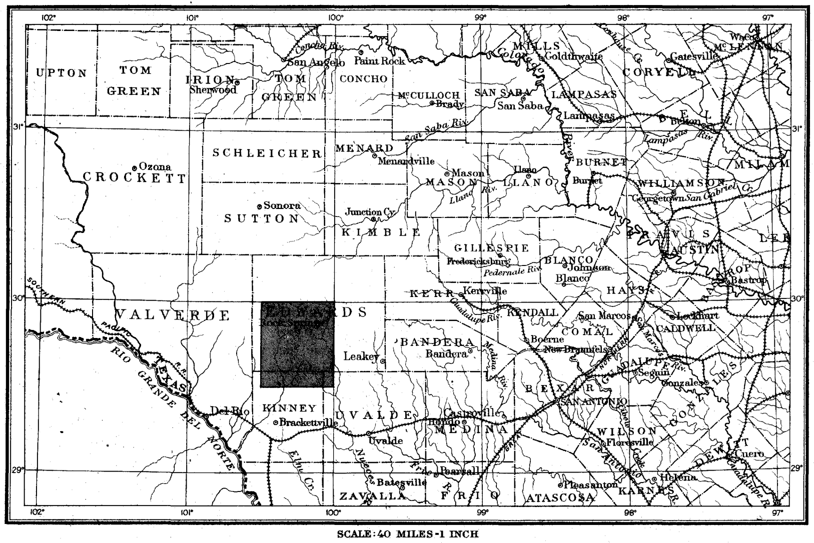
DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
CHARLES D. WALCOTT, DIRECTOR

GEOLOGIC ATLAS
OF THE
UNITED STATES

NUECES FOLIO
TEXAS

INDEX MAP



SCALE: 40 MILES = 1 INCH

■ AREA OF THE NUECES FOLIO

LIST OF SHEETS

DESCRIPTION
TOPOGRAPHY
HISTORICAL GEOLOGY
COLUMNAR SECTION
SPECIAL ILLUSTRATIONS

FOLIO 42
LIBRARY EDITION
NUECES

WASHINGTON, D. C.
ENGRAVED AND PRINTED BY THE U.S. GEOLOGICAL SURVEY
BAILEY WILLIS, EDITOR OF GEOLOGIC MAPS S. J. KÜBEL, CHIEF ENGRAVER

EXPLANATION.

The Geological Survey is making a geologic map of the United States, which necessitates the preparation of a topographic base map. The two are being issued together in the form of an atlas, the parts of which are called folios. Each folio consists of a topographic base map and geologic maps of a small area of country, together with explanatory and descriptive texts.

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 which are most important 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 horizontal outline, or contour, of all slopes, and to indicate their grade or degree of steepness. This is done by lines connecting points of equal elevation above mean sea-level, the lines being drawn at regular vertical intervals. These lines are called *contours*, and the uniform vertical space between each two contours is called the *contour interval*. Contours and elevations are printed in brown.

The manner in which contours express elevation, form, and grade is shown in the following sketch and corresponding contour map:

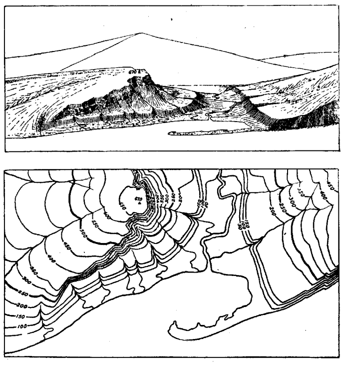


Fig 1.—Ideal sketch and corresponding contour map.

The sketch represents a river valley between two hills. In the foreground is the sea, with a bay which is partly closed by a hooked sand-bar. On each side of the valley is a terrace. From the terrace on the right a hill rises gradually, while from that on the left the ground ascends steeply in a precipice. Contrasted with this precipice is the gentle descent of the left-hand slope. In the map each of these features is indicated, directly beneath its position in the sketch, by contours. The following explanation may make clearer the manner in which contours delineate elevation, form, and grade:

1. A contour indicates approximately a certain height above sea-level. In this illustration the contour interval is 50 feet; therefore the contours are drawn at 50, 100, 150, 200 feet, and so on, above sea-level. Along the contour at 250 feet lie all points of the surface 250 feet above sea; and similarly with any other contour. In the space between any two contours are found all elevations above the lower and below the higher contour. Thus the contour at 150 feet falls just below the edge of the terrace, while 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 sea. The summit of the higher hill is stated to be 670 feet above sea; accordingly the contour at 650 feet surrounds it. In this illustration nearly all the contours are numbered. Where this is not possible, certain contours—say every fifth one—are accentuated and numbered; the heights of others may then be ascertained by counting up or down from a numbered contour.

2. Contours define the forms of slopes. Since contours are continuous horizontal lines conforming to the surface of the ground, they wind smoothly about smooth surfaces, recede into all reentrant angles of ravines, and project in passing about prominences. The relations of contour curves and angles to forms of the landscape can be traced in the map and sketch.

3. Contours show the approximate grade of any slope. The vertical space between two contours is the same, whether they lie along a cliff or on a gentle slope; but to rise 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.

For a flat or gently undulating country a small contour interval is used; for a steep or mountainous country a large interval is necessary. The smallest interval used on the atlas sheets of the Geological Survey is 5 feet. This is used for regions like the Mississippi delta and the Dismal Swamp. In mapping great mountain masses, like those in Colorado, the interval may be 250 feet. For intermediate relief contour intervals of 10, 20, 25, 50, and 100 feet are used.

Drainage.—Watercourses are indicated by blue lines. If the stream flows the year round the line is drawn unbroken, but if the channel is dry a part of the year the line is broken or dotted. Where a stream sinks and reappears at the surface, the supposed underground course is shown by a broken blue line. Lakes, marshes, and other bodies of water are also shown in blue, by appropriate conventional signs.

Culture.—The works of man, such as roads, railroads, and towns, together with boundaries of townships, counties, and States, and artificial details, are printed in black.

Scales.—The area of the United States (excluding Alaska) is about 3,025,000 square miles. On a map with the scale of 1 mile to the inch this would cover 3,025,000 square inches, and to accommodate it the paper dimensions would need to be about 240 by 180 feet. Each square mile of ground surface would be represented by a square inch of map surface, and one linear mile on the ground would be represented by a linear inch on the map. This relation between distance in nature and corresponding distance on the map is called the scale of the map. In this case it is "1 mile to an inch." 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 an inch" is expressed by $\frac{1}{63{,}360}$. Both of these methods are used on the maps of the Geological Survey.

Three scales are used on the atlas sheets of the Geological Survey; the smallest is $\frac{1}{250{,}000}$, the intermediate $\frac{1}{125{,}000}$, and the largest $\frac{1}{62{,}500}$. These correspond approximately to 4 miles, 2 miles, and 1 mile on the ground to an inch on the map. On the scale $\frac{1}{62{,}500}$ a square inch of map surface represents and corresponds nearly to 1 square mile; on the scale $\frac{1}{125{,}000}$, to about 4 square miles; and on the scale $\frac{1}{250{,}000}$, to about 16 square miles. At the bottom of each atlas sheet the scale is expressed in three different ways, one being a graduated line representing miles and parts of miles in English inches, another indicating distance in the metric system, and a third giving the fractional scale.

Atlas sheets and quadrangles.—The map is being published in atlas sheets of convenient size, which are bounded by parallels and meridians. The corresponding four-cornered portions of territory are called *quadrangles*. Each sheet on the scale of $\frac{1}{250{,}000}$ contains one square degree, i. e., a degree of latitude by a degree of longitude; each sheet on the scale of $\frac{1}{125{,}000}$ contains one-quarter of a square degree; each sheet on the scale of $\frac{1}{62{,}500}$ contains one-sixteenth of a square degree. The areas of the corresponding quadrangles are about 4000, 1000, and 250 square miles, respectively.

The atlas sheets, being only parts of one map of the United States, are laid out without regard to the boundary lines of the States, counties, or townships. 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 the names of adjacent sheets, if published, are printed.

Uses of the topographic sheet.—Within the limits of scale the topographic sheet is an accurate and characteristic delineation of the relief, drainage, and culture of the district represented. Viewing the landscape, map in hand, every characteristic feature of sufficient magnitude should be recognizable. It should guide the traveler; serve the investor or owner who desires to ascertain the position and surroundings of property to be bought or sold; save the engineer preliminary surveys in locating roads, railways, and irrigation ditches; provide educational material for schools and homes; and serve many of the purposes of a map for local reference.

THE GEOLOGIC MAP.

The maps representing areal geology show by colors and conventional signs, on the topographic base map, the distribution of rock formations on the surface of the earth, and the structure-section map shows their underground relations, as far as known, and in such detail as the scale permits.

KINDS OF ROCKS.

Rocks are of many kinds. The original crust of the earth was probably composed of *igneous rocks*, and all other rocks have been derived from them in one way or another.

Atmospheric agencies gradually break up igneous rocks, forming superficial, or *surficial*, deposits of clay, sand, and gravel. Deposits of this class have been formed on land surfaces since the earliest geologic time. Through the transporting agencies of streams the surficial materials of all ages and origins are carried to the sea, where, along with material derived from the land by the action of the waves on the coast, they form *sedimentary rocks*. These are usually hardened into conglomerate, sandstone, shale, and limestone, but they may remain unconsolidated and still be called "rocks" by the geologist, though popularly known as gravel, sand, and clay.

From time to time in geologic history igneous and sedimentary rocks have been deeply buried, consolidated, and raised again above the surface of the water. In these processes, through the agencies of pressure, movement, and chemical action, they are often greatly altered, and in this condition they are called *metamorphic rocks*.

Igneous rocks.—These are rocks which have cooled and consolidated from a liquid state. As has been explained, sedimentary rocks were deposited on the original igneous rocks. Through the igneous and sedimentary rocks of all ages molten material has from time to time been forced upward to or near the surface, and there consolidated. When the channels or vents into which this molten material is forced do not reach the surface, it either consolidates in cracks or fissures crossing the bedding planes, thus forming dikes, or else spreads out between the strata in large bodies, called sills or laccoliths. Such rocks are called *intrusive*. Within their rock enclosures they cool slowly, and hence are generally of crystalline texture. When the channels reach the surface the lavas often flow out and build up volcanoes. These lavas cool rapidly in the air, acquiring a glassy or, more often, a partially crystalline condition. They are usually more or less porous. The igneous rocks thus formed upon the surface are called *extrusive*. Explosive action often accompanies volcanic eruptions, causing ejections of dust or ash and larger fragments. These materials when consolidated constitute breccias, agglomerates, and tuffs. The ash when carried into lakes or seas may become stratified, so as to have the structure of sedimentary rocks.

The age of an igneous rock is often difficult or impossible to determine. When it cuts across a sedimentary rock, it is younger than that rock, and when a sedimentary rock is deposited over it, the igneous rock is the older.

Under the influence of dynamic and chemical forces an igneous rock may be metamorphosed. The alteration may involve only a rearrangement of its minute particles or it may be accompanied by a change in chemical and mineralogic composition. Further, the structure of the rock may be changed by the development of planes of division, so that it splits in one direction more easily than in others. Thus a granite may pass into a gneiss, and from that into a mica-schist.

Sedimentary rocks.—These comprise all rocks which have been deposited under water, whether in sea, lake, or stream. They form a very large part of the dry land.

When the materials of which sedimentary rocks are composed are carried as solid particles by water and deposited as gravel, sand, or mud, the deposit is called a mechanical sediment. These may become hardened into conglomerate, sandstone, or shale. When the material is carried in solution by the water and is deposited without the aid of life, it is called a chemical sediment; if deposited with the aid of life, it is called an organic sediment. The more important rocks formed from chemical and organic deposits are limestone, chert, gypsum, salt, iron ore, peat, lignite, and coal. Any one of the above sedimentary deposits may be separately formed, or the different materials may be intermingled in many ways, producing a great variety of rocks.

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

The surface of the earth is not fixed, as it seems to be; it very slowly rises or sinks over wide expanses, and as it rises or subsides the shore-lines of the ocean are changed: areas of deposition may rise above the water and become land areas, and land areas may sink below the water and become areas of deposition. If North America were gradually to sink a thousand feet the sea would flow over the Atlantic coast and the Mississippi and Ohio valleys from the Gulf of Mexico to the Great Lakes; the Appalachian Mountains would become an archipelago, and the ocean's shore would traverse Wisconsin, Iowa, and Kansas, and extend thence to Texas. More extensive changes than this have repeatedly occurred in the past.

The character of the original sediments may be changed by chemical and dynamic action so as to produce metamorphic rocks. In the metamorphism of a sedimentary rock, just as in the metamorphism of an igneous rock, the substances of which it is composed may enter into new combinations, or new substances may be added. When these processes are complete the sedimentary rock becomes crystalline. Such changes transform sandstone to quarzite, limestone to marble, and modify other rocks according to their composition. A system of parallel division planes is often produced, which may cross the original beds or strata at any angle. Rocks divided by such planes are called slates or schists.

Rocks of any period of the earth's history may be more or less altered, but the younger formations have generally escaped marked metamorphism, and the oldest sediments known, though generally the most altered, in some localities remain essentially unchanged.

Surficial rocks.—These embrace the soils, clays, sands, gravels, and bowlders that cover the surface, whether derived from the breaking up or disintegration of the underlying rocks by atmospheric agencies or from glacial action. Surficial rocks that are due to disintegration are produced chiefly by the action of air, water, frost, animals, and plants. They consist mainly of the least soluble parts of the rocks, which remain after the more soluble parts have been leached out, and hence are known as residual products. Soils and subsoils are the most important. Residual accumulations are often washed or blown into valleys or other depressions, where they lodge and form deposits that grade into the sedimentary class. Surficial rocks that are due to glacial action are formed of the products of disintegration, together with bowlders and fragments of rock rubbed from the surface and ground together. These are spread irregularly over the territory occupied by the ice, and form a mixture of clay, pebbles, and bowlders which is known as till. It may occur as a sheet or be bunched into hills and ridges, forming moraines, drumlins, and other special forms. Much of this mixed material was washed away from the ice, assorted by water, and redeposited as beds or trains of sand and clay, thus forming another gradation into sedimentary deposits. Some of this glacial wash was deposited in tunnels and channels in the ice, and forms characteristic ridges and mounds of sand and gravel, known as osars, or eskers, and kames. The material deposited by the ice is called glacial drift; that washed from the ice onto the adjacent land is called modified drift. It is usual also to class as surficial rocks the deposits of the sea and of lakes and rivers that were made at the same time as the ice deposit.

AGES OF ROCKS.

Rocks are further distinguished according to their relative ages, for they were not formed all at one time, but from age to age in the earth's history. Classification by age is independent of origin; igneous, sedimentary, and surficial rocks may be of the same age.

When the predominant material of a rock mass is essentially the same, and it is bounded by rocks of different materials, it is convenient to call the mass throughout its extent a *formation*, and such a formation is the unit of geologic mapping.

Several formations considered together are designated a *system*. The time taken for the deposition of a formation is called an *epoch*, and the time taken for that of a system, or some larger fraction of a system, a *period*. The rocks are mapped by formations, and the formations are classified into systems. The rocks composing a system and the time taken for its deposition are given the same name, as, for instance, Cambrian system, Cambrian period.

As sedimentary deposits or strata accumulate the younger rest on those that are older, and the relative ages of the deposits may be discovered by observing their relative positions. This relationship holds except in regions of intense disturbance; sometimes in such regions the disturbance of the beds has been so great that their position is reversed, and it is often difficult to determine the relative ages of the beds from their positions; then *fossils*, or the remains of plants and animals, are guides to show which of two or more formations is the oldest.

Strata often contain the remains of plants and animals which lived in the sea or were washed from the land into lakes or seas or were buried in surficial deposits on the land. Rocks that contain the remains of life are called fossiliferous. By studying these remains, or fossils, it has been found that the species of each period of the earth's history have to a great extent differed from those 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.

When two formations are remote one from the 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 found in the rocks of different areas, provinces, and continents, afford the most important means for combining local histories into a general earth history.

Colors and patterns.—To show the relative ages of strata, the history of the sedimentary rocks is divided into periods. The names of the periods in proper order (from new to old), with the color or colors and symbol assigned to each, are given in the table in the next column. The names of certain subdivisions of the periods, frequently used in geologic writings, are bracketed against the appropriate period name.

To distinguish the sedimentary formations of any one period from those of another the patterns for the formations of each period are printed in the appropriate period-color, with the exception of the first (Pleistocene) and the last (Archean). The formations of any one period, excepting the Pleistocene and the Archean, are distinguished from one another by different patterns, made of parallel straight lines. Two tints of the period-color are used: a pale tint (the underprint) is printed evenly over the whole surface representing the period; a dark tint (the overprint) brings out the different patterns representing formations.

Period.	Symbol.	Color.
Pleistocene	P	Any colors.
Neocene { Pliocene Miocene }	N	Buffs.
Eocene (including Oligocene)	E	Olive-browns.
Cretaceous	K	Olive-greens.
Juratrias { Jurassic Triassic }	J	Blue-greens.
Carboniferous (including Permian) . .	C	Blues.
Devonian	D	Blue-purples.
Silurian (including Ordovician)	S	Red-purples.
Cambrian	Є	Pinks.
Algonkian	A	Orange-browns.
Archean	Æ	Any colors

Each formation is furthermore given a letter-symbol of the period. In the case of a sedimentary formation of uncertain age the pattern is printed on white ground in the color of the period to which the formation is supposed to belong, the letter-symbol of the period being omitted.

The number and extent of surficial formations of the Pleistocene render them so important that, to distinguish them from those of other periods and from the igneous rocks, patterns of dots and circles, printed in any colors, are used.

The origin of the Archean rocks is not fully settled. Many of them are certainly igneous. Whether sedimentary rocks are also included is not determined. The Archean rocks, and all metamorphic rocks of unknown origin, of whatever age, are represented on the maps by patterns consisting of short dashes irregularly placed. These are printed in any color, and may be darker or lighter than the background. If the rock is a schist the dashes or hachures may be arranged in wavy parallel lines. If the rock is known to be of sedimentary origin the hachure patterns may be combined with the parallel-line patterns of sedimentary formations. If the metamorphic rock is recognized as having been originally igneous, the hachures may be combined with the igneous pattern.

Known igneous formations are represented by patterns of triangles or rhombs printed in any brilliant color. If the formation is of known age the letter-symbol of the formation is preceded by the capital letter-symbol of the proper period. If the age of the formation is unknown the letter-symbol consists of small letters which suggest the name of the rocks.

THE VARIOUS GEOLOGIC SHEETS.

Historical geology sheet.—This sheet shows the areas occupied by the various formations. On the margin is a *legend*, which is the key to the map. To ascertain the meaning of any particular colored pattern and its letter-symbol on the map 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 given formation, its name should be sought in the legend and its color and pattern noted, when 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 symbols and names are arranged, in columnar form, according to the origin of the formations—surficial, sedimentary, and igneous—and within each group they are placed in the order of age, so far as known, the youngest at the top.

Economic geology sheet.—This sheet represents the distribution of useful minerals, the occurrence of artesian water, or other facts of economic interest, showing their relations to the features of topography and to the geologic formations. All the formations which appear on the historical geology sheet are shown on this sheet by fainter color-patterns. The areal geology, thus printed, affords a subdued background upon which the areas of productive formations may be emphasized by strong colors. A symbol for mines is introduced at each occurrence, accompanied by the name of the principal mineral mined or of the stone quarried.

Structure-section sheet.—This sheet exhibits the relations of the formations beneath the surface. In cliffs, canyons, shafts, and other natural and artificial cuttings, the relations of different beds to one another may be seen. Any cutting which exhibits those relations is called a *section*, and the same name 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 the natural and artificial cuttings for his information concerning the earth's structure. Knowing the manner of the formation of rocks, and having traced out the relations among beds on the surface, he can infer their relative positions after they pass beneath the surface, draw sections which represent the structure of the earth to a considerable depth, and construct a diagram exhibiting what would be seen in the side of a cutting many miles long and several thousand feet deep. This is illustrated in the following figure:

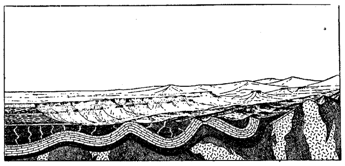


Fig. 2.—Sketch showing a vertical section in the front of the picture, with a landscape beyond.

The figure represents a landscape which is cut off sharply in the foreground by a vertical plane that cuts a section so as to show the underground relations of the rocks.

The kinds of rock are indicated in the section by appropriate symbols of lines, dots, and dashes. These symbols admit of much variation, but the following are generally used in sections to represent the commoner kinds of rock:

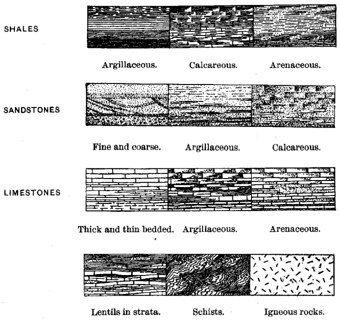


Fig. 3.—Symbols used to represent different kinds of rock.

The plateau in fig. 2 presents toward the lower land an escarpment, or front, which is made up of sandstones, forming the cliffs, and shales, constituting the slopes, as shown at the extreme left of the section.

The broad belt of lower land is traversed by several ridges, which are seen in the section to correspond to beds of sandstone that rise to the surface. The upturned edges of these beds form the ridges, and the intermediate valleys follow the outcrops of limestone and calcareous shales.

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.

When strata which are thus inclined are traced underground in mining, or by inference, it is frequently observed that they form troughs or arches, such as the section shows. But these sandstones, shales, and limestones were deposited beneath the sea in nearly flat sheets. That they are now bent and folded is regarded as proof that forces exist which have from time to time caused the earth's surface to wrinkle along certain zones.

On the right of the sketch the section is composed of schists which are traversed by masses of igneous rock. 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 well-founded inference.

In fig. 2 there are three sets of formations, distinguished by their underground relations. The first of these, seen at the left of the section, is the set of sandstones and shales, which lie in a horizontal position. These sedimentary strata are now high above the sea, forming a plateau, and their change of elevation shows that a portion of the earth's mass has swelled upward from a lower to a higher level. The strata of this set are parallel, a relation which is called *conformable*.

The second set of formations consists of strata which form arches and troughs. These strata were once continuous, but the crests of the arches have been removed by degradation. 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 at the left of the section. The overlying deposits are, from their positions, evidently younger than the underlying formations, and the bending and degradation of the older strata must have occurred between the deposition of the older beds and the accumulation of the younger. When younger strata thus rest upon an eroded surface of older strata the relation between the two is an *unconformable* one, and their 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 plicated by pressure and traversed by eruptions of molten rock. But this pressure and intrusion of igneous rocks have not affected the overlying strata of the second set. Thus it is evident that an interval of considerable duration elapsed between the formation of the schists and the beginning of deposition of the strata of the second set. During this interval the schists suffered metamorphism; they were the scene of eruptive activity; and they were deeply eroded. The contact between the second and third sets, marking a time interval between two periods of rock formation, is another unconformity.

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

Columnar-section sheet.—This sheet contains a concise description of the rock formations which occur in the quadrangle. The diagrams and verbal statements form a summary of the facts relating to the character of the rocks, to the thicknesses of the formations, and to the order of accumulation of successive deposits.

The rocks are described under the corresponding heading, and their characters are indicated in the columnar diagrams by appropriate symbols. The thicknesses of formations are given under the heading "Thickness in feet," in figures which state the least and greatest measurements. The average thickness of each formation is shown in the column, which is drawn to a scale—usually 1000 feet to 1 inch. The order of accumulation of the sediments is shown in the columnar arrangement: the oldest formation is placed at the bottom of the column, the youngest at the top, and igneous rocks or other formations, when present, are indicated in their proper relations.

The formations are combined into systems which correspond with the periods of geologic history. Thus the ages of the rocks are shown, and also the total thickness of each system.

The intervals of time which correspond to events of uplift and degradation and constitute interruptions of deposition of sediments may be indicated graphically or by the word "unconformity," printed in the columnar section.

Each formation shown in the columnar section is accompanied by its name, a description of its character, and its letter-symbol as used in the maps and their legends.

CHARLES D. WALCOTT,
Director.

Revised June, 1897.

DESCRIPTION OF THE NUECES QUADRANGLE.

GEOGRAPHY.

Geographic position.—The Nueces quadrangle is bounded by parallels of latitude 29° 30′ and 30° and meridians 100° and 100° 30′. Its dimensions are approximately 34.44 miles from north to south and 30.05 miles from east to west; it embraces, therefore, about 1035 square miles, including portions of Edwards, Kinney, and Uvalde counties, Texas. Only two adjacent quadrangles have been surveyed — the Rock Springs on the north and the Brackett on the south.

Counties embraced.

General relations.—This quadrangle lies along the southern margin of the Great Plains region of the United States, which in Texas is composed of the Llano Estacado and the Edwards Plateau. The Edwards Plateau is the continuation of the Llano Estacado south of the thirty-second parallel, extending from the Pecos River eastward to the western margin of the Central Province of Texas and the Rio Grande Plain. The rather abrupt southern margin of this plateau is the Balcones escarpment. Defined more specifically, the Nueces quadrangle lies along the southern margin of the Edwards Plateau, immediately north of the Rio Grande Plain. The latter is a low, level plain, extending from the Balcones escarpment southward to the eastern front of the Mexican Cordilleras.

Southern extension of the Llano Estacado.

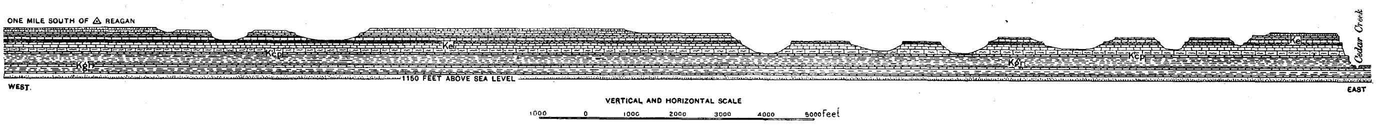


Fig. 1.—Profile and section of the Edwards Plateau from the summit 1 mile south of Reagan to Cedar Creek, showing the relation of topography to geologic structure.

TOPOGRAPHY.

The topography of the Brackett quadrangle, south of the Nueces, should be considered in connection with the latter in order to gain a proper understanding of the geography of this region. Together they exhibit the contrast between the high, grass-covered plateau of the Great Plains, of which the Nueces quadrangle is a type, and the lower-lying chaparral desert of the Rio Grande Plain. They differ accordingly in geologic and cultural conditions.

Relief.—The general relief of the Nueces quadrangle is that of a nearly horizontal upland plain, standing 2250 feet above the sea, divided by canyons into numerous summits. The valleys are cut upon and through horizontal strata of limestone of varying thickness and hardness. The relief presents three conspicuous elements — summit areas, valley slopes, and stream ways.

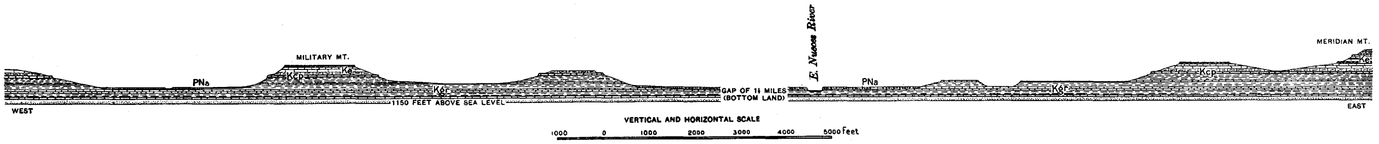


Fig. 2.—Cross section of the Nueces Valley south of Barksdale.

The summit areas, more or less extensive patches of level land, are the remnants of the plain which formerly constituted the surface of the quadrangle. This plain corresponded in level with the thick strata of Edwards limestone, which retarded erosion throughout the plateau region of Texas. It is only in the north-central portion of the area mapped, along the high divides between the streams, that fragments of the original plateau level are still preserved. The most extensive remnant is found between the two forks of the Nueces River. This is the southern continuation of the extensive grass-covered summit region of the main area of the Edwards Plateau.

Summit areas.

The summit region of the northern half of the quadrangle, having an elevation of approximately 2400 feet, is nearly horizontal, sloping southward at a gradient of less than 16 feet to the mile. It will be noted that the chief drainage, that of the two Nueces rivers, conforms in direction with this general regional slope almost to the southern margin of the quadrangle. This low slope is characteristic of all the Great Plains region to the northward. At the south margin of the quadrangle, especially the western portion, the slope suddenly increases to 75 feet to the mile, leading rapidly down to the lower-lying Rio Grande Plain, which has an average altitude in this portion of its extent of 1000 feet. This increased slope of the surface is coincident with a gentle monoclinal fold, which characterizes the Balcones scarp line in this immediate region. Its margins, especially toward the east, are intensely dissected by the head-water drainage of the numerous minor laterals of the Nueces River and are carved into many rounded, steeply sloping hills. The southern and eastern half of the quadrangle is a notable example of the manner in which the scarped edge of a nearly horizontal elevated plain may be dissected, by the interlocking head-water drainage which rises against it, into innumerable circular buttes and mesas.

Gentle southerly slope of the plateau.

Increased slope and greater dissection of the surface.

Owing to alternation of hard and soft layers constituting the succession of strata, the marginal topography of the slopes leading down to the stream ways produced by this erosion is of the bench-and-terrace type, marked by steep scarps and flat benches on thick limestone beds, alternating with gentler slopes on softer layers. Near the summit of the plateau, where flaggy layers of the Edwards limestone are present, the first noticeable descent into a canyon is a gentle slope, interrupted by slight vertical steps of from 2 inches to 2 feet. This slope ends, in descending, on a thick stratum which weathers into vertical bluffs, constituting the cornice layer of the plateau. This, in turn, is succeeded by other slopes and scarps until the basal canyon rock is reached, beneath which the Comanche Peak bed weathers out in concave profile. The accompanying figures (figs. 1 and 2) illustrate these features.

Terraced slopes of the valleys.

Where extensive summit areas are preserved the soil is usually fairly deep, but the bordering breaks and slopes are in general rocky, and often marked by extensive areas of naked limestone surfaces, with occasional patches of soil and loose débris.

Where the strata exposed are limestone rocks of homogeneous texture the surfaces weather into little ridges, crests, and drainage lines, presenting to the eye in miniature the whole process of erosion and mountain carving. This miniature erosion of the limestone surfaces is technically known by the Germans as "Karrenfelder," the furrows being formed by the solvent effect of rain upon limestone which has been heated by the sun.

Detailed features of the surface.

Some of the outcropping strata make bold, persistent cliffs nearly 50 feet in height. These are composed of hard, subcrystalline limestone. Although apparently of homogeneous texture, the faces of these cliffs weather into small open caverns, which sometimes show thin laminæ coated with white efflorescence. The bottoms of caverns of this character are filled with a layer of white pulverulent earth. Still other massive ledges weather into caverns where the residual products are brilliant vermilion mixtures of clay and iron, accompanied by beautiful fossils, sometimes composed of crystallized calcite. The slopes result from the weathering of the softer beds of chalky or argillaceous texture. Where there are great thicknesses of beds of homogeneous texture the rocks weather into conical hills resembling gigantic pyramids, as may be seen in the southern portion of the quadrangle.

Drainage.—The drainage from this plateau finds its outlet to the sea in several directions. The little caletas at the center of the northern edge of the quadrangle lead northward into the Llano River and thence into the Gulf of Mexico by the Colorado of Texas. In the extreme southwest corner, west of the McKenzie trail, a few drainage heads lead off to Pinto Creek and finally reach the sea through the Rio Grande. The remainder of the drainage gathers into the Nueces system, the principal river of the quadrangle. Owing to the diverse distribution of water from the plateau, the summit region (all of which is not included in this quadrangle, however) is locally called by the inhabitants "the Divide."

Three directions of drainage.

The two forks of the Nueces, which flow from north to south across the quadrangle, although apparently coeval, are dissimilar in history and importance, as will presently be shown. They traverse wide, flat-bottomed, canyoned valleys indenting the plateau, and are inclosed by scarped and terraced slopes from 200 to 500 feet in height. The depth of the valley of the East Nueces is 500 feet below the summit of the plateau; that of the West Fork averages 300 feet below. The bottoms of the wide, flat valleys between the canyon walls are ancient flood plains, standing about 50 feet above the present stream beds, which are trivial in comparison with them. The canyon walls are nearly always steep, and frequently perpendicular, but usually consist of an alternation of steep scarps and slopes, as shown in the profiles. These canyons are types of those accompanying all the drainage ways indenting the eastern and southern borders of the Plateau of the Plains.

The Nueces system.

The water in these stream ways is intermittent, the beds of most of them being usually either smooth horizontal limestone strata or clean-washed flints and limestone bowlders bleached in the glaring sunshine to a chalky white color; in fact, they are streams of gravel rather than of water. Here and there, however, stretches of the stream way are filled with flowing water, which bursts out in large running streams, having the peculiar light sea-green color characteristic of all the spring rivers breaking from the Cretaceous limestone of southwestern Texas. The traveler unaware of the habit of these streams, standing on the banks of one of them, would believe that it was a large and continuous river; but upon following its course he would find that this running water usually disappears within a very short distance downstream, either by absorption into the gravel-filled stream way or through fissures in the bed rock. Still farther down it may reappear at the surface. This running water is constant. Although supplied by rain, it does not rise and fall in sympathy with local showers, but represents the steady flow from the rocks underlying the Edwards Plateau. It appears at the surface in springs, which invariably occur where the rivers in their descending course first cut into certain persistent water-bearing strata.

Intermittent character of the streams.

Permanent flowing water.

The smaller side canyons, with a few exceptions, are dry arroyos. These in turn are of two types. Those draining into the East Nueces have very steep gradients and are rocky canyons. They indent the marginal canyon wall with thousands of reentrant angles and curves. The secondary drainage of the remainder of the area is of quite different character, as exemplified by Griffin Creek at the southwest corner. This consists of a number of palmately ramifying head-water laterals (caletas), which begin in short, steep, rocky arroyos of the hills surrounding large, nearly level, amphitheater-like, grass-covered valleys. These amphitheater-like valleys, covered with the transported soil and rock débris of the adjacent hillsides, are locally known as "grass valleys." Water occupies the head-water arroyos only at rare and brief intervals succeeding each cloudburst, and is usually only sufficient to gather and carry the hillside débris down into the grass valleys, where the moisture is evaporated or imbibed before reaching the main stream ways. Upon reaching the valleys the torrential streams spread out a flood of débris which so nearly obliterates all previously defined drainage that the latter can be but faintly traced across the valleys. Thus it is that the stream ways are always strongly etched upon the slopes and but faintly discernible in the flats.

Grassy amphitheater-like valleys.

Usually, but not always, a gap has been worn through the lower portion of the hills surrounding the valleys, through which all the drainage in time of excessive rainfall may escape to the main drainage of the Nueces by rocky arroyos.

The drainage system, from the head-water caletas through principal laterals to permanent water, is seldom if ever occupied by water continuously from head to mouth. A sudden cloudburst upon the dry, rocky, and precipitous slopes fills the dry stream ways with gigantic and ephemeral torrents of mud and gravel, which deposit débris irregularly, according to circumstances of quantity, slope, evaporation, and sinking of the water. The general result of each cloudburst, however, is another onward push of the débris toward the lower country of the Rio Grande Plain. Thus it is that an intermittent stream of gravel is and has been for a long time flowing away from the Edwards Plateau and spreading over the lower-lying Rio Grande Plain, developing what is herein called the Uvalde formation — a phenomenon which is of widespread occurrence throughout the whole of the great arid regions of southwest Texas and Mexico.

Effect of cloudbursts.

The history of this drainage presents a most interesting scientific study, which can not here be amplified in full. The portion of the East Nueces Canyon in this area is undoubtedly the older stream way, as is testified by the greater depth to which it has cut into the underlying rock and by the great extent of the Uvalde formation within its valley. On the northeast margin of the quadrangle the East Fork has an elevation of 1900 feet; on the southern margin its altitude is less than 1250 feet. The West Fork of the Nueces has an elevation of 2100 feet at the northern margin of the quadrangle; on the south margin its bed has an elevation of 1300 feet. Thus it will be seen that the East Nueces has a cut 200 feet lower into the rocks upon which it is imposed.

Relative ages of the Nueces rivers.

All the drainage courses have adjusted themselves to fundamental lines of structure, such as dips, faults, and folds. The main drainage of the two Nueces flows southward across the uniformly inclined portion of the quadrangle until the flexures and faultings at its southern margin are encountered. Between Whistler and Swantner the West Fork deflects eastward along the strike of the Griffin monocline, and then cuts across its strike, along the course of the axis of the Little Pinto fault. After following this for a few miles it deflects southeastward along the approximately east-west strike of the Whistler fold to the Brackett quadrangle, when it again turns southward across the fold by following the line of the Elm fault. After crossing the latter it once more bends eastward along the northern scarp line of the Turkey fold, which it crosses southward by a rocky canyon, until it meets and follows the east-west scarps of Shoal Creek limestone from Mustang Water Hole onward to its mouth. These diverse courses of the West Fork do not represent the life work of one continuous stream, but are the result of the union of several streams through a complex system of capture, by which the West Fork was deflected from its original course into the Rio Grande.

Relation of drainage to rock structure.

There can be little doubt that the West Fork of the Nueces once continued due southward across the quadrangle instead of deflecting to the eastward, as it now does, and then found an outlet through a now abandoned course into the Rio Grande, debouching on the plain in the vicinity of the southwest quarter of the Brackett quadrangle, where immense deposits of ancient gravel attest the former presence of some such stream. This former course, however, was changed by the capturing head waters of another large stream which now forms the great eastward bend of the West Nueces.

Former course of the West Nueces River.

The southern margin of the district mapped has been the scene of a continuous warfare between the courses of the minor headwater drainage, whereby the channels of streams have been deflected from one course into another. The numerous inverted laterals throughout this area testify to the extent of this process of capture and lead to the conclusion, independently reached from other data, that the summit of the Edwards Plateau once stood much higher than now, and during the long interval of time since the close of the Cretaceous period has been horizontally and progressively worn down from one plain to another.

Stream capture.

METEOROLOGY.

The temperature of the region is marked by great diurnal changes — warm days and cool nights — causing excessive rock disintegration through expansion and contraction. Numerous ledges exhibit at the surface excessive shattering which can be attributed to no other cause than this, and in this manner much débris is accumulated during the intervals between the heavy showers which remove it to lower levels.

The rainfall is sporadic, local, and irregular in time of fall. It is normally of the cloudburst type, falling in sudden and fierce showers upon limited areas. The monthly and annual precipitation also shows great irregularity, varying at Fort Clark, 21 miles south of the quadrangle, from 0 to 23 inches a month and from 13.76 to 40.54 inches a year, and averaging 24.02 inches annually for a period of twenty years. No statistics have been kept within the limits of the quadrangle, but there are reasons for believing that its precipitation is slightly greater than that of the lower-lying Rio Grande Plain. This conclusion is based upon personal observation, and studies of statistics of observation stations of the surrounding area.

Rainfall.

The region is constantly swept by strong winds, usually from the north and southeast. These winds are undoubtedly an important geologic agent in removing and distributing rock débris.

VEGETATION.

Within this quadrangle we see the meeting of several floral provinces. The summit of the plateau is covered by a dense growth of nutritious grasses, without trees or shrubs, except that at rare intervals, along some outcropping ledge, there may be patches of scrub oaks, locally known as "shin oaks." This is the flora of the plains. In the low, alluvium-filled valleys, especially where springs seep out of the rocks, favorable conditions are presented for the growth of trees; hence narrow ribbons of forest are found around the water-holes: These embrace many species, such as elm, chestnut oak, walnut, sycamore, cypress, live oak, and pecan, the trees attaining great size and beauty. The occurrence of cypress along some of these streams is a peculiar anomaly. These groves of the wet valleys are isolated outliers of the great Atlantic timber belt, from which they are now separated by miles of treeless country. Along the vertical slopes of the scarps the flora of the Cretaceous prairie regions of Texas is found, accompanied by growths of juniper and Texas laurel (Sophora), which, following certain strata, encircle the yellow hills with bands of evergreen. The piñon, or edible pine, also sparingly occurs along these slopes near Whistler, which, so far as we are aware, is its eastermost occurrence in the United States. The chaparral flora of the Rio Grande Plain, characterized by thorny deciduous trees, mostly acacias (mesquite, guaxillo, etc.), beneath which is an undergrowth of the Mexican nopal (Opuntia), makes tongue-like extensions up the canyons of the drier stream valleys of the southern margin of the area below Camp Wood. On the almost barren limestone slopes of the numerous buttes along the southern edge of the quadrangle, still a fourth flora is encountered. This is the remarkable resurrection flora of the arid region — thick-skinned, coriaceous plants, such as yucca, sotol, ixtle, etc., and mamillary cacti. Ferns and club mosses of this character (*Selaginella lepidophylla*) grow in crevices and along the stratification planes of the rocks. These are adapted by nature to withstand long periods of drought and reveal a wonderful recuperative vitality immediately after the rare and eccentric rainfall, suddenly unfolding from dry, brown, and lifeless-looking objects into vigorous green plants.

Flora of the plains.

Chaparral growth.

Resurrection plants of the arid region.

POPULATION.

The Nueces quadrangle is but sparsely populated, and mostly in the valley of the Nueces River. Only three villages — Barksdale, Vance, and Montell — occur in it, and these aggregate less than a thousand people. In the lower valley of the Nueces settlements are comparatively frequent, but the remainder of the quadrangle is occupied only by ranchmen living at remote distances from one another. In 1890 the total population exclusive of the Nueces Valley was about one person to each two square miles of area. The people are mostly engaged in pastoral pursuits.

GENERAL GEOLOGY.

The geology of this quadrangle is of a simple type. It is an area of evenly bedded rocks which have been greatly uplifted without serious deformation; it is an example of uniform and persistent horizontal stratification, and illustrates the relation of topography to structure. It also exhibits the elementary principles of the occurrence of rock water.

Classification.—The rocks found within this quadrangle belong to two great classes: (1) sediments deposited in the sea and subsequently elevated into land, and (2) residual and transported deposits locally accumulated on the land. The sea-deposited sediments, now consisting of evenly bedded horizontal limestone with occasional beds of clay, constitute the substructure of the country and are exposed in summits and scarps; the residual and transported deposits of the second class, such as soil, gravel, and alluvium, are derived from the former through the work of the atmosphere in the process of erosion, and are accumulated on flats and slopes and in valleys.

SEDIMENTARY ROCKS.

CRETACEOUS PERIOD.

The massive limestones with occasional alternating beds of marls which constitute the rocks of the country from the summits of the plateau to far beneath the deepest stream ways are all composed of material which was originally deposited in the waters of the ocean, and embedded in them are found the remains of the marine animals which inhabited those waters. These rocks represent the three divisions of the Comanche series of the lower Cretaceous period. On the highest summits at the northern margin of the quadrangle a small portion of the basal strata of the Washita division is preserved. The steep rocky bluffs, and, with the exception of the lower slopes of the East Nueces Valley, nearly all the rest of the country, consist of the Edwards limestone of the Fredericksburg division. In that portion of the valley of the East Nueces lying lower than the 1750-foot contour the Glen Rose formation of the Trinity division is exposed.

Three divisions of the Comanche series.

Glen Rose formation.—These beds consist of flaggy, argillaceous limestone, of white or yellowish color, alternating with thin strata of marly clay. When transected by the drainage ways these alternations of hard and soft layers produce a striking topography, the harder beds weathering into precipitous benches, and the softer marls into slopes.

Alternate strata of limestone and marly clay.

The characteristics of these beds, both lithologic and paleontologic, are very constant from Austin, Texas, to the Nueces quadrangle, the variations being chiefly in thickness. The rocks of the middle of the Glen Rose formation are the oldest exposed in this quadrangle, but the thickness estimated from the nearest exploration of the entire division, in the vicinity of Kerrville, 50 miles to the east, is approximately 500 feet. These beds are exposed only in the lower slopes of the valley of the East Nueces and its tributaries between Vance and Montell and in two places on the West Nueces. The lowest channel of the West Nueces has cut down barely to the top of the Glen Rose formation in places, and it is exposed along the stream bed at low water at Kickapoo Springs and in the north bend of the river along the southern margin of the quadrangle.

Comanche Peak formation.—This is a bed of yellow, argillaceous limestone presenting a nodular, reticulated, chalky appearance. It is partly characterized by a peculiar fauna containing a large number of the oyster *Exogyra texana* Roemer, which is especially abundant in its basal portion. This formation is always from 40 to 50 feet thick, and although it is insignificant as regards thickness, it is one of the most persistent beds, both in paleontologic and in lithologic characters, of the Texas Cretaceous section, and is economically important in locating the position of underground water. This formation occurs along portions of the East and West Nueces, as shown on the map. The clays (Walnut formation) so rich in *Exogyra texana*, which are usually found just below the Comanche Peak limestone in Hood, Comanche, Travis, Gillespie, and other counties, are absent in the Nueces quadrangle.

Persistent bed of yellow limestone.

Edwards formation. — Under this name is included what has hitherto been designated the Caprina limestone.

This formation is the chief one in importance, constituting all the rocks of the quadrangle except those in the lower slopes of the Nueces canyons and those along the north margin of the quadrangle at the very summit of the plateau. Its strata give character to the bluffs, scarps, hills, and mesas. Its thickness within this quadrangle is about 628 feet.

The scarp rock of the region.

Not only in the Nueces quadrangle, but throughout all the Texas and Mexican regions inland beyond the Coastal Plain, this is the most conspicuous and extensive sedimentary formation. This formation is likewise topographically the most important, inasmuch as its harder strata resist erosion more than do other formations, and hence it is the chief component of the scarps and mesas of the Grand Prairie, the Edwards Plateau, and the Callahan Divide of the central portion of the State. To its hardness is also largely due the topography of the limestone mountains of Mexico.

This formation shows nearly every variation in color, composition, texture, alteration, and weathering that limestones may display. In general the rocks are of whitish colors, but on weathering they show layers of buff, cream yellow, or dull gray. In composition most of them are as nearly pure carbonate of lime as can be found in nature, but some beds have slight admixtures of epsomite, chloride of sodium, and perhaps other salts. Clay is usually absent except as a constituent of the few marly layers rarely found intercalated between the beds of limestone. Exceedingly fine siliceous particles are found mixed with the lime in a few beds, which are popularly known as "magnesian." Whether these are the finest of the land-derived sands which were carried out to the area of calcareous deposition, or whether they are the siliceous skeletons of marine organisms, such as make up the flints, we can not at present say. No pebble, bowlder, lignite, or other undoubted piece of land débris has ever been found in these rocks. As is generally the case with limestones, iron is present in the form of pyrites, as is shown by the deep-red color of the residual clays formed from a few of the beds.

Nearly pure carbonate of lime.

These limestones vary in texture from hard, ringing, durable strata to soft, pulverulent chalk that crumbles in the fingers. Some of the pure white beds are of coarsely crystalline texture, with calcitized fossils; others are of the homogeneous texture and color of lithographic stone. Still others are "spotty" in texture, having hard and soft lumps, the latter dissolving away by the percolation of underground water, thus producing what is popularly termed "honeycombed" rocks. The harder spots in some of the beds are indurations, and suggest a process by which flints may be formed.

Texture of the limestones.

These limestone beds can nearly always be distinguished by the immense quantity of flint nodules embedded in them and scattered everywhere over the surface. The Edwards limestone is the only flint-bearing formation of the American Cretaceous. These flint nodules occur in the center of the massive ledges along the separation planes. They are of many shapes. Some are flattened oblong oval, others are discoidal; some are fusiform, like elongated roots; others are knotty, like warty potatoes; others are parts of extensive sheets or very flat lenses. In size they vary from that of a hen's egg to a foot or more in diameter. They also vary greatly in color upon fresh fracture; some are almost jet black; others are light blue, gray, or opalescent; still others are delicate pink in color. The flints occur throughout the limestone except in the upper 100 feet, and there is some evidence that each particular kind occupies a definite horizon, but this can not be stated as a fact.

Numerous flints of various forms and colors.

Another distinguishing feature of the Edwards limestone is the presence of the peculiar aberrant mollusks of the genera Monopleura, Requienia, and Radiolites — bivalve fossils which have the cornute form of the horns of domestic animals.

The upper 100 feet of the beds consist of flaggy layers of hard white limestone devoid of flints. Below this are thick ledges of yellowish limestone. The central portion, marked by numerous black flints, contains a great thickness of white limestone of homogeneous texture. The lower portions consist of thick ledges and flags containing considerable numbers of flint nodules, or strata of flint.

Details of the strata.

These deposits apparently are the deepest of the Comanche sea, and this is probably the reason that they are more purely calcareous than the other extensive beds. It is true that in the Glen Rose formation of the Trinity division there are occasional thin beds of chalk, some of which are composed almost entirely of foraminifera, but even the foraminifera themselves are usually in a bed containing a large percentage of clays.

Since both the Edwards limestone and the Comanche Peak formation are composed chiefly of carbonate of lime, originally deposited as a marine chalk, which, under the influence of atmospheric and chemical action, has been for the most part consolidated, they are not always distinguishable. The Comanche Peak, however, is less consolidated and of a more marly texture than the Edwards. Usually the Edwards limestone is harder, of subcrystalline texture, and weathers into cliffs, while the Comanche Peak beds are softer, of chalky texture, and occur at the base of the slopes. In most exposures reliance must be placed upon paleontologic determinations to differentiate the two formations.

Fort Worth limestone and Del Rio clay.—It is very probable that the upper 50 or 100 feet of the highest summit of the plateau may represent beds which we regard as the basal portion of the Washita division. On the high summits of the Rock Springs quadrangle, immediately northeast of the area shown on the Nueces sheet, little knolls of brownish clay and impure ferruginous limestone were found containing *Exogyra arietina* and other fossils characteristic of the Del Rio clay and the Fort Worth limestone. The clays and limestones

Brownish clay and limestone capping the plateau.

of the northern portion of the Nueces quadrangle present such poor paleontologic criteria that these beds are not positively identifiable or separable from the underlying Edwards limestone, into which they grade without break, although it is probable that the beds belong to the Washita division. A mile and a half south of Whistler the Del Rio clay is exposed in a limited area in the bluffs on the east side of the Nueces Canyon, and on the downthrown side of a fault.

SURFICIAL ROCKS.

NEOCENE AND PLEISTOCENE PERIODS.

The formations belonging to these periods are all indicated on the map by one color, for the reason that, although in places they may be distinguished one from another, the lines of demarcation between them can not usually be drawn. They are composed of the same material, the product of processes similar but slightly varied, and are similar in lithologic aspect. They represent the products of upland degradation, and when transported are usually carried but a moderate distance to a lower level.

Uvalde formation.—The wide valleys of the two Nueces rivers are entirely disproportionate to the present streams and are filled with an ancient alluvial deposit which has been termed the Uvalde formation.

Gravel terraces.

The Uvalde formation is composed of flint and limestone bowlders and gravel derived from the adjacent country, and is sometimes consolidated into a massive conglomerate. It constitutes a sheet of material filling from side to side the old valleys, through the center of which the present stream ways meander at a depth averaging 50 feet below the surface of the formation, so that the remnants of this older formation form a terrace on either side.

This formation increases in width and importance in descending the stream, to the southward. As the stream ways pass out of the Edwards Plateau into the lower Rio Grande Plain the formation spreads out so as to cover the present divides and constitutes one of the most widely spread and important geologic features of Texas.

Fluviatile marl deposits.

Leona formation.—Below the level of the plane of the Uvalde formation, but above the present alluvium, there is a formation of peculiar, light-yellow, fluviatile marl, containing occasional finely worn, yellow, calcareous pebbles. It is named from its typical development on the Leona River in Uvalde County. It is probably identical with the Onion Creek formation of Travis County (see Austin folio). This formation has wide occurrence in the stream valleys of the Central and East Central provinces of Texas. It may be the equivalent of the San Diego formation of the Coast Prairie. From fossils found in it in Travis County, it is considered to be the equivalent of the Equus beds stage of the early Pleistocene. This marl is traceable below the Uvalde terrace in all the streams of the border of the Edwards Plateau, in the Cretaceous region of Texas, and undoubtedly represents a distinct period and event in the Pleistocene history of the region.

Broad sheets of limestone débris.

The wash.—The observant traveler through the country will see that the edges of the outcropping ledges of hard limestone rocks forming the scarps and crests are being shattered into fragments by the alternate expansion and contraction due to variations of temperature. These loosened pieces may remain in place until a sudden cloudburst occurs, when they are gathered by the torrents and washed down the slopes. A peculiarity of this rainfall, however, is that, although it comes in great torrents and gathers in rills and sheet floods upon the upper slopes, it is either imbibed or evaporated before reaching an outlet into another stream, and thus this débris is scattered in great sheets over local lower-lying slopes or levels. Sedimentary material of this kind constitutes formations of vast areal extent in the arid and semi-arid regions, and may appropriately be known as the "wash." It occupies a considerable portion of the surface of the Nueces quadrangle, especially in the wide hemispherical drainage basins of the minor stream ways, such as those of Griffin, Dry Sycamore, Sycamore, and Hackberry creeks.

In addition to the wash, one other distinct surficial deposit is recognizable—i. e., the recent or present river alluvium, which is composed almost entirely of rolled pebbles of flint and limestone with a comparatively small proportion of calcareous mud.

STRUCTURE.

Monoclinal fold to the southward.

In the northern two-thirds of the quadrangle the rock strata are either horizontal or so nearly horizontal that no dips can be measured. These conditions are those of all the rocks constituting the floor of the plains for 200 miles or more to the northward. In the southern third of the quadrangle, however, the rock sheets begin to flex southward, marking the commencement of a monoclinal fold, which soon carries them far beneath the Rio Grande Plain, not to rise again until they are upturned in the mountains of northern Mexico. Accompanying this fold are numerous small faults generally running in northwest-southeast directions, cutting the strike of the fold and accompanied by much jointing. These faults are difficult to trace, and they are not continuous over great distances. Often blocks of strata are faulted down, without affecting the continuous horizontal condition of the stratification of the rocks on either side of the block. They will be more fully discussed in the Brackett folio.

UNDERGROUND CAVERNS.

Hillcoat Cave.

In the great thickness of limestone constituting the most extensive formation of this area are many interesting caverns. One of these, just west of the McKenzie trail, about 6 miles due northwest of Hillcoat's ranch, may be taken as a type. The entrance to this cave is near the summit of an oval conical butte. The recesses of the cavern apparently undermine the whole hill, and are elongated chambers having cross sections shaped like Norman arches. The total depth from the entrance to the bottom, as far as explored, is over 140 feet. The many chambers are lined with stalactites and stalagmites of great beauty and a variety of forms. Views of the cave are shown on the sheet of illustrations. The cave is very dry, only a little water being found at its lowest depths. Although apparently not well known to the people of Texas, this cave is a natural object of great interest.

GEOLOGIC HISTORY.

Lower Cretaceous subsidence.

The Cretaceous rocks were laid down as sediments in the ocean. Previous to their deposition a land area had existed to the north of the region since Paleozoic time, but was slowly covered by the sea during the subsidence of earlier Cretaceous time, as is recorded in the character of the rocks. The basal beds of the Trinity division are coarse, land-derived débris, with occasional beds of lignite. As we ascend to higher and higher strata the rocks are found to be more uniform in composition and more evenly sorted. Strata of chalky limestone appear, alternating with very fine calcareous clays, as seen in the lowest beds exposed in the Nueces quadrangle, and the land-derived débris becomes finer and finer. Finally the clays cease, in the ascending series, and chalky limestones representing chemically and organically derived deposits on the off-shore bottom prevail. This deepening of the sea culminated in the Edwards formation of the Fredericksburg division. These sediments were deposited so far from the shore that they are entirely free from the coarser débris of the land, which is cast down first by land waters on reaching the sea.

The less pure sediments of the Washita division show that after the lower Cretaceous subsidence which culminated in the Fredericksburg epoch the land began to rise again.

Upper Cretaceous subsidence.

During upper Cretaceous time there was another great subsidence and emergence, another migration of the shore line of the ocean back and forth across the Texas region; but the record of events of this period is not preserved in the Nueces quadrangle, for the upper Cretaceous sediments which no doubt once added their thickness to the former height of the plateau were all removed by processes subsequently active.

Later emergence and erosion.

At or immediately after the close of the Cretaceous period sediments now constituting the surface, with thousands of feet of others which lay above them, were elevated into permanent dry land.

It is probable that during Eocene time the summit of the plateau was much higher than it is now. This additional height equaled the thickness of the upper Cretaceous formations now washed away (over 3000 feet), less the amount of the subsidence of Eocene time. During this period the interior margin of the ocean extended from near San Antonio toward Eagle Pass, making a slight indentation up what is now the valley of the Rio Grande. The plateau region at this time was undergoing great erosion, and was probably then stripped of much of its former upper Cretaceous capping.

Production of folds.

The tremendous loading down of the coast by sediments during the Eocene period was probably accompanied near its close by the folding and faulting of the Balcones scarp line, of which the monocline at the southern edge of this quadrangle is a part.

In Miocene time the land was rising; great erosion continued, the summit of the plateau was degraded, and the present canyons of the main forks of the Nueces were outlined. During this period the progressive erosion which had been stripping away layer after layer of the beds of the Cretaceous formation reached the Edwards limestone, which forms the hard cap or resistance plane of the Edwards Plateau, and in the Pliocene epoch had cut completely through it.

The erosion of the present canyons.

The main Nueces, or East Fork, existed prior to the Lafayette epoch (late Pliocene). Its great canyon through the Edwards limestone was cut principally during the early part of that epoch. At the close of this epoch the canyons were short, deep estuaries. During the Lafayette epoch the land was subsiding, as is attested by the manner in which canyons were partially refilled by the deposits of the Uvalde formation. The West Fork of the Nueces was a feebler stream at this period of its history, and it probably had its outlet directly into the Rio Grande.

Succeeding the Lafayette sub-periods of canyon-cutting and canyon-filling, there were slight oscillations of the land. The most marked of these was in early Pleistocene time, the epoch of the deposition of the marly alluvium of the Leona formation, which is equivalent with what is known as the Equus beds epoch.

Since the early Pleistocene, erosion has continued, and is going on to-day at a rapid rate. But the great sculpturing of the quadrangle was accomplished in the Lafayette and Pleistocene epochs. The events of later Pleistocene time are not so clearly recorded in the rocks of the Nueces quadrangle as in the coastal region. It is probable, however, that during the Columbian epoch erosion continued in this particular region with great activity, and that then much of the stream capture along the monoclinal folds took place.

Formation of the "wash."

The recent erosion has been of irregular character. The rocks, disintegrated through the alternations of temperature and the desiccation and evaporation due to winds, have rolled down the hills or have been carried by the cloudburst rainfall to lower levels, usually being deposited on the slope before reaching the level of the principal drainage. They constitute the formation, so extensive throughout arid America, which we have herein termed the "wash." The outer borders of the old plain of the Uvalde formation in the ancient Lafayette valleys are thus being covered. The length of time which has elapsed since this method of degradation began is, as yet, purely conjectural. It has probably continued intermittently since the end of the Cretaceous.

ECONOMIC GEOLOGY.

The materials of economic value found in this area are: stone of excellent quality for building and making lime, ornamental marbles, flints of the kind so extensively used in pottery and glass manufacture, and limestones and gravels for road material. Occasional segregations of limonite are found in the limestone rocks, but not in sufficient quantities for profitable utilization.

Agricultural lands.

Agriculturally the country is not well adapted for any industry except stock raising. The more fertile soils lie upon the highest summits of the plateau, but these are not available for agriculture owing to the impossibility of irrigating them. The bottom lands of the East Fork of the Nueces are in general too stony for agriculture, but in places, especially where the Leona marl prevails, from Barksdale southward, particularly in the vicinity of Montell, some land is cultivated. More land could be brought under cultivation by the scientific utilization of the waters of that river.

UNDERGROUND WATER.

The barren limestones of the Edwards formation, composing the hilly topography, might not be supposed to contain underground water, yet in this geologic series there are several horizontal layers of water-bearing rock which afford an abundant and pure supply when penetrated by the well digger or cut by ravines. In addition to these it is probable that in the Trinity division, below the lowest rocks exposed in the quadrangle by the cutting of streams, there are still other strata containing a large amount of water.

Natural springs.

There are two series of noteworthy springs in southern Texas which occur along lines extending in a southwestern direction from the Colorado River to the Pecos, both of which demonstrate the existence of immense quantities of water in the rocky structure of the Edwards Plateau. One of these, approximately following the line of the railroad from Austin to Del Rio, consists of fault springs—i. e., springs which rise under hydrostatic pressure through fissures in the rock. These lie south of this quadrangle, and will not be further mentioned here. The other line of springs occurs near the head waters of the principal streams draining the Edwards Plateau. These are gravity springs. The springs of the latter class drain from cavernous and arenaceous layers intercalated in the more massive limestones of the Edwards beds.

Character of the water-bearing strata.

The horizontal distribution of water in the Edwards limestone is facilitated by the occurrence in the series of certain strata which, through solution, become cavernous and honeycombed. This limestone in a cliff may appear hard, durable, and of homogeneous texture, but some portions of its interior are more soluble than others. These portions may represent fossils, or very small particles of pyrites, or certain tubular molds suggestive of fucoids. Near Austin the cavernous decomposition of the Edwards limestone is well shown in the peculiar red blotches which appear in the otherwise massive limestone bluffs. There are also so-called "fucoidal" layers which weather into honeycombed rock.

Whatever may be the origin of the honeycombed texture, strata possessing it transmit water in immense quantities, and it is from these and the occasional thin arenaceous layers in the general mass of limestone that the gravity head-water springs of the rivers of the Edwards Plateau above mentioned and the artesian wells of the San Antonio system obtain their water.

Evidence of subterranean water in the quadrangle.

There can be little doubt that certain beds of the Edwards limestone in the series of strata underlying the main Edwards Plateau are thoroughly impregnated with water. Wherever the gradient of a stream first crosses these water-bearing beds in descending from the plateau to the lower canyons, the gravity springs suddenly break forth, producing beautiful pools of water in the dry rock-canyons. Of this character are the so-called head-water holes of the forks of the Llano, Guadalupe, Medina, Frio, Nueces, and Devils rivers. The constant water of the stream ways of the Nueces quadrangle is derived from springs of this character. This is also attested by the fact that the ranchmen of the high plateau region bore wells down to these strata. This was proved by a series of studies made by the writers along an east-west line from the head of the Llano to Rock Springs approximately following the thirtieth parallel. At widely separated intervals along this line the deep wells all penetrated the water-bearing strata presently to be described, their depths checking almost to a foot with the measurements of the rock sections.

These water-impregnated strata of the Edwards limestone are of wide extent and great uniformity, being more or less productive from the head of the Colorado to the Pecos. The bold head-water springs of the Hackberry, Nueces, Frio, and Guadalupe derive their waters from the water-bearing beds of the Edwards limestone. They are also the source of supply for the town wells at Rock Springs, just north of this quadrangle, and at Ford and Holliday's ranch.

In the Nueces quadrangle the known water-bearing layers occur at the base of and in the

Edwards limestone. In ascending series, the first may be called the Kickapoo water-bed; the second, the Black Water Hole beds; and the third, the Justice Spring horizon. The supply from the last-mentioned layer is trivial and uncertain in character; the other two are of great economic importance.

Kickapoo water-bed.—At Kickapoo Springs, on the West Nueces, where the erosion of the West Fork of the Nueces and of Kickapoo Creek cuts down to the level of the Comanche Peak limestone, enormous springs break forth, creating a bold and beautiful running stream, which continues for 4 miles, abounding in fish and aqueous vegetation, and disappearing, as suddenly as it appeared, into a fissure in the Edwards limestone. This water is derived from near the contact of the Edwards limestone and the Comanche Peak beds. Observations elsewhere in the quadrangle tend to show that this geologic horizon is saturated with water. From it the springs along the East Fork of the Nueces and its principal tributaries, where they cut down to this formation, derive their water. Nearly all the abundant living waters in this quadrangle, except the Black Water Hole of the West Fork of the Nueces, come from this water-bearing horizon.

The most important water horizon.

In the northern half of the quadrangle, where the rocks are horizontal, this water-bearing stratum lies about 650 feet below the summit of the plateau, at a level of about 1750 feet above the sea, and (except in the lower valley of the East Nueces, which has cut below its level) is available for wells. Along the southern monocline it is reached in the well at Hillcoat's ranch at an underground altitude of 1447 feet above sea, and at two wells in the area of Griffin Creek, west of Hillcoat's ranch, at altitudes of 1450 feet above sea.

Black Water Hole bed.—This occurs about 150 feet above the base of the Edwards limestone, and occupies a horizontal position of 1900 feet above sea level in the northern half of the quadrangle, or in that portion where the rock layers are horizontal, and from 1900 feet to 1450 feet along the monocline at the southern margin, as indicated by the contours.

Other water-bearing beds.

Justice Spring horizon.—Justice Spring, Cedar Spring, and Cherry Spring, on the western border of the quadrangle, probably derive their waters from a third and still higher water-bearing horizon of the Edwards beds. The waters in the vicinity of Seep Springs Mountain may also be derived from this source. These springs are feeble, however, and the horizon has not been sufficiently studied to justify at present any conclusion tending to show continuous horizontal distribution or availability. Yet there are strong reasons for believing that in the region lying to the east of the Nueces quadrangle this water-bearing stratum becomes more productive, especially in the heads of the Frio. This water in the plateau region lies at an altitude of from 2000 to 2100 feet above sea level, or from 300 to 350 feet above the base of the Edwards limestone. Its altitude decreases along the monocline at a gradient parallel with that of the other water-bearing strata.

The depth at which any one of the water-bearing strata can be reached from the surface can be determined by subtracting its altitude above sea level from the altitude of the surface location at the place where the well is desired, as indicated on the contour map.

It is probable that, in the greatly eroded portion of the area lying between the two forks of the Nueces and south of an east-west line almost across the center of the quadrangle, connecting the head waters of Cedar and Kickapoo creeks, much of this water has been drained by the erosion cutting, and hence wells can not be always relied upon in this portion of the area.

The water-bearing beds of the Edwards limestone in the Nueces quadrangle are non-artesian and will not rise in wells, but on the downthrown side of the Balcones scarp line, as is proved at Manor and San Antonio, these rocks afford an abundant artesian supply.

In the valley of the East Nueces shallow wells are successful in many places in the alluvial deposits of the river valley, as at Vance, Barksdale, and Montell.

The Trinity (*Travis Peak*) *water.*—Although no artesian borings or other experiments have been made, there is every reason to believe that in the rocks lying below all those exposed in the deepest canyons there exists an abundant supply of water which can, in places at least, be made available. This water, if it exists, will be found in the basement beds of the Trinity division, which lie at least 500 feet below the Comanche Peak limestone.

A probable deep-seated horizon.

Our reasons for believing that the Travis Peak sands are to be found beneath these valleys and that they are water bearing are as follows: Where last exposed (at Fredericksburg) and where penetrated by drills (at Kerrville), 60 miles distant, the structure showed that the strike of these beds extends in the direction of the Nueces quadrangle, and that they consist of porous water-bearing sands. Wherever these sands have been exploited in Texas they have yielded abundant water. Artesian wells sunk into them in the valleys lying immediately to the east of the East Fork of the Nueces yield supplies of flowing water. The artesian wells at Kerrville are instances. As the topographic and geologic conditions in the Kerrville artesian-well district are the same as those in the valleys of the East Fork of the Nueces, we see no reason why artesian water should not be procured in the latter. Furthermore, at Camp Wood, on the Nueces, there is a large spring rising through joints and fissures from rocks lower than the Glen Rose formation, here exposed at the surface, and there is every reason to believe that the Travis Peak sands are the source of this supply.

ROBERT T. HILL,
T. WAYLAND VAUGHAN,
Geologists.

April, 1898.

U.S.GEOLOGICAL SURVEY
CHARLES D. WALCOTT, DIRECTOR

TOPOGRAPHIC SHEET

TEXAS
NUECES QUADRANGLE

LEGEND

RELIEF
(printed in brown)

Figures
(showing heights above mean sea level instrumentally determined)

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

DRAINAGE
(printed in blue)

Surface streams

Water pockets and springs

Subsurface streams

CULTURE
(printed in black)

Towns and villages

Roads and buildings

County boundary lines

Triangulation stations

Names of adjoining published sheets are printed on the margin.

A.H.Thompson, Geographer.
R.U.Goode, Geographer in charge.
Triangulation by Chas.F.Urquhart.
Topography by E.McL.Long.
Surveyed in 1891-92.

Scale $\frac{1}{125\,000}$

1 ½ 0 1 2 3 4 5 Miles

1 ½ 0 1 2 3 4 5 Kilometers

Contour interval 50 feet.

Datum is mean sea level.

Edition of Sept. 1897.

U.S. GEOLOGICAL SURVEY
CHARLES D. WALCOTT, DIRECTOR

HISTORICAL GEOLOGY SHEET

TEXAS
NUECES QUADRANGLE

(Brackett)

Scale $\frac{1}{125000}$

1 ½ 0 1 2 3 4 5 Miles

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Topography by E. McL. Long.
Surveyed in 1891-92.

Geology by Robt. T. Hill
and T. Wayland Vaughan.
Surveyed in 1895.

LEGEND

SURFICIAL ROCKS

(Areas of Surficial rocks are shown by patterns of dots and circles.)

PNa
Alluvium and terrace deposits
(gravel and silt, marl, and limestone conglomerate)

PLEISTOCENE
(and probably Neocene)

SEDIMENTARY ROCKS

(Areas of Sedimentary rocks are shown by patterns of parallel lines.)

Kdr
Del Rio clay
(greenish clay, weathering yellow, with beds of limestone)

Kfw
Ft. Worth limestone
(soft, white, argillaceous limestone)

Ke
Edwards limestone
(white limestone of varying hardness, frequently massive, and contains flint nodules)

Kcp
Comanche Peak limestone
(soft argillaceous limestone weathering into rounded blocks)

Kgr
Glen Rose formation
(alternating beds of soft limestone, clay, and marl)

Comanche Series

CRETACEOUS

Faults

○ *Wells*

U.S. GEOLOGICAL SURVEY
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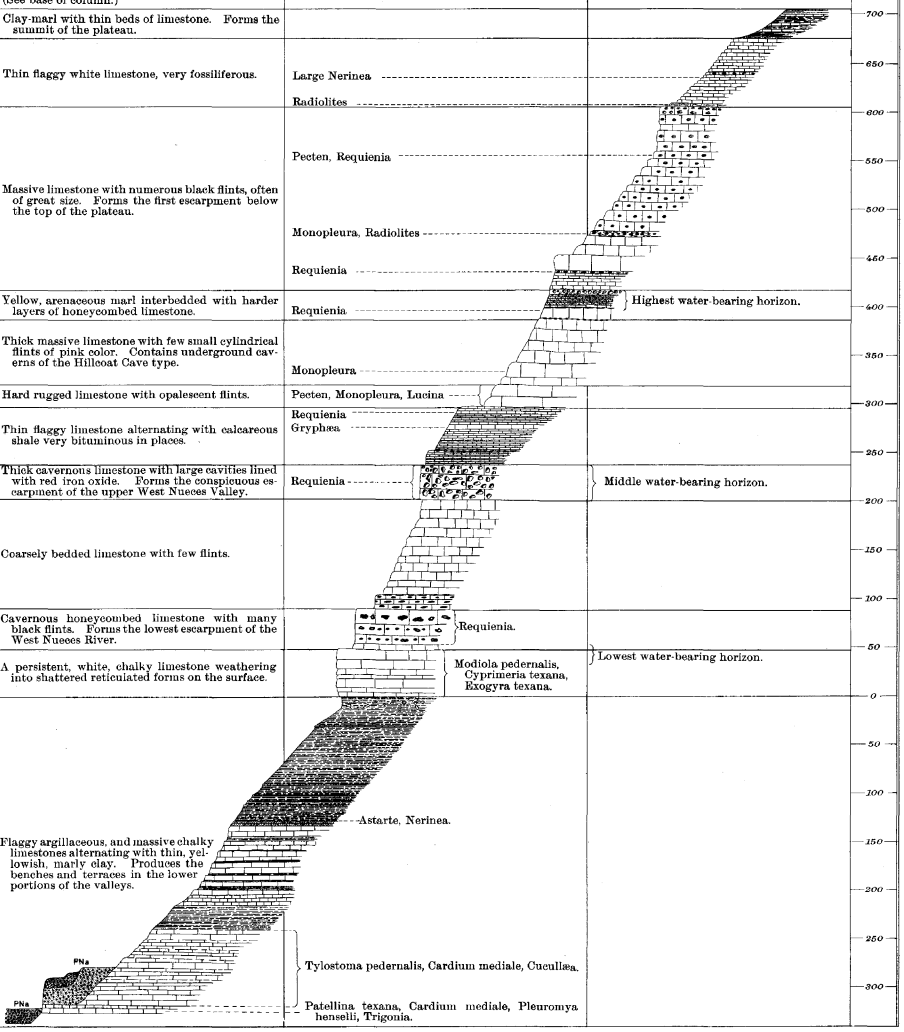
COLUMNAR-SECTION SHEET

TEXAS
NUECES QUADRANGLE

GENERALIZED SECTION FOR THE NUECES QUADRANGLE.

SCALE: 100 FEET = 1 INCH.

Period.		Formation Name.	Symbol.	Character of Rocks.	Characteristic Fossils.	Water-bearing Strata.
Pleistocene and Neocene?		Alluvium and terrace deposits.	PNa	Gravel, silt, flint conglomerate, and limestone conglomerate. Forms the bottom lands and low terraces of the broad valleys. (See base of column.)		
Cretaceous	Washita Div.	Fort Worth limestone.	Kfw	Clay-marl with thin beds of limestone. Forms the summit of the plateau.		
	Fredericksburg Division	Edwards limestone.	Ke	Thin flaggy white limestone, very fossiliferous.	Large Nerinea Radiolites	
				Massive limestone with numerous black flints, often of great size. Forms the first escarpment below the top of the plateau.	Pecten, Requienia Monopleura, Radiolites Requienia	
				Yellow, arenaceous marl interbedded with harder layers of honeycombed limestone.	Requienia	Highest water-bearing horizon.
				Thick massive limestone with few small cylindrical flints of pink color. Contains underground caverns of the Hillcoat Cave type.	Monopleura	
				Hard rugged limestone with opalescent flints.	Pecten, Monopleura, Lucina	
				Thin flaggy limestone alternating with calcareous shale very bituminous in places.	Requienia Gryphæa	
				Thick cavernous limestone with large cavities lined with red iron oxide. Forms the conspicuous escarpment of the upper West Nueces Valley.	Requienia	Middle water-bearing horizon.
				Coarsely bedded limestone with few flints.		
				Cavernous honeycombed limestone with many black flints. Forms the lowest escarpment of the West Nueces River.	Requienia.	
		Comanche Peak limestone.	Kcp	A persistent, white, chalky limestone weathering into shattered reticulated forms on the surface.	Modiola pedernalis, Cyprimeria texana, Exogyra texana.	Lowest water-bearing horizon.
	Trinity Division	Glen Rose formation.	Kgr	Flaggy argillaceous, and massive chalky limestones alternating with thin, yellowish, marly clay. Produces the benches and terraces in the lower portions of the valleys.	Astarte, Nerinea. Tylostoma pedernalis, Cardium mediale, Cucullæa. Patellina texana, Cardium mediale, Pleuromya henselli, Trigonia.	



ROBERT T. HILL,
T. WAYLAND VAUGHAN,
Geologists.

HILLCOAT CAVERN ILLUSTRATIONS

U. S. GEOLOGICAL SURVEY
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TEXAS
NUECES QUADRANGLE

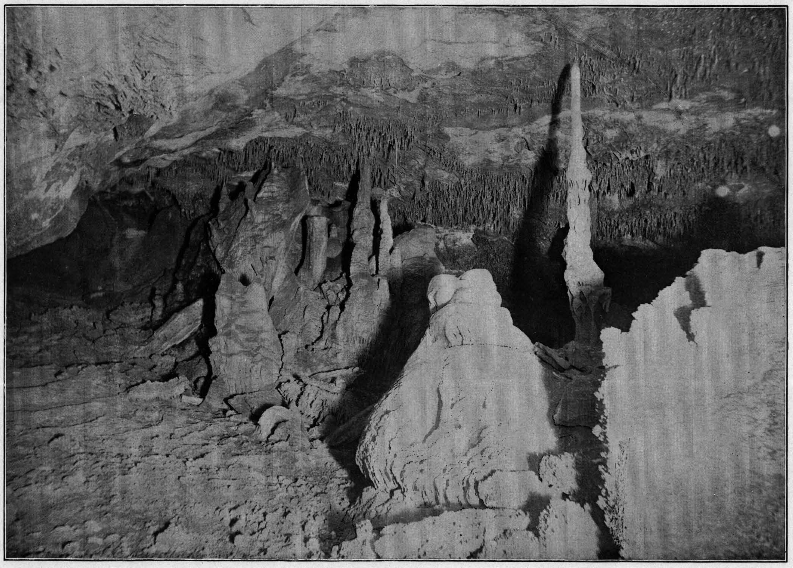

FIG. 1.—VIEW IN LOWER PORTION OF THE CAVE.

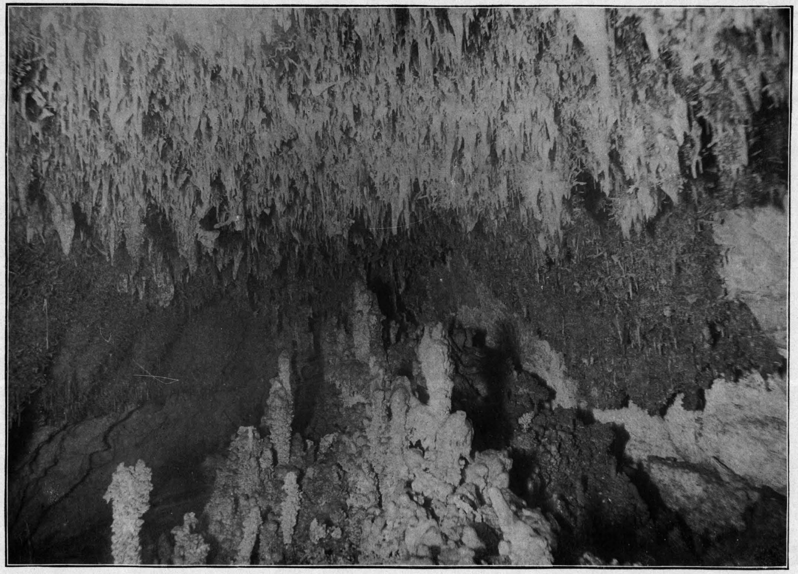

FIG. 2.—BRANCHING STALACTITES AND BOTRYOIDAL STALAGMITES.

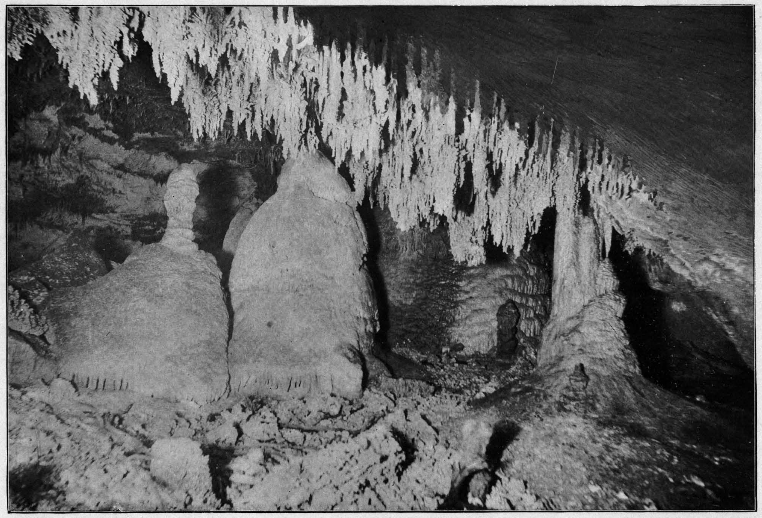

FIG. 3.—PORTION OF THE CAVE NEARLY FILLED WITH STALAGMITIC MATERIAL.

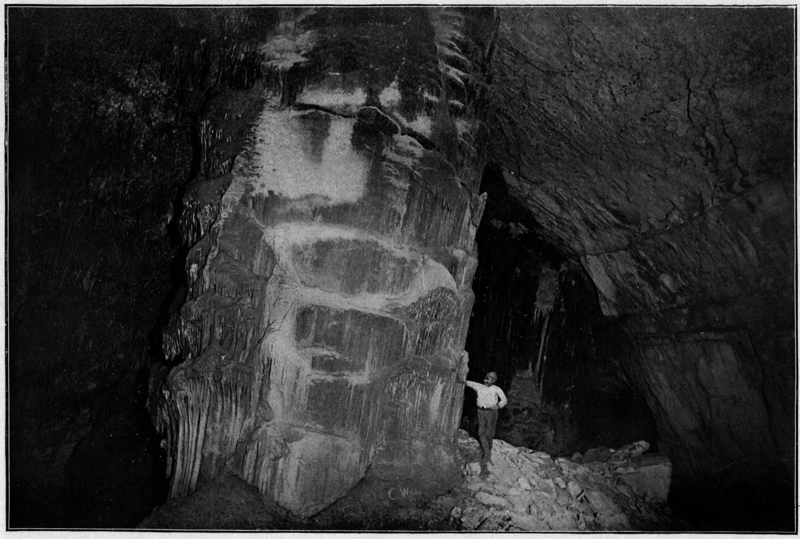

FIG. 4.—GIANT PILLAR AND ARCH OF ROOF.