It should be noted, however, that the general absence of structural disturbance in this area during the Paleozoic and Mesozoic eras is in contrast with the sharp folding of the Paleozoic strata in the vicinity of Marathon, Brewster County, Tex., about 100 miles southeast of Van Horn, which R. T. Hill and J. A. Udden consider to have taken place in pre-Cretaceous time. In pre-Cambrian time profound structural disturbances occurred, in the development of which lateral pressure was the effective agent in contrast with the vertical movements which produced the dominant later structures.

STRUCTURE OF THE VAN HORN QUADRANGLE.

Types.—In the Van Horn quadrangle both the earlier lateral and the later vertical types of structure are developed, although here, as throughout the region, the vertical type is the more prominent.

The earlier structure is recorded by the steeply tilted and obscurely folded Algonkian (?) rocks, in which two main structural trends are present—one northeast and southwest and the other east and west.

The later movements, produced by vertical forces, resulted in normal faults with steep dip, which range in displacement from a few feet to more than 1000 feet. The faults strike in various directions, the most prominent trending northwest, though some strike northeast and east and others have still different trends.

Salt Flat.—Salt Flat is the central structural feature of the quadrangle. It is a depressed trough, above which the highland masses on both sides have been relatively raised. The differential movements along the border of the basin apparently began during the post-Cretaceous uplift and were continued, at intervals, through Tertiary time. Different dates of uplift are indicated by the relatively young fault scarp of the eastern Sierra Diablo and the maturely dissected zone along the base of the Delaware and Apache mountains. The attitude of the bedrock underlying Salt Flat is concealed by the thick cover of Quaternary deposits.

Carrizo Mountains.—Two main structural trends are developed in the Algonkian (?) rocks of the Carrizo Mountains. In the north the prevailing strike of the Millican formation is in general east and west and in the south that of the Carrizo formation is northeast and southwest.

In the southern Carrizo Mountains the rocks strike northeast-southwest and dip 20° SE. to 90°, averaging possibly 60° in the southeast and 25° in the northwest part. A more nearly east strike is developed in the northwestern part of the exposure of the Carrizo formation, contiguous to the Texas & Pacific Railway, indicating an approach to the structure of the Millican formation.

The area in which the Carrizo formation outcrops is bounded on the north, south, and east by normal faults. On the north the fault strikes almost east, on the east the strike is northeast, and on the south it is northwest. By these faults the Algonkian (?) area south of the railroad has been uplifted, so that the ancient rocks are in contact with the Hueco limestone on the south and with the Hueco limestone and the Comanche series on the north. The dislocation at the south is well shown by the abutting of the schists of the Carrizo formation, dipping 45° SE., against the Hueco limestone, dipping 17° SW. A subsidiary fault striking north-south is developed 1½ miles southeast of Hackett Peak, where the pre-Cambrian rocks are in fault contact with a small area of Van Horn sandstone and Hueco limestone.

In the northern part of the Carrizo Mountains the structure is more varied and obscure than in the southern part. North of the railroad the most pronounced structure is a general east-west strike, accompanied by steep southward dips. These features are best brought out by the beds of limestone and conglomerate, for the homogeneity of the fine-textured red sandstone member of the Millican formation makes it almost impossible to determine its structure over a large part of the area of its outcrop, though at some places, as at the Hazel mine, its easterly strike and steep southward dip are evident. The general easterly strike is well shown between Carrizo Spring and the Texas & Pacific Railway's pumping station, where beds of cherty limestone and breccia stand nearly vertical or are tilted southward at a high angle. East of Millican's ranch the development of a local syncline is indicated by northward and southward dipping beds of limestone, but the structure is complex and poorly defined.

Morris Peak, a mile east of Grapevine Spring, is formed by an eastward-plunging asymmetric syncline bounded on the east and south by a fault. The Millican formation, of which the mountain is composed, is in fault contact on the south and east with the Van Horn sandstone and the El Paso limestone. (See Pl. III.) In the northern part of the mountain cherty limestone overlying the fine red sandstone dips S. 45° E., but in accordance with the plunge of the syncline at the west end of the mountain the strata curve around so that at the southern end of the uplift the dip is about 20° N.

Another fault extends southwestward through Carrizo Spring, separating the Millican formation on the north from the relatively downthrown Van Horn sandstone on the south. Possibly this dislocation continues northward toward Grapevine Spring and connects with the fault south of Morris Peak, but the conditions are obscure. Presumably also the Millican formation is cut by other faults which are not mapped.

Beach and Baylor mountains.—Beach and Baylor mountains are almost entirely composed of Ordovician and Carboniferous limestones. In the Baylor Mountains these rocks lie in general nearly horizontal, but in Beach Mountain they exhibit a pronounced low inclination to the northeast, and in places in both areas they show diverse dips. The eastern termination of the two mountain masses at the border of Salt Flat is in such marked alignment that it is highly probable they are delimited by a fault which trends northeast and whose continuation cuts off the Carrizo Mountains from Salt Flat at the south end of the quadrangle.

The abrupt, almost straight termination of the northern end of the Baylor Mountains indicates also that a cross fault delimits this area on the north, but no other evidence of its existence has been found.

Faults separate Beach and Baylor mountains from each other and from the Sierra Diablo. Subsidiary faults are also present. At the north end of Beach Mountain the Hueco limestone is in fault contact with the El Paso limestone and Montoya limestone, and at the southwest end of the mountain the Van Horn sandstone and El Paso limestone are slightly offset. (See Pl. IX.)

Sierra Diablo.—The strata of the Sierra Diablo in general lie almost horizontal, but in places they dip diversely, and in the north the Hueco limestone dips about 1° W., so that the top of the mountains forms a dip slope. On the south the Sierra Diablo is delimited by two parallel faults about 3 miles apart that strike northwest and southeast. (See section E–E, structure-section sheet.) In both, the relative upthrow is on the north, the displacement of the southern fault being about 300 feet and that of the northern one approximately 450 feet, the contact of the Hueco limestone with the Millican formation affording the basis for measurement. The southern fault presumably marks the northwestward continuation of the displacement south of Morris Peak. The throw is shown in figure 6, *a*. The northern fault causes a repetition of the fine-textured red sandstone of the Millican formation in a small area north of Bound's ranch. The displacement is well exposed in the canyon a mile north of the Hazel mine, the fault plane passing up the canyon and exposing a remnant of the Van Horn sandstone abutting against the Millican formation and the Hueco limestone. (See north end of section E–E, structure-section sheet.) The displacement of the Hueco limestone by the fault at the western edge of the quadrangle is shown in figure 6, *c*.

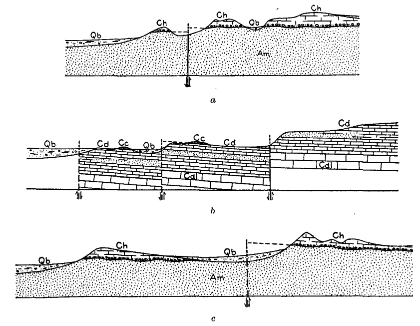


FIGURE 6.—Sections showing normal faulting.

a, Section along line I-I on areal-geology map, showing displacement of Hueco limestone and Millican formation by fault at south edge of Sierra Diablo; *b*, section along line G-G on areal-geology map, showing Castile gypsum overlying Delaware Mountain formation in faulted blocks at the south end of Delaware Mountains; *c*, section along line H-H on areal-geology map, showing displacement of Hueco limestone by fault near Sheep Peak.

Am, Millican formation; Ch, Hueco limestone; Cd, Delaware Mountain formation, with limestone member, Cdl; Cc, Castile gypsum; Qb, bolson deposits.

Horizontal scale, 1 inch=approximately half a mile.
Vertical scale, 1 inch=approximately 1800 feet.

One of the principal zones of displacement of the quadrangle is at the eastern base of the Sierra Diablo, along which the movements have taken place that have raised the mountains above Salt Flat trough. The southern extension of this displacement separates the Sierra Diablo from the Baylor Mountains, in which the Hueco limestone has been dropped relatively to its occurrence in the Sierra Diablo to the west. An idea of the approximate displacement is afforded by a comparison of the elevation of the top of the Millican formation in a hill in the downthrown block west of the north end of the Baylor Mountains, not shown on the map, with approximately the same horizon on the flanks of the Sierra Diablo to the west. This shows a displacement of about 1300 feet. An example of "drag" along the fault is shown about a mile north of the mouth of Victoria Canyon, where east-dipping beds of Hueco limestone on the downthrown side abut against practically horizontal strata on the opposite side of the fault. (See section B–B, structure-section sheet.)

Delaware Mountains.—The Delaware Mountains are an east-dipping monocline bounded on the west by a fault, which separates them from Salt Flat. The disturbed zone is marked in places by a belt of foothills, forming a downthrown block, in which the maximum dip of the strata is 15° SW. The rocks of the main Delaware Mountains dip 1°–5° NE. At the extreme southern end of the mountains there are diverse dips and a low anticlinal fold of small extent.

Area between the Delaware and Apache mountains.—Immediately south of the Delaware Mountains and north of the Apache Mountains there is a fault block of rudely triangular outline at least 10 miles long and 2 miles wide. The block is bordered on the south by a fault whose southeastward extension reaches beyond the margin of the quadrangle along the northern base of the Apache Mountains, and whose northwestward extension is concealed by the unconsolidated deposits in Salt Flat. The outcrops in this block are chiefly the Castile gypsum and the overlying Rustler limestone, which have been faulted down into the Delaware Mountain formation. The strata lie almost horizontal, but the delimiting fault lines, although in part concealed by Quaternary wash, are well exposed in places. For instance, at the head of the valley, 4 miles east of bench mark 3969, the Delaware Mountain formation in the uplifted block east of the fault is in contact with both the Rustler limestone and the Castile gypsum. The fault is shown in figure 6, *b*. A vein of quartz occurs along the fault plane. This block is intersected by minor faults, as shown on the structure-section sheet.

Apache Mountains.—The limestone of which the Apache Mountains are composed is in most places so massive that its structure is difficult to determine. Where bedding planes are apparent the strata in general are seen to lie practically horizontal, though here, as commonly throughout the region, the prevailing attitude of the beds is disturbed by local deformation. In the belt of foothills at the extreme western end of the mountains the limestone dips 5°–10° W., owing to a zone of disturbance along the lowland north of Jones's ranch. In the low hills immediately north of the railroad, northeast of Plateau, the beds dip 5° W., and the presence of Cretaceous (?) sandstone in the hills at the eastern edge of the quadrangle at a lower elevation than what appears to be the same bed in the hills to the west indicates a small fault.

GEOLOGIC HISTORY.

ALGONKIAN (?) PERIOD.

The Carrizo and Millican formations, of sedimentary origin, bear witness to the existence of an old land mass from which their component materials were eroded and transported by streams to a body of water in which beds of gravel, sand, clay, and calcareous mud accumulated, but practically nothing is known of the outline and extent of these early bodies of land and water. The deposits were indurated to conglomerate, sandstone, shale, and limestone, were intruded by igneous rocks, were deeply buried and in part metamorphosed to schist, quartzite, and slate, were deformed, uplifted to the surface, possibly to form part of a mountain area, and were acted upon by erosion. These events occurred before the beginning of Paleozoic time.

PALEOZOIC ERA.

The apparent absence of Lower and Middle Cambrian deposits implies that this area, in common with a large region in the southwest, was not submerged during the corresponding periods, when the Algonkian (?) rocks probably formed a land area. In other parts of the Cordilleran region there is evidence that the Algonkian surface was reduced to a peneplain, but in the Van Horn quadrangle the few exposures, such as the contact of the Van Horn sandstone with the Millican formation west of Beach's ranch, show that the surface was very uneven when the sandstone was laid down upon it. The character of the basal conglomerate and of the red arkosic sands in the lower part of the Van Horn sandstone suggest that they are of subaerial origin, and the well-sorted quartzose sands, containing worm borings and fucoid-like remains, in the upper part of the formation indicate that the Upper Cambrian (?) sea had finally spread over the old land area.

Apparently the Van Horn sandstone was uplifted and somewhat eroded before the deposition of the El Paso limestone. The irregular basal layer of shale and the sandstone interbedded with the limestone in its lower part indicate variable conditions of deposition in early Ordovician time. More uniform conditions followed, during which the deposition of terrigenous material practically ceased, and the several hundred feet of the upper part of the El Paso limestone containing the Beekmantown fauna was laid down.

The hiatus shown by the absence of the Middle Ordovician fauna, together with the basal conglomerate and sandstone of the Montoya limestone, indicate that a period of emergence and nondeposition was followed by submergence and by the deposition of offshore material, succeeded by the accumulation of the limestone of the Montoya, which contains the Richmond fauna.

Silurian time, so far as known, is not represented by sediments in the Van Horn quadrangle, although it is possible that some of the limestone, in which fossils have not been found, lying between the Montoya and Hueco limestones may be of Niagaran age and may represent the Fusselman limestone of the El Paso quadrangle. Devonian and Mississippian rocks do not occur in the Van Horn quadrangle, but whether they were never deposited or were removed by erosion is not known.

Presumably between Upper Ordovician and Pennsylvanian time there were several periods of emergence and subsidence produced by broad vertical movements. Practically no evidence exists of lateral pressure in this region during Paleozoic time, the only structural disturbance being the slight eastward tilting of the Van Horn sandstone before the deposition of the Hueco limestone.

The emergence immediately preceding the Pennsylvanian epoch was accompanied by profound erosion in the Van Horn region, and during the succeeding subsidence the basal conglomerate of the Hueco limestone was laid down in the advancing Pennsylvanian sea on an uneven surface of the underlying formations. As subsidence continued the deposition of terrigenous material was succeeded by the accumulation of the great thickness of Hueco limestone, which is so well developed in the Diablo Plateau. More diverse conditions marked the deposition of the Delaware Mountain formation and of the overlying Castile gypsum and Rustler limestone. The diversity of these formations and their equivalents in adjacent areas emphasizes the variability of late Carboniferous stratigraphy in this region. While limestone was accumulating in one area, sandstone was being deposited in another, and red beds in a third. This variation is an expression of changing geographic conditions which accompanied the emergence of the continent at the close of Paleozoic time. Apparently the open sea which advanced on a land area at the beginning of Pennsylvanian time gave way with some alternations to shallower water and to local inclosed basins. Finally, the close of the Paleozoic era was marked by continental uplift, which, however, in this area was not, as in other regions, accompanied by folding of the rocks.

MESOZOIC ERA.

During the early part of the Mesozoic era part of the trans-Pecos region was a land mass that served as a source of Triassic and Jurassic sediments deposited elsewhere. But to what extent rocks of these systems were laid down in this region only to be removed by erosion is unknown. Triassic rocks have not been found in trans-Pecos Texas, although deposits of that age are well developed in New Mexico, and Jurassic time in this region, so far as now known, is represented only by a small area of marine deposits in the Malone Mountains, 35 miles west of the Van Horn quadrangle, where the sediments appear to have been laid down in water connected with the Gulf of Mexico.

It is probable that the land mass which was uplifted at the close of the Paleozoic was well reduced toward base level by the beginning of Cretaceous time, when the Comanche sea advanced on the trans-Pecos region from the south and east. The Van Horn area apparently was not submerged until after Trinity time (lowermost division of the Comanche epoch), but during Fredericksburg and Washita time it was apparently entirely covered by the sea, although only isolated remnants of the deposits bear witness to the fact. Upper Cretaceous beds are also lacking, except in some small areas of Colorado strata in the vicinity of El Paso, but it nevertheless seems likely, from the character and distribution of rocks of Upper Cretaceous age in adjoining areas to the north and south, that the entire region was submerged until toward the close of Cretaceous time, and that the sediments were removed by the erosion which followed the post-Cretaceous uplift.

CENOZOIC ERA.

Continental uplift and associated disturbances occurred throughout the Cordillera at the close of Mesozoic or early in Tertiary time, when the trans-Pecos region may have attained lofty elevations. The major deformation in the Van Horn quadrangle presumably was then begun and the faults which now delimit the highland masses and the Salt Flat trough may then have been outlined. Probably during the Tertiary period there were a number of uplifts, both regional and differential. Erosion of the land followed the uplifts, and a great body of Cretaceous and underlying strata was removed. It may be presumed that, during the long Tertiary period, of which in the trans-Pecos region so little is known, the area was well reduced toward peneplanation, although there is no quantitative evidence in the Van Horn quadrangle of the extent of the erosion nor are there any outcrops of Tertiary age to assist in determining dates.

In late Tertiary or possibly in early Quaternary time renewed uplifts, both regional and differential, raised the area to its present position and defined the relative positions of the highlands and the lowlands. The most striking feature of the present topography—highland areas rising abruptly above the central lowland—is a direct consequence of differential movements, the highlands being areas of uplift and the lowland an area of corresponding depression. During and subsequent to these movements the Quaternary record is one of continued erosion and deposition. The highlands were sculptured by subaerial influences, débris was collected in the lowlands, and the country assumed its present aspect.

The existence of a moister climate in early Quaternary time is not so evident in the trans-Pecos region as it is in other parts of the Cordilleran region—as in Utah and Nevada, for instance, where great bodies of water, the best known of which are the extinct Lakes Bonneville and Lahontan, existed at the time the great ice sheet covered the northern part of the continent. Nevertheless there are some indications of such a climate. The larger valleys in most of the highland areas could not have been excavated by the temporary streams that now occupy them only during and immediately after rains. They appear to have been cut during a former period of more abundant precipitation and more vigorous stream action.

The trends of the upper parts of Apache and Victoria canyons in the Sierra Diablo suggest that they have been lengthened by the capture of the upper parts of streams that formerly flowed westward. For instance, the westward-flowing tributaries of the north fork of Victoria Canyon probably originally continued westward instead of in their present somewhat circular course. Inspection of the topographic map of the Van Horn and of the adjacent Sierra Blanca quadrangle on the west indicates that at the head of Apache Canyon similar changes have occurred and that conditions apparently are propitious for further readjustments of drainage, which will result in abnormal directions of stream flow. These conditions are due to the fact that the encroaching valleys are being eroded faster than those which are captured, so that the divide is being pushed back toward the area of lesser erosive activity.

The Salt Flat trough, being a closed basin of structural origin, probably was occupied by a lake in early Quaternary time, when the climate was more moist, which lake with the advent of arid conditions decreased in size by evaporation and finally disappeared. According to this interpretation the lower deposits underlying Salt Flat are in part lake beds, and the upper deposits are arid subaerial accumulations.

The present arid climate of the trans-Pecos region determines many of its characteristic aspects. The principal factors are the small rainfall, chiefly in heavy downpours which cause local torrential floods, the high temperature, and the large diurnal changes in temperature. In consequence, (1) there is no permanent run-off, streams flowing for only a few hours after storms and disappearing by absorption and evaporation. (2) Vegetation is scanty and of the desert type and does not protect the highlands from the effects of wash. The summits are characteristically bare, débris derived from disintegration of the rocks collecting at the base of the highlands in graded slopes that extend toward the center of Salt Flat. (3) The excessive diurnal change of temperature subjects the bare rocks to stresses of expansion and contraction which facilitate their disintegration. (4) The practical absence of true soil and the scarcity of humic acids result in comparatively little chemical change of the rock débris, so that the unconsolidated material which underlies the lowlands is but little decomposed.

The material derived from the disintegration of the rocks of the highlands is transported toward the lowlands by the wash of torrential rains, by the direct action of gravity, and by the wind. Alluvial fans, consisting of heterogeneous masses of bowlders, gravel, and sand, form about the mouths of the canyons and coalesce, scallop fashion, with the alluvial slopes which accumulate along the base of the mountains between the arroyos. The débris, composed of preponderatingly coarse material near its source, slopes steeply toward the lowlands near the mountains but flattens gradually toward the center, where it becomes almost flat. The material decreases in fineness with distance from the mountains, so that the lowlands are underlain chiefly by fine-textured deposits. The almost incessant winds are important agents in transportation, keeping the highlands bare of fine débris and accumulating it about the vegetation in the lowlands or piling it in shifting dunes. Dust storms are common. Some material is even transported across the divide out of the basin by severe storms.

ECONOMIC GEOLOGY.

The mineral resources of the Van Horn quadrangle include ores of silver, copper, and tungsten; turquoise in small amount; considerable marble; enormous quantities of limestone, sandstone, gypsum, sand, clay, and gravel; and locally plentiful underground water.

COPPER AND SILVER.

Copper and silver have been found at several places in the Carrizo Mountains, but thus far only one paying mine, the Hazel, has been opened in the quadrangle—and the Hazel for many years lay unworked.

Hazel mine.—The Hazel mine is situated close to the southern base of the Sierra Diablo, 10 miles northwest of Van Horn. It is said to have been opened about 1885 and to have been worked for eight or ten years, after which, until 1912, it remained idle. It is reported to have yielded silver ore worth several hundred thousand dollars.

W. H. von Streeruwitz[a] described the Hazel mine in 1892. The property was worked from two shafts, 575 and 375 feet deep, situated 1800 feet apart, and numerous crosscuts made the workings rather extensive. The ore was found in veins and pockets and also impregnated the country rock, the principal minerals being copper sulphides and carbonates, with associated silver sulphides and metallic silver.

Recent development shows that mineralization has taken place in a zone of small faults between the larger displacements at the southern end of the Sierra Diablo. Surface strippings show three mineralized belts striking from N. 65° E. to N. 85° E., each consisting of a band of country rock, the fine-grained sandstone of the Millican formation, from 3 to 6 feet wide, which has been bleached to a buff or creamy tint. This decolorized sandstone, standing almost vertical, carries the main veins which swell and pinch irregularly, the greatest thickness reported by the engineer in charge being 18 inches. In one place the main vein, there 2 to 4 inches thick, practically vertical, is bounded on one side by a slickensided fault surface and branches on the other side into many minute interlacing veinlets, the whole constituting a mineralized zone 3 to 5 feet thick. The most important minerals noted were chalcopyrite, tetrahedrite, malachite, and azurite in a gangue consisting largely of barite and calcite.

Prospects in the Carrizo Mountains.—Prospects at various places in the Carrizo Mountains, both in the Millican and Carrizo formations, show a rather widespread area of mineralization, but thus far no paying properties have been developed. The ore occurs in small veins or irregularly disseminated. In places, as 2 miles southeast of the Hazel mine, the ore occurs in a fault zone. At other places, as at several localities in the Carrizo formation south of the Texas & Pacific Railway, the veins are in schist and slate along joints or parallel to the planes of lamination. Sporadic occurrences are rather widespread. The ore consists of copper minerals in different stages of oxidation. At the old Maltby prospect, 6 miles west of Van Horn, copper arsenate was found. Assays are reported to show traces of silver and gold.

[a] Geol. Survey Texas Third Ann. Rept., 1892.

The yield of the old Hazel mine induces the hope that profitable deposits may be found elsewhere. The disturbed character of the Algonkian (?) formations, the many faults by which the rocks are traversed, and the presence of igneous rocks apparently afford favorable conditions for the circulation and metallization of underground solutions, and the widespread distribution of ore shows that some deposition has actually taken place. But whether ore has been deposited in commercial quantity elsewhere than in the Hazel mine has not been demonstrated and can be determined only by prospecting and development. It should be borne in mind, however, that considerable prospecting has been done and that, although the rocks are well exposed, few valuable deposits outside of the Hazel mine have yet been found.

TUNGSTEN.

Tungsten deposits are reported from the eastern end of the Sierra Diablo, 2½ miles southwest of Figure Two ranch headquarters. Samples show small tabular crystals of wolframite with associated iron oxides. The material has not been found in any considerable quantity.

TURQUOISE.

Turquoise occurs in at least two places in the quadrangle, at the Hudson prospect about 5 miles west by south of Van Horn and at the Knight (old Maltby) copper prospect a mile to the southwest. The chief occurrence is at the Hudson prospect, which was opened in search of the turquoise. The mineral forms a seam about 1 millimeter thick along joint planes in a fine-grained rock, probably altered rhyolite, in the Carrizo formation. The turquoise is of a good sky-blue or greenish-blue color, but very little of it has yet been found.

LIMESTONE AND MARBLE.

The supply of limestone suitable for the various uses to which that rock is adapted is practically inexhaustible. The deposits, however, are too distant from commercial centers to merit special attention in the near future.

There is, however, an occurrence of marble which on account of its high grade is of present importance, the chief deterrent factor in its development being its distance from the railroad. It occurs in the escarpment of the Sierra Diablo 3½ miles southwest of Figure Two ranch headquarters and 27½ miles in an air line north of Van Horn. The marble is part of the Hueco limestone, which has been metamorphosed by an igneous intrusion. The original gray color has been changed to shades ranging from pink to white by the alteration of the iron compounds and by the expulsion of the small quantities of carbon contained in the limestone. The extent to which marmarization of the limestone has occurred is not known, but it must necessarily be limited to a relatively thin zone around the periphery of the intruded rock. The marble has not been critically tested nor extensively prospected, although enough work has been done to show the presence of a considerable mass of it.

There are also deposits of white and pink marble in the Carrizo Mountains southeast of the Texas & Pacific Railway pumping station.

SANDSTONE.

The red sandstone of the Millican formation is worthy of attention as a possible source of ornamental building stone. It is a compact fine-grained homogeneous red sandstone which will take a good polish and occurs in great volume within a few miles of the railroad. One drawback to its use is that in places it is traversed by many joint planes, but it is possible that development will reveal masses that are in every way suitable for building stone. Selected beds of medium to fine grained Van Horn sandstone, particularly the more indurated varieties, furnish desirable building stone. The Culberson County courthouse at Van Horn is built of this sandstone.

GYPSUM.

Rock gypsum and less pure unconsolidated gypsum occur in considerable quantities and are available for local use in making plaster. In view, however, of the great amount of more easily accessible gypsum the deposits of the Van Horn quadrangle are commercially unimportant.

SAND, GRAVEL, AND CLAY.

Enormous deposits of sand, gravel, and clay form the surface of Salt Flat and underlie it to an unknown depth. In some areas the materials are well sorted and relatively pure deposits of each can be obtained, but over a large region they are irregularly mixed, in consequence of the conditions of deposition.

Similar materials are widespread, and necessarily the demand for them must be local. The clay has been utilized in constructing adobe houses in Van Horn, and the sand and gravel, mixed with Portland cement, have been molded into blocks on a small scale and have proved popular for building.

SOIL.

The soils of the quadrangle, particularly those of Salt Flat outside of the area underlain by gypsum, are undoubtedly fertile. Having been formed by the disintegration of the rocks of the adjacent highlands, they are composed of a variety of mineral particles, which have been preserved from decomposition by the aridity of the climate.

The great drawback to agriculture in the region is the scarcity of water, and in a large part of the quadrangle dry farming offers the only chance of success. Some small attempts at this have failed or met with indifferent success, and, in view of the small rainfall occurring late in the season and the excessive evaporation, the outlook for dry farming unsupported by pumping is not very promising.

In the lower parts of Salt Flat, where water is within easy pumping distance of the surface, certain areas may be successfully farmed; but there a factor to be contended with is the great salinity of both water and soil. Nevertheless certain alkali-resisting crops may be raised.

The soil in most places both on the highlands and lowlands supports a thriving growth of bunch grass and the area is well adapted for a cattle range.

WATER RESOURCES.

There are no permanent streams in the area. During and shortly after heavy local showers storm water gathers in arroyos, but most of it soon disappears by absorption and evaporation. Some storm water is collected, however, in reservoirs known as "tanks," where dams have been built across drainage ways. Large quantities are thus intermittently obtained for watering cattle. This is the most practical way of developing water in the highlands.

The main supply of water in the lowlands is derived from wells in unconsolidated deposits supplied by that part of the precipitation which is absorbed by the ground. The water percolates downward until it reaches the zone of saturation, the upper surface of which is known as the water table. In a large part of Salt Flat the water table is shown by numerous wells to be between 3500 and 3600 feet above sea level. The data are not sufficient, however, to show its exact position throughout the area. In the lower part of the bolson it is within 10 feet of the surface, and over a wide area it can be reached within 200 feet, the depth increasing with the surface elevation. Adjacent to the margins of Salt Flat ground water lies at a considerable depth and a number of dry holes have been sunk. The smallness of the head reported in wells in different parts of Salt Flat indicates that artesian flows can not be generally obtained, if they can be obtained at all. Water is, however, pumped by windmill from numerous shallow wells over a large area in the lower part of Salt Flat.

The most important wells in the quadrangle are those in the vicinity of Van Horn. For a number of years the Texas & Pacific Railway has operated four wells, sunk to a reported depth of 600 feet, which afford a never-failing supply of water of exceptionally good quality for this part of the State. During a number of years, in addition to being the most important source of water along that railroad in trans-Pecos Texas east of El Paso, these wells supplied the town of Van Horn. In 1909, however, a new well from which the town has since been supplied was bored to a depth of 552 feet through deposits reported to be wholly of sand and gravel, though no record was kept. Water was found at 515 feet and stands in the well at a depth of 490 feet.

Several wells have been sunk in unconsolidated deposits in valleys outside of Salt Flat. At Bound's ranch, near the western margin of the quadrangle, there are several wells less than 100 feet deep in the valley of Deer Creek. At Millican's ranch there are two shallow wells; and in the same valley, about 2½ miles north of the railroad, the Texas & Pacific Railway has a pumping station, drawing from six wells, the deepest of which is 70 feet. These wells are connected by tunnels and are reported to yield 50,000 gallons a day.

Although the main supply of underground water in the quadrangle is derived from unconsolidated deposits of sand and gravel, small amounts are obtained from bedrock. The chief source at present is the fine-grained red sandstone of the Millican formation, which yields a number of feeble springs (see topographic map) and which supplies a shallow well at the Hall-Canon ranch. The sandstone is much broken and is traversed by many joints, so that the location of successful wells is uncertain. A diabase dike, too small to be shown on the map, cuts across the valley below the Hall Canon ranch and seems to be the effective agent in impounding the underground water.

Limestone, being in general more compact and less porous than sandstone, is a relatively poor source of underground water. Water occurs in all rocks, nevertheless, however dense, and limestones that are much jointed or fissured or are traversed by solution channels, and the more porous magnesian limestones, or those which contain considerable admixtures of sand, often yield important quantities of water. Among successful wells in limestone are those sunk by the Lanier brothers in the Hueco limestone on the Diablo Plateau about 40 miles north of Sierra Blanca, between 30 and 40 miles northwest of the Van Horn quadrangle. These wells are between 900 and 1300 feet deep and yield large quantities of water. On the other hand, the Aden well in the extreme northeast corner of the quadrangle was sunk in 1902 to a depth of 916 feet, without finding water, almost the entire distance being reported through limestone of the Delaware Mountain formation.

The following analyses of water in the Van Horn quadrangle, one from the railroad well at Van Horn and the other from a well about 30 feet deep at the headquarters of Figure Two ranch show its varied character. Toward the center of Salt Flat, where there are considerable accumulations of gypsum and other evaporation products, the underground water is strongly impregnated with salts, but toward the periphery of the basin it is much less saline.

Analyses of water from the Van Horn quadrangle.

[In parts per million. R. B. Dole, Chase Palmer, and W. D. Collins, analysts.]

	Water from railroad wells at Van Horn. Collected Nov. 10, 1910.	Water from the well at Figure Two ranch headquarters. Collected Nov. 1, 1908.
Total solids at 180° C.	425	2,366
Iron (Fe)	.55	.3
Calcium (Ca)	23	243
Magnesium (Mg)	9.1	141
Sodium and potassium (Na+K)	118	310
Carbonate radicle (CO_3)	14	12
Bicarbonate radicle (HCO_3)	229	193
Sulphate radicle (SO_4)	86	938
Chlorine (Cl)	21	508

The analyses show that the water at Figure Two ranch carries more than five times as much dissolved salts as the Van Horn water. The former is notably high in sulphates and chlorides and is very hard; the latter is essentially a carbonate water with minor amounts of sulphates and chlorides. Water from the Figure Two ranch well contains enough mineral matter to give it a distinct and somewhat disagreeable taste.

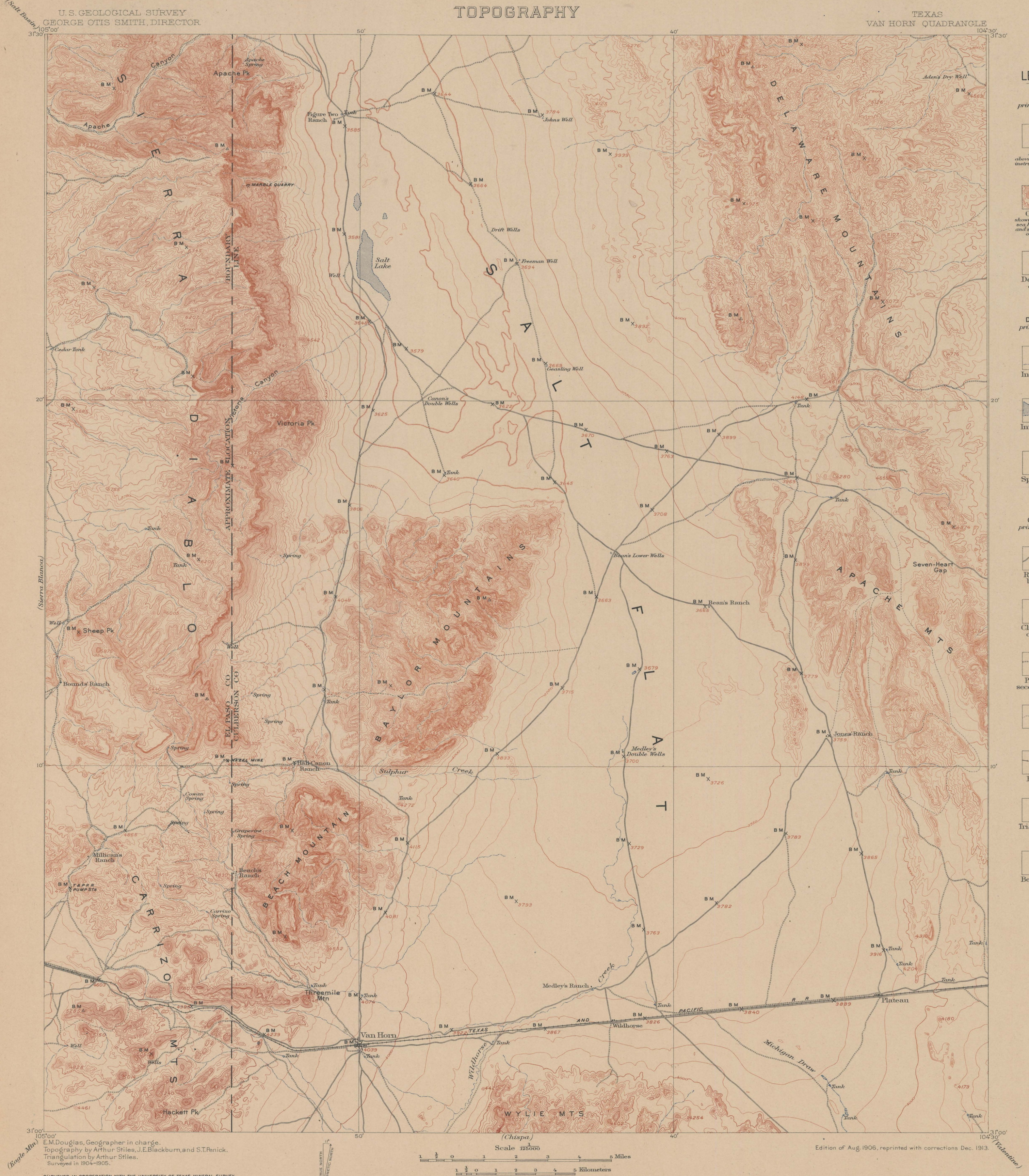
A partial analysis of a sample of the water from Salt Lake, 4 miles south of Figure Two ranch headquarters, collected by J. M. Daugherty in June, 1912, shows it to be an ordinary brine, containing principally sodium chloride and calcium sulphate.

December, 1913.

U.S. GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR

TOPOGRAPHY

TEXAS
VAN HORN QUADRANGLE



LEGEND

RELIEF
printed in brown

Altitude above mean sea level instrumentally determined

Contours showing height above sea, horizontal form, and steepness of slope of the surface

Depression contour

DRAINAGE
printed in blue

Intermittent stream

Intermittent lake

Spring, well or tank

CULTURE
printed in black

Roads and buildings

Church and cemetery

Private or secondary road

Trail

Railroad

Triangulation station

Bench mark

E.M.Douglas, Geographer in charge.
Topography by Arthur Stiles, J.E.Blackburn, and S.T.Penick.
Triangulation by Arthur Stiles.
Surveyed in 1904-1905.

SURVEYED IN COOPERATION WITH THE UNIVERSITY OF TEXAS MINERAL SURVEY.

APPROXIMATE MEAN DECLINATION 1905.

Scale $\frac{1}{125000}$

Miles 1 ½ 0 1 2 3 4 5
Kilometers 1 ½ 0 1 2 3 4 5

Contour interval 50 feet.
Datum is mean sea level.

Edition of Aug. 1906, reprinted with corrections Dec. 1913.

U.S. GEOLOGICAL SURVEY
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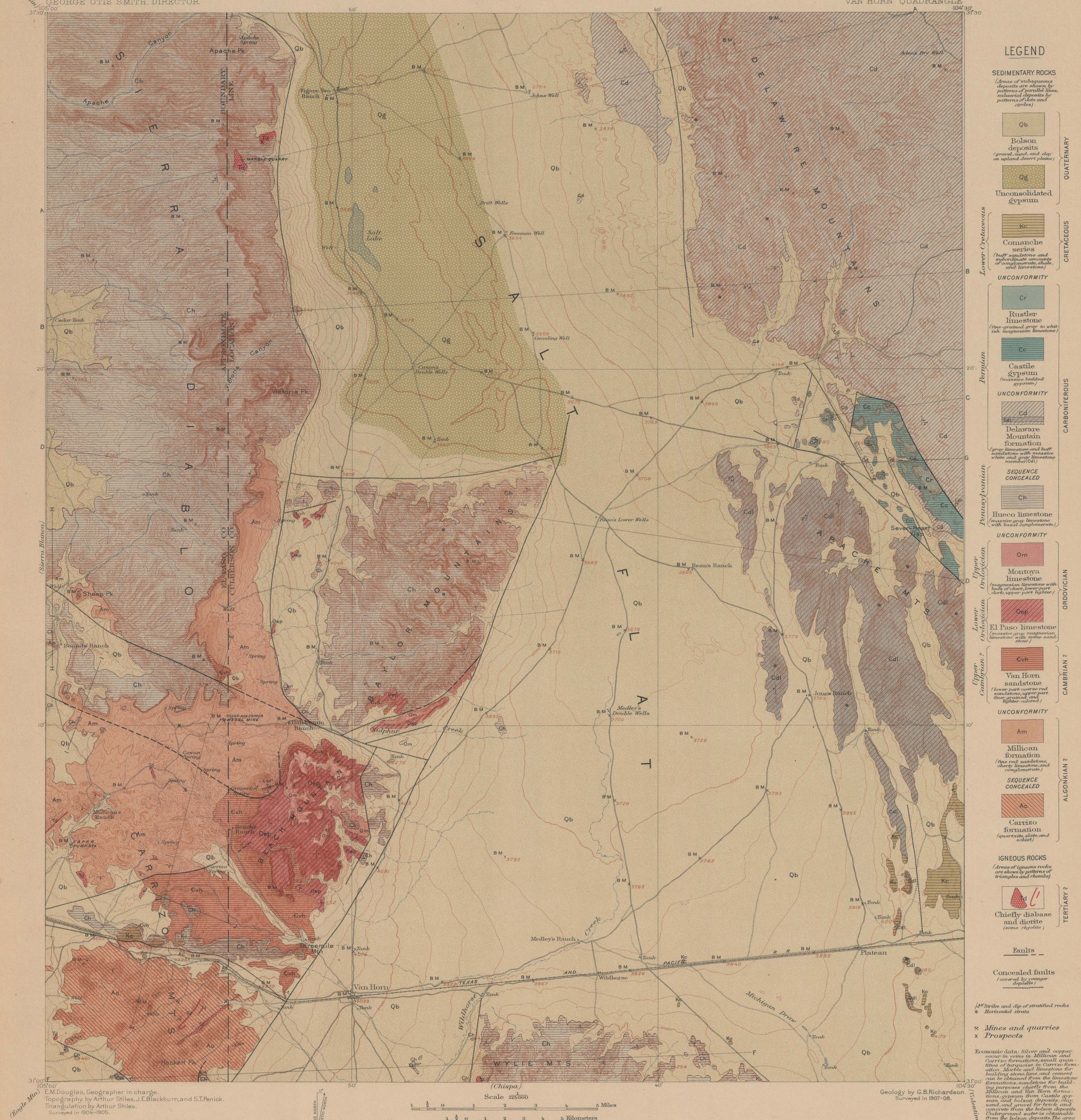
AREAL GEOLOGY

TEXAS
VAN HORN QUADRANGLE



Economic data: *Silver and copper occur in veins in Millican and Carrizo formations; small quantities of turquoise in Carrizo formation. Marble and limestone for building stone, lime, and cement can be obtained from the limestone formations; sandstone for building purposes chiefly from the Millican and Van Horn formations; gypsum from Castile gypsum and bolson deposits; clay, sand, and gravel for brick and concrete from the bolson deposits. Underground water is obtainable from the bolson deposits. The area is chiefly valuable for grazing.*

E.M. Douglas, Geographer in charge.
Topography by Arthur Stiles, J.E. Blackburn, and S.T. Penick.
Triangulation by Arthur Stiles.
Surveyed in 1904-1905.

SURVEYED IN COOPERATION WITH THE UNIVERSITY OF TEXAS MINERAL SURVEY.

APPROXIMATE MEAN DECLINATION 1905.

Scale $\frac{1}{125000}$

Contour interval 50 feet.
Datum is mean sea level.

Edition of Jan. 1914.

Geology by G.B. Richardson.
Surveyed in 1907-08.

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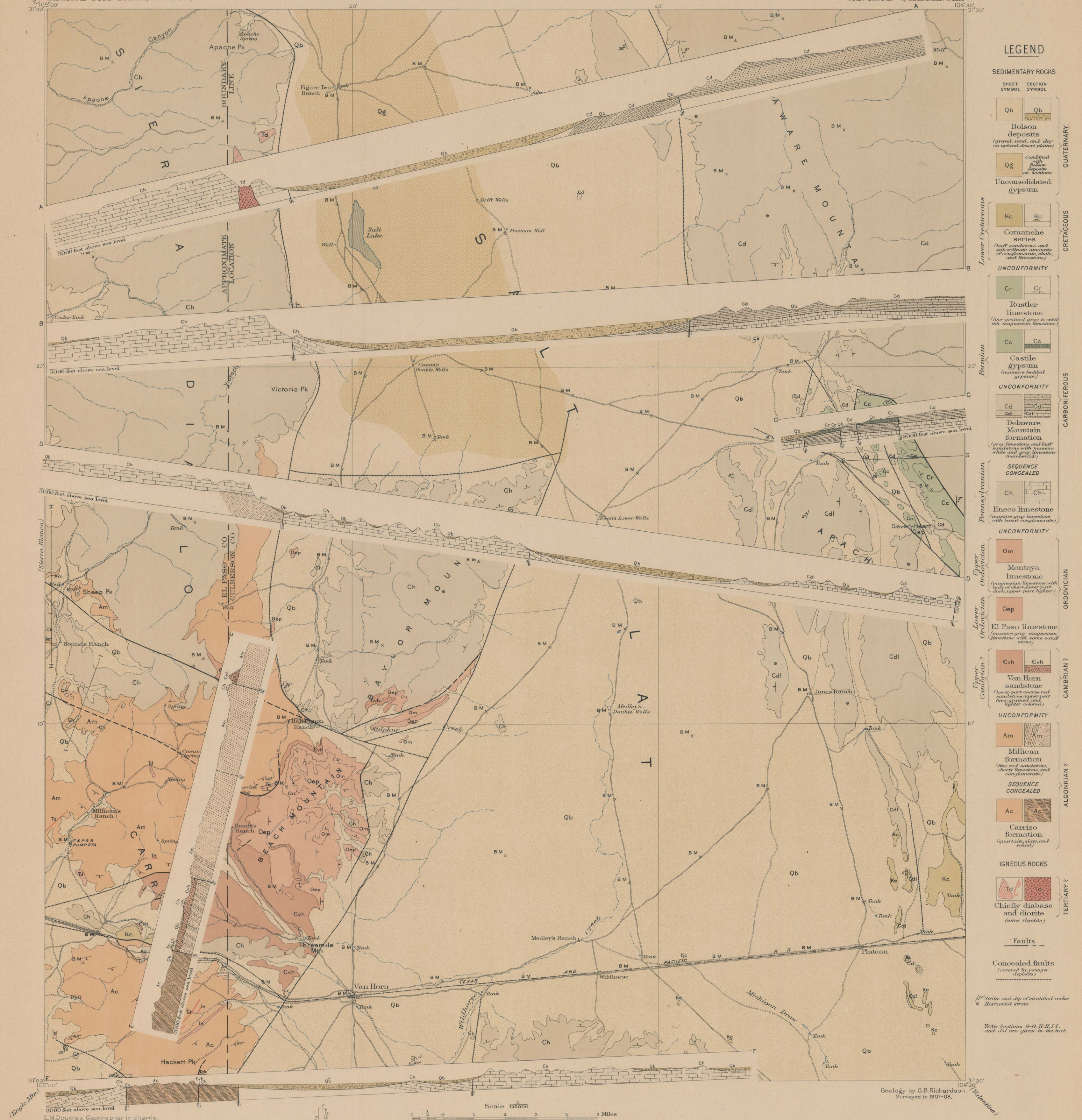
STRUCTURE SECTIONS

TEXAS
VAN HORN QUADRANGLE



Geology by G.B.Richardson.
Surveyed in 1907-08.

Scale $\frac{1}{125000}$

1 ½ 0 1 2 3 4 5 Miles

1 ½ 0 1 2 3 4 5 Kilometers

Edition of Jan. 1914.

TRUE NORTH
MAGNETIC NORTH
APPROXIMATE MEAN DECLINATION 1905.

E.M.Douglas, Geographer in charge.
Topography by Arthur Stiles, J.E.Blackburn, and S.T.Penick.
Triangulation by Arthur Stiles.
Surveyed in 1904-1905.

SURVEYED IN COOPERATION WITH THE UNIVERSITY OF TEXAS MINERAL SURVEY.

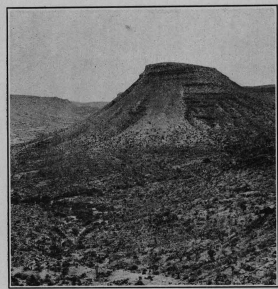


PLATE I.—UNCONFORMITY BETWEEN HUECO LIMESTONE AND VAN HORN SANDSTONE IN BUTTE 7 MILES NORTHWEST OF VAN HORN.

The almost horizontal Hueco limestone capping the butte overlies gently inclined Van Horn sandstone.

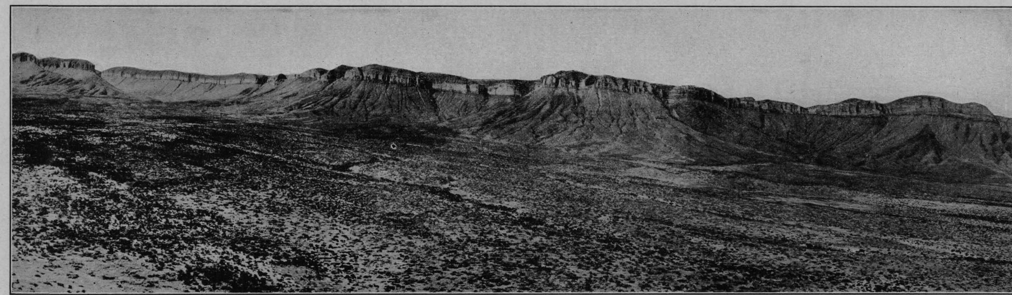


PLATE II.—ESCARPMENT OF SIERRA DIABLO SOUTH OF VICTORIA PEAK.

Shows characteristic capping of mesa by Hueco limestone, trenched slopes on the softer Millican formation, and generally sparse vegetation.

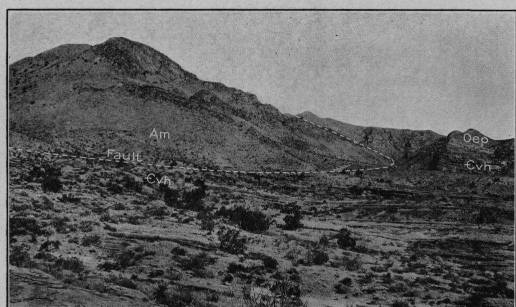


PLATE III.—FAULT NORTHWEST OF BEACH MOUNTAIN.

Looking northeast. Red sandstone of Millican formation (Am) in Morris Peak faulted up against Van Horn sandstone (Єvh) in foreground and El Paso limestone (Oep) in background.

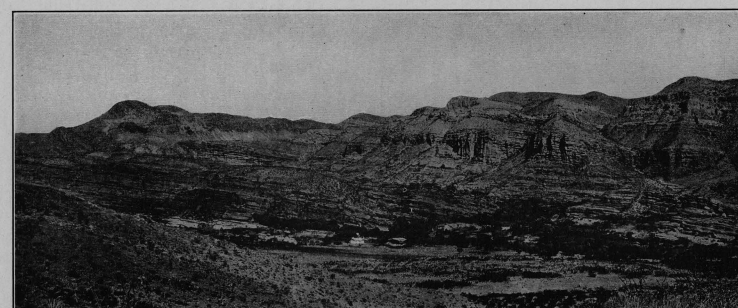


PLATE IV.—WEST FACE OF BEACH MOUNTAIN, SHOWING EL PASO LIMESTONE OVERLYING VAN HORN SANDSTONE.

Millican formation in Morris Peak at extreme left is faulted up against the Van Horn and El Paso formations. Beach's ranch house in valley in foreground.

PLATE V.—SOUTH END OF SALT FLAT, IN VICINITY OF VAN HORN.

Wylie Mountains in the distance.

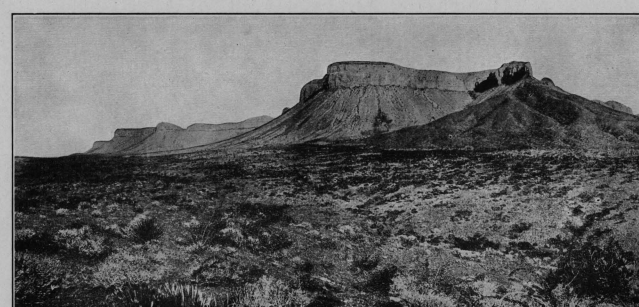


PLATE VI.—SOUTHEAST END OF SIERRA DIABLO, SHOWING HUECO LIMESTONE OVERLYING RED SANDSTONE OF MILLICAN FORMATION.

Looking northwest at end of mesa. The cliff-making rocks are Hueco limestone; the slopes are softer red sandstone of the Millican formation.

PLATE VII.—SOUTHEAST END OF SIERRA DIABLO, SHOWING VAN HORN SANDSTONE OVERLAIN BY HUECO LIMESTONE.

Looking southwest at a point 1½ miles north of Hazel mine. The upper massive cliffs are Hueco limestone; lower cliff thin-bedded Van Horn sandstone; Millican formation in foreground.

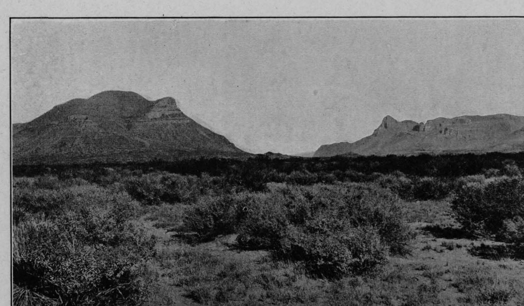


PLATE VIII.—THREEMILE MOUNTAIN (ON THE LEFT) SHOWING VAN HORN SANDSTONE OVERLAIN BY HUECO LIMESTONE.

Looking northwest. In the mountain at the right Van Horn sandstone is overlain by El Paso limestone.

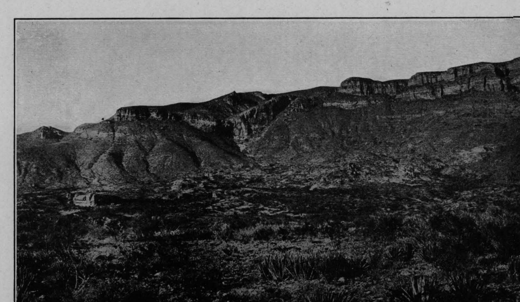


PLATE IX.—SMALL NORMAL FAULT IN SOUTHWEST FACE OF BEACH MOUNTAIN, 6 MILES NORTHWEST OF VAN HORN.

El Paso limestone and Van Horn sandstone offset by a fault in ravine in middle of view.

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			Cents.
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‡32	Franklin	West Virginia-Virginia	
‡33	Briceville	Tennessee	
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‡35	Gadsden	Alabama	
36	Pueblo	Colorado	5
‡37	Downieville	California	
‡38	Butte Special	Montana	
‡39	Truckee	California	
40	Wartburg	Tennessee	5
‡41	Sonora	California	
42	Nueces	Texas	5
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‡45	Boise	Idaho	
46	Richmond	Kentucky	5
47	London	Kentucky	5
‡48	Tenmile District Special	Colorado	
‡49	Roseburg	Oregon	
50	Holyoke	Massachusetts-Connecticut	5
‡51	Big Trees	California	
52	Absaroka	Wyoming	5
53	Standingstone	Tennessee	5
‡54	Tacoma	Washington	
55	Fort Benton	Montana	5
56	Little Belt Mountains	Montana	5
‡57	Telluride	Colorado	
58	Elmoro	Colorado	5
59	Bristol	Virginia-Tennessee	5
‡60	La Plata	Colorado	
61	Monterey	Virginia-West Virginia	5
62	Menominee Special	Michigan	5
‡63	Mother Lode District	California	
64	Uvalde	Texas	5
65	Tintic Special	Utah	5
‡66	Colfax	California	
67	Danville	Illinois-Indiana	5
68	Walsenburg	Colorado	5
69	Huntington	West Virginia-Ohio	5
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75	Maynardville	Tennessee	5
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77	Raleigh	West Virginia	5
78	Rome	Georgia-Alabama	5
79	Atoka	Oklahoma (Ind. T.)	5
80	Norfolk	Virginia-North Carolina	5
‡81	Chicago	Illinois-Indiana	
‡82	Masontown-Uniontown	Pennsylvania	
‡83	New York City	New York-New Jersey	
84	Ditney	Indiana	5
85	Oelrichs	South Dakota-Nebraska	5
86	Ellensburg	Washington	5
87	Camp Clarke	Nebraska	5
88	Scotts Bluff	Nebraska	5
89	Port Orford	Oregon	5
90	Cranberry	North Carolina-Tennessee	5
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92	Gaines	Pennsylvania-New York	5
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96	Olivet	South Dakota	5
97	Parker	South Dakota	5

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103	Nampa	Idaho-Oregon	5
104	Silver City	Idaho	5
105	Patoka	Indiana-Illinois	5
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116	Asheville	North Carolina-Tennessee	5
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120	Silverton	Colorado	5
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