University of Texas Bulletin

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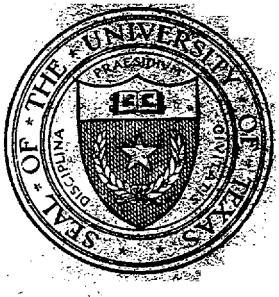
E. H. SELLARDS

BUREAU OF ECONOMIC GEOLOGY AND TECHNOLOGY
DIVISION OF ECONOMIC GEOLOGY
J. A. UDDEN, Director of the Bureau and Head of the Division



PUBLISHED BY
THE UNIVERSITY OF TEXAS
AUSTIN

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PUBLISHED BY THE UNIVERSITY SIX TIMES A MONTH, AND ENTERED AS SECOND-CLASS MATTER AT THE POSTOFFICE AT AUSTIN, TEXAS, UNDER THE ACT OF AUGUST 24, 1912

The benefits of education and of useful knowledge, generally diffused through a community, are essential to the preservation of a free government.

Sam Houston

Cultivated mind is the guardian genius of democracy. . . It is the only dictator that freemen acknowledge and the only security that freemen desire.

Mirabeau B. Lamar

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GEOLOGY AND MINERAL RESOURCES OF BEXAR COUNTY*

BY E. H. SELLARDS

Bexar County is located in south-central Texas, about 125 miles from the Gulf Coast, and approximately an equal distance from the Mexican border. The adjoining counties are Kendall and Comal on the north, Guadalupe and Wilson on the east, Atascosa on the south, and Medina and Bandera on the west. San Antonio, the county-seat, is one of the large cities of the southwest part of the United States. The area of Bexar County is estimated at 1,268 square miles. The population, according to the latest census, that of 1913-1914, was 119,676.

EARLY SETTLEMENTS

In 1718 the Spanish established the mission of San Antonio de Valero and the Villa de Bexar near the headwaters of the San Antonio River and on the site of the present city of San Antonio. The principal natural advantage inducing settlement at this place was the existence of large springs which emerge at the head of the San Antonio River a few miles farther inland. The location for this setllement is said to have been pointed out to the Spaniards by the Frenchman, Saint Denis, as a suitable place for a city "in the most pleasant place" in the province of Texas.† Subsequently, between the years 1718 and 1731, there was built up by the Spanish, the several missions of which the ruins still remain. Of these, the mission of San Antonio de Valero, already noted, and Conception Mission are within the limits of the present city of San Antonio. The others are farther south, but all are within the valley of the San Antonio River, where water from the springs was available and was used in irrigation. The presence of these springs, giving rise to a permanent flowing stream in a region otherwise lacking in surface water supplies, determined the original location of the city of San Antonio.

†Clark, Robert Carlton. The Beginnings of Texas. Univ. of Texas Bull. No. 98, p. 87, 1907.

*Issued March, 1920.

Settlement by citizens of the United States began in Bexar County while Texas was still a Spanish province, although not until 1820 was official permission secured to establish an American colony. Immigration from the United States continued and at the time of the declaration of independence of Texas, a considerable colony had been established. The historic associations of the city, especially those connected with the struggle for independence from Mexico, center around the Alamo, built originally as the chapel of the Mission of San Antonio de Valero, where in 1836 Colonel Travis and his small band of 182 followers made their famous although unsuccessful stand against the army of Santa Anna.

Since the acquisition of Texas by the United States, the military control of the southwest has in a measure centered in San Antonio, and at the present time the county is notable for the number of army camps and large military reservation that it contains. Fort Sam Houston, near the eastern limits of San Antonio, has for many years been the headquarters for the Southern Military Department. The Leon Springs military reservation is located in the northern part of the county. South of Leon Springs is the Camp Bullis reservation, now under lease by the Government. Adjoining Fort Sam Houston on the east, and partly within the city limits, is a large army training camp named in honor of Colonel W. B. Travis. Camp Stanley, a cavalry camp, is located in the Leon Springs reservation. Kelly field No. 1 and Kelly Field No. 2, both aviation camps, are located on the terrace plain about six miles southwest of the center of the city. Brooks Field, another aviation camp, is about eight miles south of San Antonio. Camp John Wise Balloon School is located just north of the city limits.

ACKNOWLEDGMENTS

An investigation of the geology of Bexar County was begun for the Bureau of Economic Geology by Mr. C. L. Baker, in 1917. The field notes made by Mr. Baker at that time have been available and have proved of much assistance in the subsequent field work in this county and in the preparation of this report.

Dr. J. A. Udden, has also made notes at various times on this county, both on surface exposures and on cuttings from deep wells. These notes likewise have been made available and have been used in this report. In 1911 and again in 1918, Dr. L. W. Stephenson of the U. S. Geological Survey visited and made notes on the geology of Bexar County. A part of the data in Dr. Stephenson's notes was incorporated by him in a paper on "The Camps Around San Antonio", published on the reverse side of the topographic map of the San Antonio quadrangle, edition of 1919. The unpublished notes by Dr. Stephenson have very generously been placed at the disposal of the Bureau of Economic Geology by the Director of the United States Geological Survey, and have added very materially to the data on this county. From Mr. Alexander Deussen many additional data have been secured, including well records collected by him in connection with a report on the water supply of Central Texas for the U. S. Geological Survey, as well as other data personally collected by himself. Brief reports on oil discoveries in Bexar County, made for the Bureau of Economic Geology by Mr. E. L. Porch, Jr., have been available and have supplied data utilized in this report. To Mr. R. M. Madison is due credit for many data on wells. To the Chamber of Commerce of San Antonio, to well drillers, and oil- and mineral-producing companies as well as to many other individuals, the writer is under obligations for courtesies and for data that have been contributed.

The base maps which have been available in this county include, first, a topographic map of the San Antonio quadrangle, by the United States Geological Survey. This quadrangle covers approximately one-half of the county. From the County Engineer of Bexar County, Mr. A. C. Pancoast, was obtained a very carefully made road map of the county which has been of much service. In addition, maps of the military reservations were available in the offices of the War Department. The soil survey map of the San Antonio area made by the United States Bureau of Soils was likewise consulted.

The published literature relating directly or indirectly to Bexar County, although not extensive, includes a number of papers that should be specially mentioned. The following list

contains the more important papers relating to this county, arranged chronologically:

A Partial Report on the Geology of Western Texas, consisting of a general Geological Report and a Journal of Geological Observations along the Routes traveled by the Expedition between Indianaola, Texas, and the Valley of the Nimbres, New Mexico, during the years 1855 and 1856; with an Appendix giving a detailed report on the Geology of Grayson County. By Prof. Geo. G. Shumard, Assistant State Geologist of Texas. Introduction by H. P. Bee, Commissioner of Insurance, Statistics and History. Austin, 1886.

Report on the Brown Coal and Lignite of Texas, by Edwin T. Dumble. Second Annual Report, Texas Geological Survey, 1892.

Geology of the Edwards Plateau and Rio Grande Plain adjacent to Austin and San Antonio, Texas, with reference to the occurence of Artesian waters, by Robert T. Hill and T. W. Vaughan. U. S. Geological Survey, 18th Ann. Rpt., Pt. II, pp. 193-321, 1898.

Geography and Geology of the Black and Grand Prairies, Texas, with detailed descriptions of the Cretaceous formations and special reference to artesian waters, by R. T. Hill. U. S. Geol. Surv., 21st Ann. Rpt., Pt. VII, pp. 666, 80 figs., 1901.

Soil Survey of the San Antonio Area, Texas, by Thomas A. Caine and W. S. Lyman. U. S. Dept. Agric., Bureau of Soils, 1904.

Underground Waters of the Coastal Plain of Texas, by Thos. U. Taylor. U. S. Geol. Surv., Water Supply Paper No. 190, 1907.

The Geology of the Artesian Water Supply of the San Antonio Area, by A. H. Muir. San Antonio, 1911.

Geology and Underground Waters of the Southeastern part of the Texas Coastal Plain, by Alexander Deussen. U. S. Geol. Surv., Water Supply Paper No. 335, 1914.

The Mineral Resources of Texas, by Wm. B. Phillips. Bulletin of the University of Texas, No. 365, 1914.

The Lower Eocene Floras of Southeastern North America, by E. W. Berry. U. S. Geol. Surv., Prof. Paper No. 91, 1916.

Review of the Geology of Texas, by J. A. Udden, C. L. Baker, and Emil Böse. Bull. Univ. Texas, No. 44, 1916.

LOCATION WITH RESPECT TO MAJOR PHYSIOGRAPHIC PROVINCES

Two of the large physiographic provinces of the United States, namely the Gulf Coastal Plain and the Great Plains, extend into Bexar County. The Gulf Coastal Plain, in which the greater part of the county lies, reaches from Central America, bordering the Gulf of Mexico, to the Atlantic Ocean, there merging with the Atlantic Coastal Plain. The Great Plains, including several

sub-divisions, extend from Mexico to the Arctic Ocean. In central and southern Texas the line dividing the Great Plains and the Gulf Coastal Plain is a pronounced southeast to south facing escarpment produced by faults and dips, and known as the Balcones Escarpment. This escarpment, coming into the state near Del Rio on the Rio Grande River, continues east to Medina County and there turns to the northeast, passing through Bexar County in a direction approximating 60 degrees east of north. Approximately seven-eighths of the county lies in the Gulf Coastal Plain southeast of the escarpment, while the remaining one-eighth, or about 150 square miles, lies to the northwest in the margin of the highlands known as the Edwards Plateau, which is the southernmost division in Texas of the Great Plains. The location of the county in the State, and with respect to these major physiographic divisions, is indicated on the accompanying sketch map (fig. 1).

Fig. 1.—Sketch map to show the location of Bexar County with respect to the major physiographic provinces of Texas. The shaded area indicates the location of Bexar County.

TOPOGRAPHY AND DRAINAGE

The topographic and physiographic divisions in Bexar County are determined very largely by the geologic structure. The formations dip in general, and with some variations, to the southeast. This also is the direction of the average maximum surface slope, but as the rate of dip of the formations is more rapid than the surface slope, it follows that in passing to the southeast younger formations come successively into the section. Each formation develops in the line of its outcrop a more or less well defined surface topography or topographic expression which is often very characteristic for that particular formation. The formations containing much hard rock resist decay and stand out as hills, often forming northwest-facing escarpments or "cuestas". The softer and less resistant formations, on the other hand, produce either valleys or plains. The strike of the formations, as already indicated, is in general northeast-southwest. Accordingly, the topographic areas developed from these formations trend in a northeast-southwest direction across the county. In addition to topographic divisions dependent upon the surface outcropping of the formations, there is in this county a large development of flood plain stream deposits. These plains, some of which are extensive in area, cut across and cover over the successive formations, concealing the surface features that otherwise would have characterized the outcropping of the underlying rocks. The formations to which it is necessary to refer in this discussion of topography are more fully described in the section on Geology. They include formations of the Cretaceous and Cenozoic systems.

The surface drainage in Bexar County is to the south or southeast in the direction of average surface slope. The maximum elevation is at the northern part of the county and approximates or exceeds 1500 feet above sea level, while near the southern boundary of the county the elevation is 500 or 600 feet above sea level. The principal stream is the San Antonio River, which heads in this county and flows southeast to the Gulf at San Antonio Bay. Among smaller streams in the county, all of which flow directly or indirectly into the San Antonio River, are the

following: Medina, Medio, Leon, Helotes, Salado, and Calaveras. Rio Cibolo forms a part of the northern and eastern boundaries of the county. With the exception of the San Antonio River and Salado Creek, which are supplied by large springs, all of these streams are in at least a part of their course intermittent, flowing for only a short time following rains.

CLIMATE AND RAINFALL

Bexar County is intermediate in location between the arid southwest and the much more moist climate of the Coastal Plains. The following data on temperature and rainfall are taken from reports of the United States Weather Bureau, and are based on the records from 1885 to 1903. The annual mean temperature at San Antonio as obtained from these records is 69 degrees F. The mean for the four seasons of the year is as follows: winter, 54; spring, 69; summer, 82; fall, 70. The maximum summer heat recorded within this period is 106 degrees F. The minimum winter temperature recorded is 4 degrees F.

The annual mean rainfall for the same interval was 28.4 inches. This is distributed throughout the year on an average as follows: January, 1.7; February, 1.9; March, 1.8, April, 2.9; May 3.0; June, 2.7; July 2.6; August, 3.1; September, 3.4; October, 1.8; November, 1.8; December, 1.7.

BALCONES ESCARPMENT

A prominent topographic feature in this county, already referred to, is the Balcones Escarpment which passes through the county in a northeast-southwest direction. To the northwest of this escarpment, the country is high, and in this county hilly; but to the southeast the land, although in places hilly, is on the average much lower in elevation, including also a larger amount of level land and flood plains. This escarpment enters the county at the west boundary a few miles north of the Culebra Road, and leaves at the big bend of the Cibolo in the northeast corner of the county. The hills of this escarpment are entered on the Bandera Road 18 miles from San Antonio; on the Fredericks-

burg Road, 16 miles; on the Blanco Road, 18 miles; and on the Bulverde Road, about 21 miles from San Antonio.

This escarpment indicates the location of the first large faults and dips of the Balcones fault zone. In the western part of Bexar County the escarpment is abrupt. In the eastern part of the county on the other hand the escarpment is not so pronounced, the Edwards Plateau rising more gradually from the lowlands. These differences in topography which indicate differences in the amount of faulting are more fully discussed in the section on structural geology.

MINOR PHYSIOGRAPHIC DIVISIONS

Several well characterized minor physiographic divisions are recognized in this county. These areas for the most part form belts which trend with the formations from which they are derived in a general northeast-southwest direction through the county. The names applied to these minor divisions indicate the formations from which they are chiefly derived. The location of these divisions is indicated on the sketch map (Fig. 2).

The Glenrose Hills: That part of the county northwest of the Balcones Escarpment, forming the eastern margin of the Edwards Plateau, may be known as the Glenrose hills. The underlying formation, the Glenrose, has here been cut into by the headwaters of many small streams forming steep sloping hills and rock-filled stream channels. This formation includes alternating hard and soft layers which weather on the slopes to a succession of small benches giving the hillsides a characteristic terraced appearance. Each terrace or bench is as a rule small, corresponding to soft layers of from one to a few feet in thickness. The slopes thus come to present the appearance of having been cultivated, the rows of planting having seemingly followed the contours of the hill. The vegetation in this area is chiefly low trees and shrubs. The predominating small tree is the mountain cedar or juniper, although in addition there are many small oak and other shrubby trees. The maximum elevation in this area, which is also the maximum for the county, is perhaps somewhat more than 1500 feet above sea level. The range in

elevation from the higher hills to the stream valleys is from 200 to 300 feet.

The Edwards Flint Hills: Adjoining the Glenrose hills on the southeast is a belt of hilly country in which flint rock is extremely abundant in the soils and surface debris. This area stands at a somewhat lower level than the Glenrose Hills. The

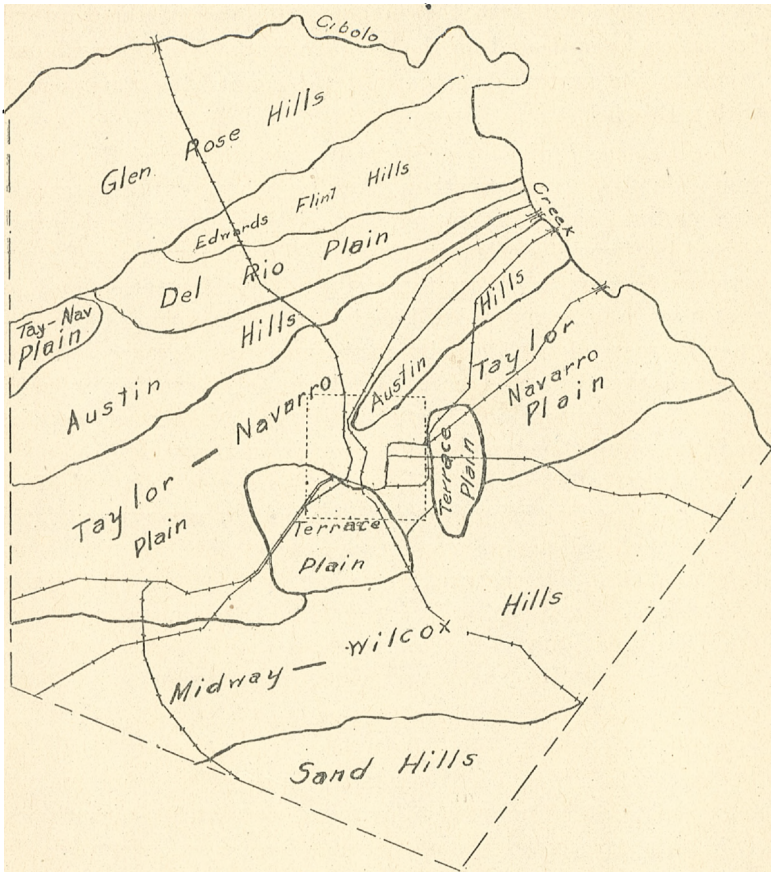

Fig.2.—Sketch map to show the minor physiography divisions in Bexar County.

prevailing rock is the Edwards limestone from which the flints have been derived by weathering. The timber growth of this area is juniper and small oaks. The soils, especially those derived from the flinty phases of the limestone, are often red,

and the belt is known locally as the "red lands". The area forms a narrow belt lying next to and southeast of the Balcones Escarpment. Near the west boundary of the county this belt narrows to such an extent as not to be appreciable. In the central and eastern part of the county, on the other hand, it enlarges to a belt of three or four miles in width, being approximately coincident with the surface exposures of the Edwards formation as indicated on the geologic map. The Peter Clausen ranch in the northeastern part of the county lies very largely within this belt.

The Del Rio Plain: The soft materials of the Del Rio formation, chiefly clays, weather rapidly when exposed at the surface, and the outcropping belt of this formation is represented in the surface features by a valley or low plain. Lateral streams frequently follow the strike of this formation and for that reason the plain developed from this formation is frequently merged with or obscured by stream terrace deposits. At both the west and east boundaries of Bexar County the clays of this formation have but a limited surface outcropping and the plain developed from them is inconspicuous. In the central part of the county, however, particularly on the Babcock and Fredericksburg roads, the belt of exposures of this clay is much widened, representing here successive exposures of this formation, interrupted by occasional belts of exposures of the Buda limestine. The predominating timber growth on the Del Rio Plain is mesquite, while the intervening Buda limestone belts are characterized by a heavy growth of live oak. This belt is crossed on the Fredericksburg Road from 10 to 15 miles from San Antonio.

The Austin Hills: In the central part of Bexar County are some belts of prominent hills trending northeast-southwest. These hills are conspicuous because of a heavy growth of live oak trees thus differing on the one hand from the prevailing mesquite growth of the plains, and on the other from the juniper of the hills of the Balcones Escarpment. These hills mark the outcropping belts of the hard rock or basal phase of the Austin formation, combined in some instances with the Buda and Eagle Ford formations. There are several of these belts of hills representing successive or repeated exposures of

this phase of the formation. When followed to the southwest, these belts of hills are found to terminate, giving place to lower, mesquite-covered land. This limitation in this direction is due to the southwest plunge of the structures, as subsequently explained, by which this phase of the Austin formation is carried below surface level.

One belt of these hills in western Bexar County is seen lying between the Castroville and Culebra roads. To the southwest, this belt of hills narrows and terminates in Medina County. To the northeast, on the other hand, the belt widens and forms the broad belt of hills of the west-central part of the county, entered on the Fredericksburg road about eight miles from San Antonio. A second belt of similar hills, originating near San Pedro Park in San Antonio, passes to the northeast. These hills, which approximately parallel the San Antonio-Austin Road, are crossed by the Perin-Beitel Road from Fratt to Wetmore.

The Taylor-Navarro Plain: The relatively non-resistant strata of the late Cretaceous, including the upper part of the Austin and the Taylor and Navarro formations, form extensive plains. Much of this plain has subsequently become covered with terrace gravel deposits, and in places has been much cut into by stream erosion. However, it may be regarded as a single plain known as the Taylor-Navarro Plain. When not influenced by terrace gravel deposits, the soils on this plain are black and in wet weather very sticky. The predominating timber growth is mesquite. This type of country includes a wide belt passing through the central part of the county. In addition to this main belt there are finger-like extensions of this plain to the northeast, lying between ranges of Austin Hills. One such extension of the plain is followed by the International and Great Northern Railroad from San Antonio. Another notable northeastward extension from the large plain is at the west side of the county on and near the Culebra Road. The plain is here gravel-covered, but is without doubt underlain, as indicated by well records, by the Taylor formation. On the northwest the plain is limited by the foothills of the Balcones Escarpment where exposures are found of the Austin and older formations. To the southeast the plain ex-

tends to the range of Austin Hills already referred to. When followed to the northeast the plain narrows and terminates within a few miles of Helotes Creek. To the southwest, on the other hand, it broadens and in Medina County coalesces with the larger plain beyond the termination of the belt of Austin Hills.

The Midway-Wilcox Hills: The areas underlain by the Tertiary formations in this county are characterized by more sandy soils than those of the Cretaceous areas. The belt of country underlain by the Midway and Wilcox formations includes low hills together with areas of level lands. The predominating timber growth is mesquite. The soils derived from the Midway formation are brown or dark in color, while those from the Wilcox are distinctly sandy and frequently are red in color.

The Carrizo Sand Hills: The surface exposures of the Carrizo formation are characterized by low hills and very sandy soils. The vegetation on the hills is chiefly deciduous oaks. In Bexar County the sand hills of this belt occupy a limited area in the southern part of the county.

Stream Terrace Plains: A prominent feature of the Coastal Plains part of the county is the river flood plains. These stream deposits are of different ages, from Pliocene or early Pleistocene to Recent. They are found likewise at different levels, and many of them have been cut into by erosion. Some of the larger plains are those on which Kelly and Brooks aviation fields are located. These plains are described in connection with the discussion of the Pleistocene geology.

STRATIGRAPHIC GEOLOGY.

The formations exposed at the surface in Bexar County are those of the Mesozoic and Cenozoic eras. The Mesozoic rocks of this county are those of the Lower and Upper Cretaceous (Comanchean and Cretaceous systems), this division of geologic time being well represented. The Cenozoic deposits are those of the Eocene, together with terrace deposits of the Pleistocene. For convenience of reference the formations found in the county are listed in the table which follows. Although not exposed at the surface, pre-Cretaceous formations are reached by deep wells in the northern part of Bexar County.

PRE-CRETACEOUS

Two of the wells of Bexar County of which records have been obtained have passed entirely through the Cretaceous formations and into older deposits. Of these two wells one is located on the Leon Springs Reservation north of the Balcones fault zone, while the other is on the Camp Bullis Reservation a few miles south of the first fault of that zone. Both wells were drilled in an effort to obtain an adequate water supply for the Leon Springs Government reservation, and in each of the wells the rocks lying next below the Cretaceous were found to be schists. In the well north of the Balcones fault zone the schists below the Comanchean formation were entered at about 1015 feet below the surface and were penetrated 1500 feet, or to the total depth below the surface of 2500 feet. Among pebbles from the basal part of the Comanchean in this well, Dr. J. A. Udden, who has studied the cuttings, recognizes pebbles resembling fragments of the Hickory formation of the Central Mineral region; also a few flint pebbles, dark in color and laminated like pebbles from the Bend series. With regard to the schists, he says, "Samples 45 to 49 inclusive (representing cuttings from the schists) are most probably pre-Carboniferous, and in my opinion they are identical with similar material described from below 1100 feet in the boring at Georgetown in Williamson County". (MSS.)

The second well reaching into the pre-Cretaceous, on the Camp Bullis Reservation, is south of the Balcones Escarpment and within the fault zone. In this well the schists were reached at the depth of 1790 feet and were penetrated 115 feet, or to the total depth below the surface of 1905 feet. With regard to the schists of this well, Dr. Udden, who has examined

TABLE OF GEOLOGIC FORMATIONS IN BEXAR COUNTY.

			Formation name	Thickness
Cenozoic	Pleistocene		Flood-plain deposits	100±
	Eocene		Carrizo	?
			Wilcox	600±
			Midway	200±
Mesozoic	Upper Cretaceous		Navarro	450±
			Taylor	450±
			Austin	350
			Eagleford	35
	Comanchean Cretaceous	Washita	Buda	65
			Del Rio	70
			Georgetown	50±
		Fredericksburg	Edwards	450±
			Comanche Peak	?
		Trinity	Glenrose	800±
			Travis Peak	1200±

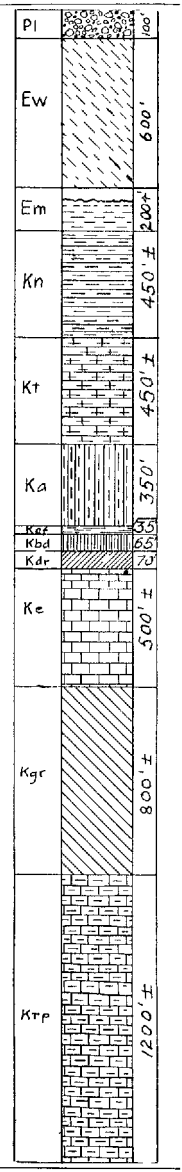

Fig. 3. Table of Geologic formations together with graphic representation of the Columnar section. Ktp, Travis Peak; Kgr, Glenrose; Ke, Edwards including Georgetown; Kdr, Del Rio; Kba, Buda; Kef, Eagleford; Ka, Austin Chalk; Kt. Taylor; Kn, Navarro; Em, Midway; Ew, Wilcox; Pl, Pleistocene.

the samples, states that the formation represented is probably the Packsaddle Schists of the Central Mineral Region. (Mss.) The logs of these two wells are given in the section on well records.

How far to the east from the Balcones Escarpment these schists lie immediately below the Comanchean formations can be determined only by subsequent drilling. The fact that the schists have been found under the Comanchean at Georgetown and at San Antonio indicates that they underlie those formations through a considerable north and south distance along the Balcones fault zone.

MESOZOIC

COMANCHEAN CRETACEOUS

The formations of the Comanchean series in this county are shown in the table on page 20. They are included on the Trinity, Fredericksburg and Washita divisions as there indicated.

TRAVIS PEAK FORMATION

The term Travis Peak formation has been applied by Hill to the lowermost rocks of the Cretaceous of south-central Texas. This formation represents in part at least the Trinity or Basement sands of northern Texas. Although not exposed at the surface, the Travis Peak formation is reached by some of the deep wells in the northern and north-central parts of the county. Records have been obtained of about six wells in the county which pass into or through this formation.

The well of R. Mercke at Bulverde on the Cibolo River at the north line of the county, is reported by Hill and Vaughan* as reaching a depth of 361 feet. The surface exposure at this locality is the Glenrose formation, and on the basis of the log, Hill and Vaughan have regarded this formation as extending to the depth of 137 feet. From 147 feet to the bottom of the well, 361 feet, the formation is identified by them as Travis Peak.

A well drilled on the Leon Springs Reservation in this county in 1909, starting in the Glenrose formation, passed entirely through the Travis Peak formation and into underlying schists. Samples of the cuttings from the well were submitted to the

*18th Ann. Rept., pt. 2, U. S. Geol. Surv., p. 272, 1898.

Bureau of Economic Geology and were examined by Dr. J. A. Udden. A log of the well and supplementary data were sent to the Bureau by Mr. Alexander Deussen. The record from this well, which is of especial importance in determining the thickness of the Glenrose and Travis Peak formations, is given on a later page. From the surface to the depth of 1025 feet, the cuttings from this well are identified by Dr. Udden as Comanchean. Mr. Alexander Deussen has assigned the strata from 535 feet to 1015 feet to the Travis Peak, indicating for the formation a thickness of about 480 feet.

The third well passing into this formation is also a Government well located on the Camp Bullis Reservation, six miles south and one-half mile east of the well on the Leon Springs Reservation. In this well the combined thickness of the Glenrose and Travis Peak formations, including Basement sand, amounts to between 1200 and 1300 feet.

A fourth well believed to enter or pass through the Travis Peak formation was drilled on the Waring Estate near the Bandera Road, seven and one-half miles northwest of San Antonio. Of this well there is preserved the driller's log, but unfortunately no samples of the cuttings. A blue print record of the log of the well has been obtained from the Constructing Quartermaster's office at Fort Sam Houston. The data for the log were preserved and the blue print record made at the time the well was drilled by Mr. F. A. Gartner. In this well the Comanchean formations were entered at 400 feet from the surface. The well was drilled to the depth of 2853 feet, thus penetrating 2453 feet of Comanchean or older sediments. The Ridder well on the Medina River southwest of San Antonio and the Kearney Pipe Line and Oil Company well south of Leon Creek, record of which is subsequently given, probably terminate in the Travis Peak formation.

As indicated by the drillers' logs and more particularly by the cutings from these wells, the Travis Peak formation underlying Bexar County includes layers of limestone alternating with softer layers, chiefly of marly clays. The limestones, as indicated by the well on the Leon Springs Reservation, include both ordinary and dolomitic layers, while the marly clays frequently contain pyrite. A phase of this formation is recorded in the logs as "red mud" or "red clay". The samples of cuttings seem to indicate that the layers so recorded include

rather soft calcareous clays or marls with, in some instances, a calcareous and ferruginous cement, together with fine sands or silts.

As this formation lies unconformably on the pre-Cretaceous, its thickness may be expected to vary exceedingly. Of the structure and rate of dip of the formation, very little can be determined from the scanty records now available. North of the Balcones fault zone it is to be expected that the formation will conform to the Glenrose and have a similar moderate southeast dip. In that part of the county within and east of the Balcones fault zone, it is to be expected that this formation shares in the disturbed conditions common to the other formations of that belt, which are more fully described elsewhere.

GLENROSE FORMATION

The Glenrose formation of the Lower Cretaceous (Comanchean) age, is the oldest of the formations exposed at the surface in this county. This formation includes chiefly alternating layers of moderately hard and soft rocks. The harder ledges are chiefly limestone, as this formation contains almost no flint. Some of the limestone layers are fine-grained and quite hard, although as a rule the limestones of this formation are of but medium hardness. The marl layers of the formation are usually thin, being from a few inches to one or two feet thick, and rather soft. At the surface the marl layers, like the limestone ledges, are usually yellow. When buried within the earth, they may be at times gray or blue. The formation may usually be recognized by the characteristic succession of hard and soft strata, although in places the formation is more heavily bedded. Occasionally also, the heavy limestone ledges are honey-combed and under these conditions resemble the non-flinty ledges of the overlying Edwards formation. The examination of any considerable section, however, will usually afford a basis for separation from the Edwards formation.

The marls of this formation have been used in road-making on some of the roads passing through this area where other materials are not readily available. The calcium sulphate mineral, celestite, is occasionally found filling cavities in this formation,

and has been mined to a limited extent near Austin, in Travis County. The sub-surface layers of the formation produce moderate supplies of water, and many of the wells yielding moderate supplies north of the Balcones fault zone terminate in this formation.

Thickness: The fact that the base of the Glenrose formation is nowhere exposed in this county makes it impossible to measure the thickness of the formation from surface exposures. By combining surface exposures and well records, however, it is possible to determine the thickness of this formation probably within reasonably close limits. Perhaps the most trustworthy measurement of the thickness of the formation in this county is that obtained on the Leon Springs Military Reservation. In the deep well on the reservation, as already noted, the Glenrose is regarded as extending from the surface to a depth of 535 feet. In the hills near the well, the Edwards limestone is provisionally identified as coming into the section at about the 1420 foot level. The ground level at the well is about 1156 feet above sea level. Hence to the 535 feet of this formation penetrated in the well must be added between 265 and 315 feet exposed at the surface, making a total thickness for this formation of about 800 feet. This measurement, however, may include the equivalent of the Walnut clays and the Comanchean Peak limestone; which, however, are of limited development in this county.

Physiographic expression: The alternately hard and soft strata of this formation gave rise in the early literature to the term "alternating beds" as applied to the formation. This succession of hard and soft layers occasions the characteristic terraced appearance already referred to as distinguishing the Glenrose Hills.

Common fossils: Among the fossils found in considerable abundance in the Glenrose, the most frequently met with are the gastropod *Lunatia (Tylostoma) pedernalis* and the bivalve *Cyprina? mediale*. Neither of these, however, is confined to the Glenrose since both are found likewise in the Travis Peak formation.

COMANCHE PEAK FORMATION

The Comanche Peak limestone has not been differentiated as

a formation in this county, and in the mapping and in the measurement of sections it is included either with the Glenrose or with the Edwards. According to Hill and Vaughan this formation is present in the Austin quadrangle to the northeast of this county and likewise in the Uvalde quadrangle to the southwest, where it is a nodular, somewhat massive limestone, containing the oyster *Exogyra texana.* In these quadrangles the formation has a thickness of from 50 to 60 feet. Hence, although not yet differentiated, it is probably present also in Bexar County.

EDWARDS FORMATION

The Edwards formation consists chiefly of limestones. The rock of the formation as developed in this county is usually coarsely crystalline, although in this respect it is variable, some parts of the formation being particularly dense and of fine texture, approaching a lithographic stone in structure. Frequently both on surface exposures and deep within the earth, as indicated by well borings, the formation is profoundly honeycombed and cavernous. These openings in the rock, where exposed in quarrying the limestone, follow more or less the bedding planes and joint planes of the formation. The Edwards formation is especially characterized by a great abundance of flints enclosed within the limestone. These flints are in the form of layers which lie parallel with the bedding planes, or replace for a considerable space the limestone layers of the formation. Some of the flint, however, is in the form of nodules, oval or flattened masses, or so-called "boulders" in the limestone. Upon the disintegration of the limestone, the flints remain on the surface in great profusion. Usually the Edwards limestone may be recognized by the presence of these flint masses both in the rock when seen in place, and in the residue. The soils derived from the flinty phase of the Edwards formation are prevailingly red, and the belt of country occupied is referred to locally as the "red lands." In parts of this formation, however, the flints are less abundant and exposures may frequently be met with in which no flints are observed. In the absence of fossils some difficulty may be experienced in separating such exposures from

the hard phases of the Glenrose on the one hand, and the Buda on the other. If in such exposures the texture is found to be coarsely crystalline, the rock may be quite definitely separated from the Buda, which never presents this appearance in this county. If, on the other hand, the rock is close-grained, dense and of fine texture, the separation from the Buda can perhaps be safely made only on the fauna.

Aside from the flint masses which it contains, the Edwards limestone is for the most part a very pure calcium carbonate. It is also, as previously noted, a very dense, hard, partly crystallized limestone. These characteristics make it valuable for a number of purposes. Several quarries have been opened in this formation in Bexar County for the manufacture of lime. Rock from this formation is taken from a quarry at Beckman for use as rip-rap in Government work on the harbors of the Gulf coast. The hard, dense rock of the Edwards formation, when crushed, should afford material favorable for concrete, although so far as observed no part of the formation is being so used at the present time, owing perhaps to the abundance of concrete material in this county. This rock should be of service also in road-building. Upon partial decay the rock in places assumes a soft, spongy appearance. This form of the rock has been used in road-building on the Bulverde and Blanco roads.

Thickness: A full measure of the thickness of the Edwards formation has not been obtained from surface exposures in this county, but from well records the thickness of the formation is estimated to be between 400 and 500 feet.

Physiographic Expression: The belt of country occupied by the Edwards formation is moderately to distinctly hilly, although in places there are areas of relatively level lands. The native vegetation is chiefly juniper and small oaks, including in places a limited amount of mesquite. The surface materials from the formation, as already noted, contain quantities of flint. The soils, especially those derived from the flinty phases of the formation, are characteristically red in color. The soil supports a good growth of grass and these lands form desirable ranch lands and are used chiefly for this purpose.

Common fossils: Although not always abundant, several of

the fossils of the Edwards formation are very unusual in appearance. This is true in particular of the bizarre mollusks of the genera *Radiolites*, *Monopleura*, and *Requienia*.

Surface exposures and local details: The surface exposures of the Edwards limestone form a belt varying in width, lying immediately south of the Glenrose area and hence at the northern margin of the Balcones fault zone. This belt is widest at the eastern margin of the county and narrows towards the west. Where crossed by the Bulverde Road, in the eastern part of the county, this belt of the Edwards formation, including possibly the Georgetown, has a width of over five miles. On the Blanco Road the belt is somewhat narrowed. At the Fredericksburg and Babcock road-crossing, the belt is further narrowed, and at the Bandera Road crossing has a width not exceeding one-half mile.

At the pit of the San Antonio Lime Company, on the Fredericksburg Road 16 miles from San Antonio, the limestones of the Edwards formation are well stratified, consisting of layers of hard rock varying from a few inches to four or five feet in thickness. Some layers of the rock contain numerous small cavities produced by ground water. Flint layers are present usually lying parallel with the bedding planes, although flint concretions are seen, and occasionally flint deposits are found filling joint planes. The solution cavities also are more or less lined with silica. The limestone rock is heavy and upon close examination is seen to be in places minutely banded.

The right bank of Helotes Creek below the Bandera Road crossing affords a good exposure of this formation. The creek here follows on or near the main fault line separating the Glenrose and the Edwards formations.

GEORGETOWN FORMATION

Lithologically the Georgetown formation if present in this area is very similar to the Edwards, and in the mapping and columnar section these formations are not separated. This treatment of the two formations has seemed the more necessary since in well logs there is almost no opportunity to separate them. An exposure which probably represents the Georgetown is seen on the Bandera Road, 17 miles from San Antonio. The

limestone rock exposed here, lying immediately below the Del Rio clay, is a very hard, close-grained rock, containing little or no flint. In the eastern part of the county a similar rock is seen lying below the Del Rio on the Peter Clausen ranch, 1½ mile north of the Nacogdoches Road. The Georgetown formation in the Colorado River section is reported to have a thickness of from 65 to 70 or 80 feet. In the Uvalde folio the formation is estimated by Vaughan to have possibly a thickness of 40 feet. These two formations, the Edwards and Georgetown, are of special economic importance in this county as the chief large water-bearing formations of the area.

DEL RIO FORMATION

The Del Rio formation consists largely of clays which on surface exposure are usually yellow, but when encountered below the surface are usually blue in color. The clays of this formation contain in places great numbers of fossils, especially of the small oyster *Exogyra arietina*. Occasionally these shells are cemented together by calcareous or ferruginous cement forming indurated layers within the clay beds. The formation contains more or less iron sulphide as pyrite and in well cuttings the amount of pyrite is not infrequently found to be considerable. On the surface exposures gypsum in small quantities is not infrequently observed in the clay.

Thickness: No surface exposure has been found in this county in which the whole thickness of this formation can be measured. In the records of wells, however, the formation is quite uniformly reported as having a thickness of from 50 to 70 feet. Rarely does the reported thickness of the formation fall below or rise above these limits. In Bexar County this formation is quite generally known to the well drillers as the "mud hole" or the "second mud", or the "big mud". These names have originated because of the character and position of the formation. It is known as the "mud hole" because the clay when churned up by the drill becomes mud. The term "second mud" is sometimes applied to it because a formation at a higher level, the Eagleford, frequently contains enough clay to cause cable tools to stick, and hence gives the formation the character of mud. The

origin of the term "big mud" is similar. As the Del Rio formation has a thickness of from 50 to 70 feet while the clayey phase of the Eagleford rarely exceeds 30 to 35 feet, the Del Rio has come come to be known as the "big mud".

Physiographic expression: The Del Rio formation, being chiefly a relatively non-resistant clay lying between relatively resistant limestones (the Georgetown-Edwards series below and the Buda limestone above), is found as a rule on surface exposures to occupy a valley, or the abrupt slope from an upland to the valley. The soils derived from this formation are black or brownish in color. The timber growth is chiefly mesquite, and frequently the Del Rio outcrop when in a valley may be followed by the dense growth of mesquite, differing in this respect from the mixed growth of timber, chiefly oak and juniper, found on the hard phases of the limestone formations.

Common fossils: As already noted, the small oyster, *Exogyra arietina,* is a very characteristic index fossil of this formation, and its stratigraphic equivalents. This fossil is particularly abundant in the lower part of the formation. Near the top the deposits become relatively unfossiliferous. A fossil occasionally found in the upper part of the formation is the oyster, *Gryphea mucronata.* Lithologically, the beds change somewhat towards its upper limit, becoming more calcareous and including in places shelly lime rock. Near the contact with the Buda is seen occasionally a soft, light-colored phase of the formation superficially resembling in a degree the partially disintegrated phases of the Eagleford formation.

Surface exposures and local details: The surface exposures of the Del Rio formation are found throughout a belt of country next south of the exposure of the Georgetown-Edwards formations. The formation being thin, this belt of surface outcropping is relatively narrow, usually not exceeding a half mile. There are, however, some localities where the belt of surface exposures of this formation is widened, owing to minor faulting, which brings the formation successively to the surface. This belt of minor faulting is crossed on the Fredericksburg Road from 10.2 to 13.2 miles from San Antonio, and on the Babcock Road from 12 to 15 miles from San Antonio. Within this belt on the Fred-

ericksburg Road, owing to a combination of faulting and folding together with variations in surface level, the Del Rio formation shows itself in five successive belts as follows: First belt, from 10.2 to 10.3 miles from San Antonio; second belt, from 10.5 to 10.7; third belt, from 11.4 to 11.6; fourth belt, from 11.9 to 12.3; fifth belt, from 12.7 to 13.2 miles. On the Babcock Road, successive belts of this formation come in as follows: First belt, 12.05 to 12.1 miles from San Antonio; second belt, 12.4 to 12.5; third belt, 12.6 to 12.7; fourth belt, 12.8 to 12.85; fifth belt, Valley of Leon Creek probably occupied chiefly by this formation, about 13 to 13.5 miles.

The formations alternating with the Del Rio in these exposures are the underlying Georgetown-Edwards and the overlying Buda, including the Eagleford and a part of the Austin. As already stated, the successive exposures of the formation are due in part to faulting and in part to changes in the surface elevation.

East of the Leon Springs Reservation in this county and also west of the Bandera Road, this formation so far as observed appears as but a single belt with usually but few actual surface exposures. On the Blanco Road the belt is crossed, without any observed exposures immediately on the road, at about 12 miles from San Antonio. On the Bulverde Road, the Buda formation is well exposed at the foot of a north-sloping hill 13.5 miles from San Antonio. Although no exposures of the Del Rio clays are seen on the road, this formation may be expected to occupy the valley at the foot of this hill and to extend to the limestone hills which begin on this road at about 13 miles from San Antonio. To the east of the Bulverde road the Del Rio formation has not been traced in detail, but is to be expected as a relatively narrow belt extending as mapped in a general northeastward direction to the county line at the Cibolo River. Near the county line an exposure is seen at a water-tank on the Clausen Ranch, 1½ miles north of the Nacogdoches Road crossing of the Cibolo River. West of the Bandera Road exposures of this formation continue for two or three miles, beyond which the belt narrows and the formation in places is faulted out of sight.

The Del Rio formation is extensively used in its belt of sur-

face outcropping in the construction of ponds. On the Bandera Road a pond made from this formation is seen near Helotes Creek 17 miles from San Antonio. The clays of the formation are utilized in making a pond on the Clausen ranch, near the east county line, 1½ miles north of the Nacogdoches Road. At these localities the small fossil *Exogyra arietina* is extremely abundant.

BUDA FORMATION

The Buda formation as developed in this county is quite uniformly a close-grained, dense, hard limestone. On surface exposures this rock is usually light-colored, or tinged with gray, yellow, or blue. As seen in well cuttings, the limestone is usually of light color, although a part of the formation frequently shows as a blue rock. Black specks in the limestone is a characteristic frequently referred to by drillers in describing the cuttings from wells. The change in sedimentation from the Del Rio to the Buda and from the Buda to the Eagleford formations appears to have been abrupt, there being little or no gradation between the formations. The hard limstone of the Buda formation lying between the softer rocks of the Del Rio and Eagleford forms a horizon both conspicuous and readily followed on the surface. The Buda limestone in this county is but little utilized at the present time. Its hardness and close texture indicate that as here developed the limestone would be suitable for concrete material.

Thickness: Both in lithologic characteristics and in thickness the Buda formation is perhaps the least variable of the Cretaceous formations as developed in this county. Well records indicate that the Buda limestone is here quite uniformly between 55 and 65 feet thick. Rarely is the formation reported to vary beyond these limits.

Physiographic expression: In its surface exposures the Buda limestone appears as hard, thickly bedded rock. The surface is frequently rough owing to partial dissolution through the agency of surface waters. The soils derived from the formation are dark colored and usually relatively thin, including many rock fragments. When found capping hills the soils from the Buda

formation support a rather heavy growth of timber made up chiefly of oaks. In this respect, the Buda formation resembles the hard rock phases of the Austin formation.

Common fossils: The Buda limestone on surface exposures is usually found to contain fossils, sometimes in considerable number. The shells of invertebrates have, however, for the most part been replaced or filled with a mineral deposit, probably usually calcite. Hence the fossils are seldom easily removed from the matrix, and are with difficulty used in identifying the formation. Thin sections of the rock have shown that in this formation are found numbers of foraminifera.* Lithologically the formation may be in a measure recognized by its uniformly close-grained, dense structure, although similar dense masses of rock are found also at places in the Georgetown and Edwards formations, and less distinctly so in the hard rock phases of the Austin formation. The position of the Buda limestone, lying between the lithologically very different Del Rio and Eagleford formations, assists materially in locating this formation on surface exposures and in well drillings determines its position definitely.

Surface exposures and local details: The Buda formation in Bexar County comes to the surface in a relatively narrow belt having a general northeast-southwest trend. On the Bulverde Road the rocks of this formation are exposed near the base of a north-sloping hill about 13.5 miles from San Antonio. The formation here dips into the hill under the Eagleford and Austin formations, the belt of exposed rock being narrow. So far as observed the rocks of the Buda are not again exposed on this road. To the east of the road the line of outcropping of this formation has not been traced in detail although it is known to continue in a general northeast direction to the county line.

A small anticline in this formation is observed at the Salado Creek crossing of the Blanco Road. Just above this crossing as much as 35 or 40 feet of the Buda formation is exposed in the right bank of the stream. Downstream the Buda disappears beneath the Eagleford and Austin formations within about one-fourth mile below the road crossing. When followed upstream

*U. S. Geol. Surv., 18th. An. Rpt. pt. 2, p. 228, 1898.

the rocks of the Buda formation are found likewise to dip below the stream level, giving place to the Eagleford and Austin formations in the stream banks. However, the Buda reappears in this stream within about three-fourths or one mile further upstream, indicating a relatively limited development of the west slope of the anticline. On the Blanco Road the Buda is exposed at the Salado Creek crossing, and again between eleven and one-half and twelve miles from San Antonio.

On the Fredericksburg and Babcock roads the Buda formation is found to share in the minor faulting which, as already mentioned, brings these thinner formations repeatedly to the surface. On the Fredericksburg Road the Buda formation is first met with lying below the Eagleford formation a short distance beyond the Lockhill-Selma Cross-road, about 10.1 miles from San Antonio. It is last seen on this road at the Bacon Ranch cross-road, 12.7 miles from San Antonio. On the Babcock road the formation appears at intervals from 12 to 12.9 miles from San Antonio. On both of these roads this formation alternates by changes in surface elevation and by faulting with the Del Rio and other formations.

The belt of Buda exposures may be seen at intervals as far west as the Hoffman Ranch, about three miles west of Helotes Creek. Beyond this place the belt of Buda exposures narrows and the formation shows but limited exposures to the Medina County line. The place of the formation below the surface is recorded in well records throughout most of the central part of the county. From its surface exposures the formation dips with variations due to faulting and folding toward the south and southeast. At the northern limits of the city of San Antonio this formation may be expected at from 300 to 350 feet beneath the surface, depending upon variations in surface elevation. At the southern city limits, six miles farther south, owing to steep dips and faults, this formation lies much deeper and is there encountered in well drilling at between 1200 and 1300 feet. A few miles farther south, near the Chavanneux Cross-road, it is found by well drilling to be buried to a depth of 1600 or 1700 feet.

UPPER CRETACEOUS

The Upper Cretaceous series is well represented in the Bexar County section. The formations in order, beginning with the oldest, are: Eagleford, Austin, Taylor and Navarro.

EAGLEFORD FORMATION

The Eagleford formation as developed in Bexar County includes a very characteristic series of calcareous and more or less sandy shales. The rock is granular in appearance, and breaks horizontally into thin slabs, giving a flaggy appearance. With this light-colored flaggy rock are found frequently layers of much harder indurated clay-lime rocks. These interpolated layers frequently have a thickness of from one-half to one foot or more and are probably continuous over considerable areas. The formation is to some extent bituminous and when encountered in drilling is frequently of a dark color. It also contains sufficient clay material in parts of the formation to cause the tools to stick more or less in drilling. For this reason the formation is sometimes known to the drillers as the "first mud" (the Del Rio formation being the "second mud"). To most of the drillers in the central part of Bexar County this formation is known as the "lignite". This name, although scarcely justified by the characteristics of the formation, is firmly fixed in the nomenclature of the drillers of this county. It is not to be confused, however, with the true lignite deposits which are found in much later formations (Tertiary) not represented in the central and northern parts of the county.

Thickness: The Eagleford formation is relatively thin in Bexar County. Practically all well records place the thickness of this formation at from 30 to 35 feet. In a few records this thickness is exceeded slightly, while in others the thickness is recorded as less, the formation being recorded as absent in a few wells. With regard to the reported absence of the formation in wells, it is not impossible that occasionally a well is so located with respect to a fault that this formation is missed in drilling. Such would be the case if the well were located at a place where the Austin formation is faulted against the Buda formation. On

the other hand, the apparent thinness and possibly the supposed absence of the formation may also be due to local induration in the formation so that it is not recognized in drilling. Two exposures have been found in the county in which it is believed that the full thickness of this formation is shown. Both of these exposures are on Salado Creek near the Blanco Road crossing, one below and one above the crossing. In these exposures the base of the formation, resting upon the Buda limestone, is definitely limited. The top of the Eagleford where this formation passes into the Austin formation is much less definitely marked. It appeared to the writer, however, that not more than about 30 or 35 feet of the exposure at these localities can be referred to the Eagleford formation.

Physiographic expression: The exposures of the Eagleford are scarcely extensive enough to develop well marked topographic features. However, as the formation is softer and less resistant than either the Buda below or the lower part of the Austin above, the formation when exposed on relatively level land is usually represented by a slight although more or less well-marked valley. On steep hill slopes the rocks of this formation, though in themselves characteristic by their lithologic characters, do not notably affect the surface features.

Common fossils: Among the characteristic fossils which may be frequently utilized in identifying the Eagleford formation are plant stems and fragments, fish scales and shark's teeth. As developed in Bexar County, the formation is rather more lacking in plant remains than at some other localities. Fish scales and teeth are occasionally present, although rarely abundant. However, the lithologic characters of this formation are so distinctive that little or no difficulty will be experienced in locating the formation on surface exposures. In well drillings likewise the place of the formation is readily recognized by its place between the Austin and the Buda formations.

Surface exposures: As the Eagleford is the thinnest of the formations recognized in Bexar County, the surface exposures are correspondingly limited. The belt of surface exposures of this formation is closely associated with the belt of exposures of the Buda formation already described. On the Bulverde Road

it is found exposed, as already noted, with and just above the Buda formation at about 13.5 miles from San Antonio. On the Blanco Road are found the exposures of the full thickness of this formation on Salado Creek which have previously been mentioned, and also an exposure in the road on the hill beyond the creek. An isolated exposure of this formation is seen also on a small stream on the Lockhill-Selma Road, slightly south of west of the Blanco Road crossing on Salado Creek. On the Fredericksburg and Babcock roads the formation is first crossed at about 10 and 11 miles respectively from San Antonio. In the western part of the county the formation is found in a narrow belt too limited to map except by exaggeration. Exposures may be seen on Canyon Creek on the Hoffman Ranch, within a few miles of the west boundary line of the county.

In its sub-surface position, the Eagleford formation partakes of the general southward dip, passing under the later formations The depth at which it may be expected from the surface may be deduced from the structural contour map accompanying this report, on which the actual level of the top of the Del Rio formation is indicated. The stratigraphic interval from the top of the Del Rio to the base of the Eagleford is about 60 or 65 feet.

AUSTIN FORMATION

The Austin formation includes a thick deposit of limestone, chalk, and marl. The lower beds of the formation are hard limestones. Higher up the formation passes into a more chalky and as a rule softer phase, while near the top the deposits become chalky marls. The formation is stratified and consists in places of alternating harder and softer beds, which on weathering give a banded appearance, in some instances not entirely unlike that of some exposures of the Glenrose formation. On surface exposures the rocks of this formation are prevailingly creamy yellow, while in sub-surface exposures the rock is either blue, white, or yellow.

In drilling, the cuttings from the upper part of this formation, including perhaps one or two hundred feet, as they come to the surface are blue in color and resemble a clay or mud and are in some instances so recorded in the drillers' logs. At lower

levels the formation is white or yellow in color and is usually somewhat harder than near the top. This phase of the formation is often referred to as the "Magnesian" rock, although so far as known, it is a calcium carbonate. Beneath the "magnesian" phase of the formation are the harder limestone layers already referred to, often described in well logs as blue, gray, white, or yellow limestones.

The chalk rock of the Austin formation is used near San Antonio in the manufacture of portland cement. The harder limestones from the lower part of the formation are used for concrete. The formation yeilds moderate supplies of water, although frequently containing more or less hydrogen sulphide gas. The oil of the Alta Vista and Mission fields is from this formation.

Thickness: The thickness of the Austin formation is difficult of exact measurement either on surface exposures or from well records. No locality has been found in the county where the full thickness of the formation can be measured at the surface. On the other hand, in the well logs it is extremely difficult if not impossible to determine the level at which the drill passes from the Taylor to the Austin formation. The most trustworthy measurements of the formation are those obtained from wells known to be located near the contact line on the surface of the Austin and Taylor formations together with data from wells passing entirely through the whole Upper Cretaceous. Of a number of wells so located, the following may be cited as affording the most trustworthy records available. The average obtained from these wells indicates a thickness of between 300 and 400 feet. The Government well at the old target range, now the aviation post, on the Austin Road, 6 miles from San Antonio, is probably located within the belt of Taylor exposures but quite near the Taylor-Austin contact. In the bed of Salado Creek about one mile northeast of the well and at a level approximately 75 feet lower, is an exposure placed by Dr. Stephenson as the probable Taylor-Austin contact. Judging from the surface exposures at the well and from this exposure in the stream bed it is probable that as much as 50 or 75 feet of the deposits at the well are to be referred to the Taylor formation. In this well the base of the Austin was recognized at the depth of 353 feet.

In the log this interval is divided up as follows: "Soil, 2 feet; yellow and blue clay and soft limestone or shale, 218 feet; and chiefly hard limestones, light gray, blue-gray, and white, 133 feet". On the basis of the data given above, it is probable that between 275 and 300 feet of this interval is to be referred to the Austin formation, representing the full thickness of the formation at that place. A well on the Waring estate near the Bandera Road, 7½ miles from San Antonio, is believed to be located within the belt of surface exposures of the Austin formation or with only a thin covering of the Taylor. In this well there is recorded beneath the surface soil and gravel, 145 feet of "blue clay", and 155 feet of yellow, white, and blue limestones, giving a total of 300 feet, all of which with the possible exception of some clays near the surface is to be referred to the Austin formation. A well drilled at Schertz on the Cibolo River is also near the contact line of the Austin-Taylor formations. A short distance upstream from this well are found surface exposures of the Austin formation, while immediately downstream are exposures of the Taylor formation. In this well there are recorded 14 feet of yellow clays, 215 feet of blue clay, and 149 feet of magnesian and other limestones. This would seem to indicate a possible thickness of 378 feet for the Austin. However, upon other data it is suspected that a fault or a very steep dip passes immediately north of this well; that is between the well and the exposures of the Austin formation. If this is true, only a part of the 229 feet of yellow and blue "clays" of this record is to be referred to the Austin formation. A well at the residence of A. E. Goforth on the Culebra Road, 18 miles northwest of San Antonio, appears to be located near the contact line of the Austin-Taylor formations. In this well the base of the Austin was recognized at the depth of 349 feet, all of which apparently, aside from the surface materials, is to be referred to the Austin formation.

From these records it appears that the Austin formation in Bexar County in its belt of surface exposures, approximates 300 feet in thickness. From the record of a considerable number of wells drilled south of the belt of surface exposures it appears probable that the formation thickens toward the south. Among

the wells which indicate a thickening of the limestones southward are the following: City water supply wells on Market Street in San Antoino, hard rock above the base of the Austin about 380 feet; City water supply well near Conception Mission in south San Antonio, magnesian and other limestones, 417 feet, with blue clays above; Hoffheintz well, southwest city limits, magnesian and other limestones, exclusive of overlying blue clay, 310 feet; Hill and Roby well, 7 miles south of San Antonio, magnesian and other limestones, exclusive of overlying clay, 480 feet. In the Benke well on the Culebra Road near the west county line, limestone above the Eagleford are reported through an interval of 485 feet, which if referable in full to the Austin, represents the maximum recorded thickness of the formation in the county. With due allowance for the indefinite record afforded by the well logs, it appears that the harder limestones of this formation vary in thickness. In the columnar section the thickness of 350 feet is assigned to the formation, which is probably an average, being neither the maximum nor the minimum thickness in the county.

Physiographic expression: The Austin formation appears on surface exposures under two different phases corresponding to the hard and soft rocks of the formation. The limestones of the lower part of the formation, when exposed, usually make up ranges of hills having a northeast-southwest trend. On these hills the soils are thin and contain considerable rock debris. The timber growth includes a preponderance of oaks with relatively little mesquite. This phase of the formation where exposed usually forms a conspicuous feature of the landscape and the belt of the hills may often be seen and its trend across the county mapped, at a distance of some miles. The softer rocks of the upper part of the Austin formation, however, present on surface exposures entirely different topographic features. The country underlying the exposures of this part of the formation is usually gently rolling with rounded hills and gentle slopes. The native timber is largely mesquite. The soils are black and at the present time the lands are largely cleared for agricultural purposes. This physiographic development corresponds to the upper 150 or 200 feet of the formation as now delimited.

Common fossils: The Austin formation is highly fossiliferous and a large number of species of marine invertebrates is included in the fauna. Among conspicuously abundant fossils of the lower limestones of the formation are the oysters, *Gryphea aucella* and *Exogyra laeviuscula.* These fossils are particularlly abundant in certain layers of the limestones of the Austin formation. One of the best exposures showing these fossils is found in the rock quarry near the north side of San Pedro Park where the fossil horizon includes a ledge of rock from one to two feet thick, lying five or six feet above the base of the exposure. A similar fossiliferous ledge appears in the Ling Quarry at the west side of San Antonio River at the north city limits, lying near the base of the exposure. From a well drilled nearby, it is known that the base of the Austin formation at this place lies about 100 feet below the bed of the river, hence unless affected by concealed faulting the horizon of these fossils at this place is between 100 and 125 feet above the base of the formation. A notable exposure of a similar fossiliferous bed of the Austin formation is seen in the bluffs on Leon Creek near the Bandera Road crossing.

The upper beds of the formation contain considerable numbers of the large oyster, *Exogyra ponderosa,** found also in the Taylor formation. This oyster is believed not to extend its range below the softer beds of the upper part of the formation, being apparently absent from the hard limestones of the lower beds. This fossil is found in the upper part of the formation at many localities. At the Bandera Road crossing on Leon Creek, the species seems to extend its range downward to the top of the hard limestones of the formation and to within a few feet of the level of the Gryphea bed.

Surface exposures and local details: Surface exposures of the Austin formation are found throughout a broad belt having a northeast-southwest trend across this county. The Austin belt is somewhat interrupted in part by surface erosion and in part by terrace deposits, but more especially by faulting and folding

*The Exogyra of the Austin formation, according to Böse is specifically distinct from **E. ponderosa** of the Taylor formation. Univ. Texas Bull., No. 1902, 1919.

by which other formations are interpolated into the belt of country otherwise occupied chiefly by this formation. On the line across the Austin formation in the eastern part of the county marked by the Bulverde and Perrin-Beitel roads, there are two distinct belts of Austin. The northern belt of Austin exposures is crossed on the Bulverde Road from 1½ miles north of Wetmore to Wetmore; the southern belt is crossed on the Perin-Beitel Road from about 1½ miles south of Wetmore to Fratt station on the Austin Road.

On the Blanco Road extending due north from San Antonio, are likewise found two belts of the Austin formation. On this road, however, the northern belt is found to be much wider than on the Bulverde Road, having a width of about five miles. The southern belt on the other hand is much narrowed, having a width probably of scarcely more than a mile. This southern belt, as indicated in the mapping, passes below the surface within the city of San Antonio, giving place to the Taylor formation. The broad belt of surface exposures of the Austin formation is crossed on the Culebra Road from Leon Creek to about 18½ miles from San Antonio. From surface exposures it is known that the Taylor formation lies on this road both at the southeastern and at the southwestern boundaries of the Austin exposures. The evidence relating to structure of these formations is more fully presented subsequently. The high lands of the central part of this belt present surface exposures that on lithologic characters must be placed as well down in the Austin formation. The Potranca Road which branches off from the Culebra Road at the Leon Creek crossing, and runs slightly south of west, affords for some miles exposures which are probably near the top of the Austin, many of them containing an abundance of *Exogyra ponderosa*. However, from about Medio Creek to the county line, this road in places affords exposures including the Gryphea zone that are to be referred to the lower half of the Austin formation.

In its sub-surface position, this formation presents the characteristics of the other formations of this part of the state. In general the dip is to the south or southeast. The southernmost well in this county in which the formation has been definitely

recognized, is that on the J. K. Lamb property 16 miles south and 2½ miles east of San Antonio. At this place the top of the formation lies approximately 1600 feet below the surface. To the southeast the formation lies somewhat deeper. From the log of the Bradley and Winters well at Saspamco it appears that the formation at the county line on the Goliad Road altho not reached must lie at least 2500 feet from the surface.

The rock bluffs and cliffs at the west side of Brackenridge Park in San Antonio are composed of this formation and afford good exposures of the heavy limestones. The Ling rock quarry just across the city limits at the north side of the park, is opened up also in the Austin formation. In a well drilled at the north city limits in Brackenridge Park, in 1918, a log of which is given elsewhere, the Eagleford shales were recognized at the depth of 101 feet. It is thus seen that the exposures in Brackenridge Park and in the rock quarry north of the park lie within the lower part of the Austin and represent the formation from about 100 to 140 or 150 feet above its base. The rock as seen at these exposures is light-colored or tinged with yellow; it is evenly bedded, consisting of layers from six inches to several feet in thickness. Pyrite nodules originally on the limestone have become oxidized and are represented by spots or nodules of rusty-colored iron oxide. Near the base of the section at the quarry is a layer in which a small Gryphea is very abundant. At the west limits of Alamo Heights, overlooking the valley of Olmos Creek, there is a bluff into which a quarry has formerly been opened, representing a phase of the Austin formation similar to that seen in Brackenridge Park. The Gryphea layer at this exposure lies 45 feet or more above the stream bed, indicating that the section here affords an exposure lying a little lower in the formation than the exposures at Brackenridge Park. Immediately west of the West Texas Military Academy, a little more than a mile north of the north city limits of San Antonio, is another west-facing bluff, exposing a similar section of the Austin formation. The exposures of this formation at the cement plant two miles north of the city limits are described elsewhere. At San Pedro Park are seen exposures of the hard limestones of the Austin formation from which springs emerge. The exposures

here described lie within and represent an upthrust block of the Austin formation which forms the range of Austin Hills indicated on the sketch map (Fig. 2). The southernmost exposure seen of this belt of Austin is found near the intersection of Zalzamora and Ruiz streets in west San Antonio, where a much later phase of the formation is seen, consisting of soft marly rock. To the northeast, exposures of this belt of the Austin formation may be seen to the county line at the Austin Road crossing on the Cibolo River. Particularly good exposures are seen at the crossing of the Austin Road on Salado Creek, and at the Perin-Beitel Road crossing of a tributary entering from the east. On these exposures Baker has made the following notes:

> When fresh the chalk has a light bluish-gray color while on weathered exposures it is light yellowish-buff, passing upward, upon weathering, to a brown substance resembling marl. It is much jointed in very irregular fashion and breaks often with a semi-conchoidal fracture. Nodules of pyrite are present which weather to limonite. Some beds of the rock are slightly more indurated than others and so stand out more prominently on exposed surfaces. This rock forms the bed rock at Fratt. Near the mouth of the small creek tributary to Salado Creek and heading northeast of Fratt, the dip (probably not true dip) is 1° S 65° E. About one-fourth mile downstream and about 200 yards above the junction with Salado Creek, the dip (perhaps not maximum) is 4° to the south.

In the soft chalk rock of the Austin formation at the crossing of the Perrin-Beitel Road near Fratt, Stephenson has noted the presence of the following fossils (Mss. notes): *Scaphites* sp., *Placenticeras* sp., and a large *Baculites.* In the more indurated rocks of this formation about one mile farther west, he notes the presence of the following fossils: *Exogyra laeviuscula, Avicula?, Pecten* sp., *Liopsitha elegantula* (Roemer) ?, *Barbatia* sp.

Exposures in the large belt of the Austin formation passing through the county north of San Antonio are too numerous to receive separate description. This belt of the Austin is crossed by all roads running north and northwest from San Antonio. At the Leon Creek crossing on the Bandera Road are seen good bluffs exposing the hard limestones of the formation including in some layers an abundance of fossils. Other good bluffs are seen

at the first and second crossings of the Culebra Creek on the Culebra Road. At the Salado Creek crossing of the Bulverde Road, the bluffs seen at the right are a part of the limestones of the Austin formation and represent the west margin of the block originating in San Antonio.

TAYLOR FORMATION

The Taylor formation includes chiefly marls and calcareous clays. In surface exposures and to the depth affected by weathering, the clays are yellow, although where unaffected by weathering they are for the most part blue in color.

As a water-bearing formation, the Taylor is of but slight importance as the marls and clays are too close in texture to carry large quantities of water. The bentonite deposits of this county probably lie within the Taylor formation. The fuller's earth deposits are either near the top of this formation or in the next later formation, the Navarro. The gas of the Gas Ridge field is probably from this formation, while the oil of the Somerset field appears to be either from this or from the Navarro formation, or possibly in part from the Midway.

Thickness: A measurement of the thickness of the Taylor formation is extremely difficult. No surface exposures found in Bexar County are adapted to that purpose while in well records, it is difficult to determine from logs or from cuttings, the depth at which the formation is either entered or passed through. In the Terrell well six miles south of San Antonio there was assigned to this formation by Hill and Vaughan* a thickness of about 400 feet. In the Alta Vista oil Fields the combined thickness of the Navarro and Taylor formations, if present, apparently does not exceed six or seven hundred feet, although here a part of the Navarro may have been removed by erosion.** In the Kearney test well for oil south of Leon Creek, the combined thickness of the Navarro and Taylor formations may be as much as 900 feet. In the columnar section, this formation has been

*Hill, R. T. and Vaughan, T. W., 18th Ann. Rept. U. S. Geol. Surv., Part II.

**Record of Elder-Wolf well.

assigned a thickness of 450 feet which may be regarded as an average thickness where the formation is fully developed.

In the Mathey well of the Bexar Petroleum Company the Tertiary as noted subsequently under the discussion of the thickness of the Midway formation, appears to extend to the depth of between 1340 and 1402 feet, while the Austin formation according to the driller was entered at 1892 feet and continued to the bottom of the well 2025 feet. If this is true there remains for the Taylor and Navarro formations at this place a combined thickness of not more than 552 feet. The reduced thickness of these formations may of course be accounted for by possible erosion from the top since the Tertiary-Cretaceous contact is very probably an erosion unconformity. Samples of cuttings from this well from 1938 feet and below submitted by the driller and examined by Dr. J. A. Udden apparently represent the Austin formation.

Physiographic expression: Much of the area underlain by the Taylor formation in this county consists of a level plain often gravel covered by terrace deposits. When subjected to stream erosion, the hills formed from the Taylor marls are rounded, with moderate slopes. The soils derived from this formation are black and in wet weather very sticky. The prevailing timber growth is mesquite.

Common fossils: The lower part of the Taylor formation contains an abundance of the large oyster, *Exogyra ponderosa,* which is also present as already noted in the upper part of the Austin formation. The Taylor formation may be separated from the Austin probably within approximate limits upon lithologic characters, particularly by the presence of an increased clay ingredient. From the overlying Navarro formation it may be separated probably also within approximate limits.

Glauconite is usually more or less abundant in the Navarro, while it is present in much smaller quantities, if at all, in the Taylor.

The following notes on the Taylor formation have been made by Stephenson (manuscript notes):—

Taylor marl, consisting of weathered greenish-gray, calcareous clay, is poorly exposed in the west-facing slope of Salado Creek at

the crossing of the Seguin Road about four miles north by east of the post-office building at San Antonio. The thickness exposed is about 10 feet. It is overlain by a Pleistocene gravel bed and the latter is overlain by sandy loam. The Pleistocene is 15 or 20 feet thick.

On the east-facing slope of Salado Creek Valley about one mile above the crossing of the Missouri, Kansas and Texas Railroad, the following section is exposed along a private roadway or trail:

Section

Feet

Pleistocene:

3. Yellow sandy clay loam with lines of pebbles at irregular intervals 15
2. Bed of gravel with chiefly flint pebbles and cobbles 8

(Unconformity)

Cretaceous (Taylor):

1. Gray calcareous clay or shale with a few poorly preserved fossils..... 6

From the Taylor (layer No. 1) obtained the following fossils (Collection No. 182):

Hamulus onyx Morton
Ostrea plumosa Morton
Anomia argentaria Morton
Paranomia sp.
Pecten sp. (small)
Liopistha (Cymella) bella (Conrad)?

Bluff on Salado Creek, left bank, 3½ miles due east of Alamo Heights, Bexar County, Texas.

Section

Feet

Pleistocene:

Irregularly bedded loam and calcareous sand and gravel. The sand and gravel are extremely calcareous in places, consisting chiefly of a spongy mass of lime. In places the chief matrix of the gravel is spongy lime. Frequently pebbles are noticed with concentric layers of lime about them 20

(Unconformity)

Cretaceous (Taylor):

Gray (greenish gray to yellow where weathered) calcareous shaly clay carrying a

few poorly preserved fossils. The shale contains occasional seams of gypsum....25

The fossils collected include:

Lima (young individual)
Pecten (small)

Two feet of relatively soft bluish-gray chalk is exposed in the bed of Salado Creek, about a half mile above the preceding. The following poorly preserved fossils were obtained (Collection No. 184):

Inoceramus sp.
Ostrea plumosa Morton
Placenticeras sp.
Crustacean (fragment)

This locality is one mile below the crossing of the Austin Road. The rock is probably at the extreme top of the Austin chalk.

Surface exposures and local details: Surface exposures of the Taylor formation are found in successive belts which extend in a general northeast to southwest direction across the county. Owing to structural features subsequently to be described, the belts of exposures of the Taylor formation in part surround Austin exposures. The northernmost belt of Taylor is that which lies on the north side of the Austin exposures on the Culebra Road. The Taylor in this belt extends north to within a mile or less of the Balcones escarpment. Exposures representing this formation may be seen on the property of H. Wehmeyer, H. Mossman, and R. Brown, north of the Culebra Road. Exposures may be seen also farther east on the Hoffman Road on the property of R. Brown and G. Wehmeyer, where the clays are utilized in making ponds. At many of these exposures, particularly those on the Brown and Wehmeyer properties, the fossil *Exogyra ponderosa* is abundant. This belt of Taylor apparently terminates somewhat east of the Hoffman Road at the north turn north of the Steubing cross-road.

A large area of Taylor exposures lies south of the main Austin exposures. At the west county line these exposures are found north of the Castroville Road, and extending northeast, lying somewhat south of, and approximately paralleling the Potranca Road to the Leon Creek crossing. East of Leon Creek the Taylor is seen on the Culebra Road at a cut in the road 8 miles from

San Antonio. At about this place, the Taylor belt is divided by a southward projecting nose of Austin exposures. On the Fredericksburg Road, marls containing *Exogyra ponderosa* are seen from 9.3 to 9.7 miles from San Antonio.

In the city of San Antonio, the Taylor exposures are again divided by a southward projecting nose of the Austin formation. The western area of Taylor marl is interpreted as crossing the Bandera and Fredericksburg roads at from 2.6 to 6.6 and from 2.5 to 5.4 respectively miles from San Antonio. This Taylor belt may be expected to narrow farther to the east, and probably does not extend as far as the east county line. The oyster, *Exogyra ponderosa*, is found in clays resembling the Taylor on the slope to the alluvial plain of the Cibolo on the Nacogdoches road about 15 miles from San Antonio.

In the western part of San Antonio are seen several exposures which are referred more or less definitely to the Taylor formation. One of these is seen in the cut on the Fredericksburg road at the crossing of a small stream about two miles from the Courthouse. Another is seen at the Culebra Road crossing of the same stream a little farther south. In neither of these exposures are fossils found and the reference to the Taylor formation is on the lithology. A similar exposure of yellow clay is seen on the same creek still further south, at the crossing of the old Castroville Road near its union with Zalzamora Street.

The southernmost belt of Taylor exposures in this county is that which extends from San Anotnio northeastward to the county line. Exposures of the Taylor of this area may be seen at a cut in the public road on River Avenue, at the north city limits, and again on the Austin road opposite the Aviation Post about 6 miles from San Antonio. At neither of these exposures so far as observed are fossils found and the identification is chiefly on lithologic characters. The belt of the Taylor marls is here narrow as the Austin formation is exposed a short distance to the north, while fossils indicating the Navarro are found not far to the south of these localities. To the east of Salado Creek the Taylor formation lies south of and approximately parallel to the Austin road, to the county line.

NAVARRO FORMATION

The Navarro formation includes chiefly deposits of clay and marl although in parts of the formation, particularly toward the upper limits, there are layers of well indurated lime rocks and in places limestone ledges. Lithologically the formation on surface exposures resembles the Taylor. In the Navarro, however, is found considerable glauconite which is frequently in such abundance as to give a greenish tinge to the clays and shales of the formation. Within the formation, probably in its upper part, is a green glauconitic sandstone, often met with in drilling and usually recorded in the well logs as "green marl". At the surface exposures on Leon Creek, this stratum has a thickness of from 12 to 15 feet

The water supply in the Navarro, as in the Taylor, is very limited, the marls and clays containing but little water. The greensands of the formation contain a limited amount of potash and phosphate, which at the present time is not utilized. The oil of the Somerset field, as already stated, is obtained either from this formation or from near the top of the Taylor formation.

Thickness: The thickness of the Navarro formation is difficult to determine, since in well logs and cuttings the transition from this formation to the underlying Taylor is not sufficiently well marked to be easily recognized. In a well on the property of J. K. Lamb, south of the Medina River, samples from which were examined by Dr. J. A. Udden; a thickness of about 1000 feet was provisionally assigned to these two formations. On the Ritter property on Medina River near the Frio road, the stratigraphic interval between the top of the Del Rio formation and the uppermost green sands assumed to lie near the top of the Navarro formation, is apparently between 1250 and 1300 feet. Assigning approximately 400 feet as the combined thickness of the Austin, Eagleford and Buda formations, there is an indicated thickness for the Taylor and Navarro formations of 850 or 900 feet at that place. Approximately the same thickness is indicated by the Kearney well and well of the Superior Oil Company. On the basis of this somewhat indefinite data, the thickness of the formation is given in the columnar section at

about 450 feet. However, it is necessary to consider in these measurements the apparently great thickness of the Tertiary in the Mathey well and the correspondingly reduced thickness of the Navarro-Taylor. (p. 45.)

Physiographic expression: The belt of country underlain by the Navarro formation presents surface features not unlike those of the Taylor marl. The slopes of the hills developed from this formation are possibly somewhat more abrupt than are those from the Taylor formation, due probably to the presence of the indurated limy layers of the Navarro formation. The soils are black and the prevailing timber growth is mesquite.

Common fossils: The Navarro formation contains rather more fossils than does the Taylor formation. The large oyster, *Exogyra costata,* is abundant in this formation. Two other oysters, *Gryphea vesicularis* and *Alectryonia larva,* are listed by Hill and Vaughan* as common in this formation.

Surface exposures and local details: The Navarro formation has been recognized at surface exposures in a belt of country passing across the county from northeast to southwest immediately south of the southernmost belt of Taylor marl. In the western part of the county, this formation is seen exposed on the Castroville Road, at the crossing of a small creek about 1½ miles from the county line and again at the top of the hill about 2 miles from the county line. The fossil, *Exogyra costata,* is very abundant at each of these exposures. Another exposure probably to be referred to the Navarro is found near and stratigraphically above the fuller's earth beds north of the Castroville Road 17¼ miles from San Antonio. About one mile south of the Castroville Road, on the Cagnon cross road 14 miles from San Antonio, is an exposure on the hill slope containing many shells of *E. costata.* At the north side of the Castroville Road, 9 miles from San Antonio, is seen an exposure made by an excavation for a pond. The yellow clay of this exposure contains *E. costata.* On the Culebra Road five miles from San Antonio is an exposure which is to be referred either to this formation or to the Taylor marl, containing an abundance of *E. costata.* On the Austin Road opposite the Country Club

*Austin Quadrangle, page 5, 1902.

grounds at the north limit of the city of San Antonio is an exposure containing many *E. costata* which is probably to be referred to this formation. An exposure of the Navarro is seen in the cut made by the Camp Travis switch north of the Seguin Road near the east city limits of San Antonio.

A series of good exposures of the Navarro formation is seen on Leon Creek from the Castroville to the Pearsall Road crossings. About one-eighth mile below the Castroville Road crossing on the right bank of the stream is a bluff exposing clays and limestone ledges of the Navarro formation. The clays on surface exposure are dun-colored. A well dug nearby, however, shows that the unweathered clays are blue. The harder ledges in this exposure are frequently concretionary. The dip as observed at this exposure, in the direction about due northwest, is about 7 degrees. About 30 or 35 feet of the formation is seen at this exposure, overlaid by terrace gravel deposits. At the north side of the Castroville Road in the right bank of a small tributary entering Leon Creek from the southwest, about one-eighth mile from Leon Creek, exposures are seen of a glauconitic sandstone horizon. The glauconitic sandstone at this exposure dips rapidly to the northwest.

In the right bank of Leon Creek south of Kelly Field, from three-fourths to one mile above the Pearsall Road crossing, is a bluff of the Navarro formation. The exposure here includes 70 or 80 feet of calcareous clays which are yellow on exposure. The bedding planes here are obscure, but the dip in the strata is apparently to the northwest. On the left bank of the stream in Kelly Field, an excavation made for a sewage disposal tank exposes thin-bedded clays, blue in color or partially oxidized yellow. The dip as seen in this pit in the direction 30 degrees west of south, amounts to about 7 degrees. Overlying the clays at this exposure are the gravel terrace deposits. This exposure is interpreted as lying lower in the Navarro formation than the exposure seen at the Castroville Road crossing, the dip being as noted to the southwest. About one and a half miles upstream from this exposure is a

bluff on the right side of the stream. The following section is seen near the middle of this bluff:—

	Feet
Heavy gravel deposits at the top of the bluff	16
Calcareous clays weathering yellow	30
Glauconitic sands, harder ledges at top and base	12
Dark-colored clays	30
Light marly white clays	12

The dip at this exposure is to the west or southwest, amounting in places to as much as 4 degrees. Near the south end of the bluff, the glauconitic sandstone layer lies within about 15 or 18 feet of the top of the bluff, or directly under the gravel deposits. Near the north end, this horizon falls as low as about the middle of the exposure.

In the bluffs between the Pearsall and Quintana Road crossings are seen similar exposures of the Navarro formation. In these exposures, however, the dip is in the opposite direction, or to the east or northeast. In this bluff, the glauconitic sandstone comes into the section near the north end of the bluff, where it lies from 90 to 100 feet above the stream. It drops rapidly and passes below water-level somewhat near the International and Great Northern Railway crossing close to the Quintana public road crossing. Baker has made the following notes on this exposure:

At the south end of the International and Great Northern Railway bridge over Leon Creek is a blue-gray unctuous clay weathering yellow-brown, containing fossils and very small streaks of sand. At the south end of the Southern Pacific Railway bridge, just to the west, glauconitic sand containing small quartz pebbles is interbedded with sandy blue-gray clay. The dark green glauconitic sand containing small pebbles and fossils, notably sharks' teeth, begins at the railroad bridges and extends up Leon Creek for about a mile. It dips 15° to the south. It probably represents the Navarro formation. It is underlain by light gray limonite-stained sandy clay. These clays contain large gray sandstone concretions, some of which are very well indurated. The clays weather tawny (yellowish-brown). The clays pass downward into fine-grained, thin-bedded, ripple-marked, light gray sandstone. A layer con-

taining many black sharks' teeth lies in the clay just above the sandstone. The thin sandstones are interbedded with the clays and the dip still continues. Lower down the clays are darker in color (greenish or olive) and are more argillaceous and unctuous. The dip flattens out northward.

The structure revealed by these exposures is interpreted as a broad asymetrical anticline or tilted block, near the west side of which the gas wells west of Leon Creek are located. This structure, continued to the northeast, forms the Austin Hills elsewhere described.

CRETACEOUS-TERTIARY CONTACT

The contact line between the Cretaceous and the Tertiary as placed on the map is at best approximate in location, the surface being much obscured by Pleistocene gravels. At the west margin of the county the Tertiary apparently extends as indicated by sandy hills and occasional limestone concretions, to the slight bluff overlooking the valley of the Medina River. On Leon Creek, the Navarro formation is observed to extend south as far as, or somewhat across, the International and Great Northern Railway. At the Pearsall Road crossing on the Medina River, however, the glauconitic sands which are provisionally placed as near the top of the Navarro formation, are encountered in drilling at from 100 to 200 feet below the surface. Accordingly, the eastern margin of the Cretaceous in this area between the Medina and Leon Creek in which the surface is terrace-covered, is provisionally mapped as approximately paralleling the Galveston, Houston and San Antonio Railway. Between Leon Creek and the San Antonio River the contact is obscured by the Pleistocene gravels. Between the San Antonio River and Salado Creek the Tertiary represented by the Midway formation extends north, reaching across the southeast corner of the city limits of San Antonio. Between Salado and Rosillo Creeks the contact is again concealed by the flood plain. On Rosillo Creek the Tertiary extends as far north at least as the St. Hedwig Public Road crossing and the Galveston, Houston and San Antonio Railway crossing, but probably does not extend much farther upstream. From

here to the east line of the county, owing to limited exposures, the contact is mapped approximately from the soil characteristics, those of the Tertiary being more sandy than the soils derived from the late Cretaceous formations.

CENOZOIC

EOCENE

The Eocene formations recognized in this county are the Midway, Wilcox, and Carrizo, and possibly outliers of the Mount Selman formation.

MIDWAY

The Midway formation of this county includes chiefly arenaceous clays in which are imbedded many concretions of sandy or limy rocks. The concretions are of various sizes from small concretions weighing only a few pounds, to those of large size, making up masses of rock of several tons weight.

Thickness: The most reliable measurement of the thickness of the Midway formation obtained is that from the Mathey well drilled in 1919 near Losoya. The following data on this well have been kindly supplied by Messrs. H. L. Hamilton and W. L. Walker.

STRATIGRAPHIC DATA FORM MATHEY WELL
LOSOYA, TEXAS

	Horizon.
Lignite cuttings at 367, 560 and 590 feet	Wilcox.
First fossils recovered, from cuttings, at 665-670 feet were:	
*Volutilithes limopsis Conrad	Midway.
Olivella mediavia	Midway.
Fossils found in core sample from 927 to 928 feet:	
Linthia alabamensis Clark	Midway.
Pecten alabamensis	Midway.
Fossil from cuttings, 1070-1090 feet:	
Cerithium mediaviae	Midway.
Fossils from cuttings at 1110, 1135, 1170, 1195, 1270 and 1340 feet all were characteristic Midway forms except a few that carry through to Cretaceous.	
Fossils from a core sample 1402-1406 feet, were the first to definitely establish the Cretaceous:	
Ammonite	Cretaceous.
Cuspidaria	Cretaceous.

*All fossil identifications were checked by Dr. J. P. Smith.

The top of the Midway horizon is somewhere between 590 and 665 feet deep. The bottom is between 1340 and 1402 feet. While there is no lithological suggestion of lower contact, it would appear that the upper contact lies close to the 600-foot level.

From these determinations it appears that the Midway at this place has a thickness of between 675 and 810 feet, and that the Midway and Wilcox have a combined thickness of between 1340 and 1402 feet. The record of a second well showing a great thickness of the Tertiary, the Sarah Smith No. 1 of W. C. Steubing, the data for which has been supplied by the United States Geological Survey, is given in the chapter on well records.

Physiographic expression: The belt of country occupied by the Midway formation is for the most part moderately hilly, the hills having as a rule a southward slope which possibly in many instances approximates a dip slope. The soils derived from the formation are dark or brown in color and are more sandy than are the soils of the Cretaceous although less sandy than the soils of the Wilcox formation. The prevailing timber grown on the Midway hills is mesquite.

Common fossils: Marine fossils are found in the Midway although rarely abundant. Of the mollusks the genus *Venericardia* is the most abundantly represented.

Surface exposures and local details: The Midway formation is well exposed in the cut made by the Missouri, Kansas and Texas Railway in the southeastern part of San Antonio. On fresh exposures the clays of the Midway at this cut are massive, much jointed and of medium hardness. On exposure they crumble to very small particles. The clays include numerous oval or flattened small concretions, frequently hollow, or containing hematite or other minerals. *Venericardia* was obtained from this section by Stephenson. (Mss. Notes).

The following notes have been made by Mr. Baker, who first examined this exposure and recognized it as of the Midway formation:

The Midway clays beneath the Uvalde in the new "Katy" cut through the hill in the eastern part of San Antonio are not appreciably sandy but are more weathered than in the lower-lying exposures of lower horizons. This weathering was to some extent

at least accomplished in pre-Uvalde times. The clays are irregularly mottled yellowish-brown and light olive green with thin films of dendritic manganese oxide on joint planes, and an occasional small white nodule or concretion of $CaCO_3$. The clays are much jointed.

Among other exposures of the Midway noted by Baker are the following:

Greenish drab unctuous clay, weathering yellow-brown with a few red limonite sandy concretions and carrying **Venericardia planicosta** and a few other fossils as casts, is found in the gully east of ridge just below the junction of Salado and Rosilla creeks. In this gully are seen also the large yellow brown concretions, some of them with cone-in-cone structure.

The Midway apparently carries marine fossils to its very top. Thus the highest beds a mile above the mouth of Comanche Creek (south of Alta Vista oil field) carrying the unctuous clay casts of **Venericardia alticostata** and other fossils. As usual the Midway here carries the brown limestone concretions.

In the Alta Vista oil field very large concretions are exposed at the surface which with little doubt are Tertiary and probably of the Midway formation. At the crossing of the Galveston, Houston and San Antonio Railway on Rosilla Creek, east of San Antonio, exposures of the Midway clays are seen both in the stream bed and in the railway cut. In the dump from dug wells near this crossing were seen the massive clays of this formation, including numerous small concretions identical with those of the Midway at the Missouri, Kansas and Texas Railyaw cut in San Antonio.

On the Medina River exposures recognized as Midway are found as far downstream as the Palo Alto Road crossing. The following section at this crossing is from notes made by Stephenson:—

Section in ravine near north end of bridge over Medina River, Palo Alto road:

	Feet
Terrace deposit:	
1. Yellowish sandy loam	18
2. Bed of coarse gravel	2
Eocene (Midway):	

3. Hard, gray, earthy sandstone streaked with reddish limonitic iron ore. Shows faint cone-in-cone structure in the more earthy streaks 1
4. Dark gray, finely sandy, shaly clay..... 18
5. Ferruginous layer of fine earthy concretionary sandstone with some concretionary masses of hard limestone in center. Faint cone-in-cone structure noted in the more earthy portions. A few faint fossil impressions. Probably same as layer at bottom of bluff below Garza crossing 1-2
6. Dark gray, finely sandy, shaly clay..... 2
7. Concealed to water ..... 15±

The lowest layer in the preceding section dips down to water-level within about 200 yards below the bridge.

WILCOX FORMATION

The Wilcox formation is well developed in this county and includes thinly laminated sands, sandstones, sand and limestone concretions, clays and lignites. The presence of sea shells indicates the marine origin of parts of the formation, while the lignite and land plants preserved in some of the shale indicate the lacustrine or near-shore origin of parts of the formation.

Thickness: No data is at hand at present by which to approximately determine the thickness of this formation in Bexar County. A well drilled near the south county line at Saspamco starting at or near the top of the Wilcox, extended to a depth of 2500 feet. This well with little doubt passes through both the Wilcox and Midway and into the Cretaceous, but it is not possible from the log to determine the limitations of the several formations. A well drilled on the J. K. Lamb property in the southern part of the county starts near the top of the Wilcox. In this well the Eagleford formation, according to examination of the samples made by Dr. J. A. Udden, was probably reached at about 1900 feet (Mss. notes). Allowing for the Cretaceous, overlying the Eagleford, its usual thickness of about 1200 or 1300 feet, there remain 600 or 700 feet to be assigned to the Wilcox and Midway formations.

Physiographic expression: The soils derived from the Wilcox formation are sandy and frequently of a red color. The coun-

try underlain by the formation becomes somewhat hilly and rough by the development of stream channels and valleys. The timber growth is mesquite in part, although deciduous oaks and other hardwood trees are found on the more sandy lands.

Common fossils: The fossils of the Wilcox formation of this county as already indicated are in part marine invertebrates and land plants.

Surface exposures and local details: In the bluffs west of the Pearsall Road crossing on the Medina River are numerous heavy limestone concretions. The cut made for the public road on this bluff exposes thinly laminated sands carrying plant fragments. These sands and concretionary limestones appear to represent the Wilcox formation. Similar laminated sands including limestone concretions are seen in he bluffs in the vicinity of Van Ormy. Good exposures of these sands are seen on the St. Anthony farm about three-fourths of a mile south of Van Ormy. Sandy lime concretions are seen here which measure as much as 35 feet in length by 15 feet in width and 8 feet or more in thickness. They are imbedded, finely-laminated, clayey sands.

On the Gonzales Road, laminated micaceous sands of the Wilcox formation are seen on the slope to Saunders Creek, 13½ miles east of San Antonio and thence in numerous exposures to the east county line. At the intersection of the Gonzales and Prie Roads about 17 miles from San Antonio, the dump from a dug well was found to contain typical sandy clays of the Wilcox formation including a few well preserved leaves. Thin lignite beds are reported in well logs of this part of the county.

Much of the field work on the Wilcox formation in Bexar County was done by Mr. Baker, from whose notes the following observations are taken:

On Losoya Creek, at concrete bridge on the Corpus Christi Road, the strata dip 3° S 60° E, which may not be the true dip. At the base of the section are thin alternating beds of loose brown sands and laminated clays overlain by brown, much cross-bedded sandstone 3 feet, above which is mainly laminated sandy clay about 20 feet. The bottom of a small syncline is seen at the bridge, the axis

of which trends northeast-southwest. The dip on the northwest limb runs up to 10° or more, but flattens rapidly.

A splendid section of the Wilcox is exposed at the jog in the public road about three miles north of Elmendorf. The section is as follows:

Brownish stained sands, weathering into "bad lands" 8
Laminated gray, medium-grained sands, weathering light brown with some thin interlaminae of yellow-brown clay.....15
Gray drab, unctuous, structureless fire clay, passing downward into chocolate carbonaceous shale and finally into a good grade of lignite. The lignite has a minimum thickness of 2 feet with the base not exposed 6
Slightly laminated brownish-gray medium-grained micaceous sand with large flattened elliptical sandstone concretions at top and bottom 10

The observed dip in a direction about 20° south of east, appeared to be 7°, but flattened out toward the south.

The lower Wilcox on Medina River at southern boundary of San Antonio topographic sheet, west-southwest of Earle, consists of medium-grained gray cross-bedded sands, with large sandstone concretions, weathering brown. In the bed of Comanche Creek a short distance above its junction with Leon Creek are many very large flattened sandstone concretions. Associated with these are interbedded brown sands and shaly gray sandy clay. The lower Wilcox at the bridge over Six Mile Creek, where crossed by old Espada Mission ditch, is medium-grained gray sandstone, somewhat cross-bedded, weathering brown and locally cemented into sandstone.

Near mouth of first tributary on the west side of Calaveras Creek south of crossing of road running east-northeast of Elmendorf, are black and brown layers carrying carbonaceous materials in brownish laminated sands, with alum incrustations. Most of the 10-foot section is fine sand, some layers with an admixture of clay. The apparent dip here, possibly due to slumping, is about 5° to the east. Large ripple-marked flat blocks of brown sandstone occur in Calaveras Creek bed in this locality. The sands are laminated and when fresh are light gray in color but are often stained with limonite. The Wilcox soils are light brick red and generally sandy. The sandstone layers in the Wilcox here are often cross-bedded and ripple-marked. When fresh, the sandstone is gray in color, but oxidation of the iron gives the brown most generally seen. Locally

they may be almost as hard as quartzite but they seem to be almost, if not quite, always local indurations of a concretionary nature. At one place on Calaveras Creek about half a mile below the bridge before noted, ripple-marked and cross-bedded sandstone about 3 feet in thickness overlies large flattish concretionary masses cementing a conglomerate of light brown clay balls. Some have septarian structure and are seamed with crystalline calcite and cone-in-cone structure. These concretions contain marine Eocene fossils, carbonaceous fragments and grains of glauconite. In all respects they resemble the Wilcox concretions in Sabine-town bluff, this being the first locality of marine Wilcox found west of the Sabine basin. The concretionary layer is only about 4 feet above the bed of the creek. Below are 4 to 5 feet of loose laminated sands and above the sandstone layer overlying the concretions are about 20 feet of laminated gray clayey sands, limonite-stained and locally cemented. The latter are found in the bluff about 200 feet to the westward. The sandstone blocks between here and the bridge evidently belong to the same stratum, the one over the fossil-bearing concretions, only one large fossiliferous concretion being known to occur here.

Nearly half a mile farther down is another 20 foot exposure of Wilcox. Here is about 5 feet of lavender carbonaceous sandy and unctuous clays at base, succeeded by cross-bedded, laminated sands with occasional thin laminae of clayey material for the next 10 feet. The upper five feet consists of two one-foot beds of gray clayey laminated sands separated and overlain by cross-bedded brown sands, the upper 2 feet of which is more consolidated and consists of a conglomeratic sandstone with small clay-iron-stone pebbles and small sharks' teeth. This sandstone is also ripple-marked. Pebbles of clay-iron-stone in such a formation mean little, for they are soon formed in consolidated condition along stream banks and ocean or lake littoral deposits.

From this point on downstream to below the steel wagon bridge at Saspamco the banks sometimes 30 feet high are composed of alluvium of clayey sand.

The first section on Parita Creek, ½ mile above mouth, shows at base 6 feet of lavender, carbonaceous, cross-bedded, laminated, sandy clay, dipping upstream at an angle of about 10°, succeeded above by about 6 feet of laminated sand and being nearly horizontal. The whole section is prevailingly sandy, with indurated sandstone layers both above and below.

The first exposure on Parita Creek south of the bridge, about 4 miles northeast of Elmendorf (about 1-5 mile south of bridge) shows 9 feet of thinly interlaminated clay and sand layers. The sand layers are generally thicker than the clay layers, but few of the former are much thicker than an inch. The sand is brown, weathering gray when fresh. The clay laminae are gray when dry

and lavender or light chocolate when wet. Sand is fine-grained and micaceous and some layers are 2 to 3 inches thick. The next three exposures downstream show substantially the same. The interbedding of sand and clay laminae still continues. Either one may sometimes be extremely thin, sometimes not much thicker than bristol board or thin cardboard. Light exposure about 1 mile below bridge shows above 10 feet of laminated, brown, fine-grained sands, with nodules arranged in thin layers of a whitish powdery substance, probably $CaCO_3$. Below is 10 feet of mainly light gray, thinly-laminated, sandy clay but containing one 2½" layer of sand 2½ feet above base. The clay member has three interlaminae of sand as was noted farther upstream. This exposure at junction of east tributary. One-half mile downstream below last 3 feet of rusty brown ripple and rill-marked irregular-bedded sandstone overlies unconsolidated sands with interbedded laminae of clay. The next exposure downstream shows a good deal of cone-in-cone structure in brown sandstone concretionary layers, interbedded with clayey sands.

On Calaveras Creek, about 2½ miles northeast of Elmendorf, and of Parita Creek, near the Bexar-Wilson county line, about ½ mile north of southermost of two main road crossings in a northeasterly direction from Elmendorf, is exposed about 10 feet of light brown laminated sands. Next exposure, a mile farther upstream, has the usual interlaminated sands and clays with flattish sandstone concretions and selenite crystals 10 feet thick. Also a 7-foot exposure of the latter on road just east of bridge over Calaveras Creek 3 miles northeast of Elmendorf.

The first exposure of any moment on the largest eastern tributary of Parita Creek, near the Bexar-Wilson county line, about ½ mile above mouth of creek, consists of about 5 feet of thinly-laminated light chocolate clay, with very thin partings of light gray micaceous sand; above is 7 feet of thinly-laminated light gray clayey sand, seamed with limonite, and becoming sandier and less laminated in the upper 2½ feet; capped by 8 feet of light gray, fine-grained sand weathering light brown with thin beds, especially at the top, of a white kaolin-appearing substance. The basal clays contain carbonaceous remains. The next exposure, at least 3/4 mile farther upstream, consists of the same sort of materials as the last and a recent well dug in the creek bed between the two shows about 10 feet of gray micaceous sandy clays and clayey sands. Under the last exposure noted lie brown concretionary sandstones some with cone-in-cone structure. These concretionary layers, as usual, are ripple-marked. Some of them are large flattened discs, gray in color when fresh, and hard as quartzite. The concretionary layers are interbedded with the usual clayey sands, which are laminated. Some of its larger concretions are probably cemented with sphaero-siderite. A conglomeratic concretionary layer, found at least

1½ miles upstream from the mouth of the largest eastern tributary of Parita Creek, was composed of rolled iron-stone pebbles, shark's teeth and oyster fragments. The latter may have come from the Cretaceous. Also worn fragments of other shells.

As one goes upstream and consequently into lower strata, the beds become more clayey, becoming gray drab stained with oxide of manganese, and with small whitish soft, perhaps calcareous concretions.

The following notes on the Wilcox and other Cenozoic formations in Bexar County have been contributed by Dr. L. W. Stephenson:

Medina River, a few hundred yards below the crossing of the Corpus Christi Road near Losoya, Bexar County, Texas, 13¾ miles south of the San Antonio postoffice building.

Section

Feet

Pleistocene:

2. Massive brown loam, becoming sandy and pebbly toward base and locally a basal bed of gravel reaching 3 or 4 feet in thickness. The material stands up in a vertical wall along the bluff like loess. 20-35

(Profound unconformity)

Eocene (Wilcox?):

1. Gray to greenish gray, cross-bedded sand and sandstone. The sandstone constitutes local indurations of the sand. It is soft to very hard and is poorly exposed along the base of the bluff which is covered with talus 15-30

Faint banding is noticeable in layer No. 2, and about 10 feet below the top is a distinctly lighter band having a yellowish color. The bluff extends for several hundred yards along the left bank.

Earle, Texas, 11¼ miles due south of the San Antonio postoffice building. At the head of a gully on the east side of the road and south of Medina River, sandstone has been quarried for use in concrete work at the new bridge at Earle.

The rock is the indurated portion of a greenish gray, cross-bedded, rather fine sand formation. It is not very well exposed, the slopes being covered with vegetation and rock debris. Unindurated portions of the sand are exposed in the head of the gully proper. Thirty-five or forty feet of the rock and the unconsolidated

sand is exposed. The rock rises nearly to the surface of the surrounding upland.

Down the gully the rock and sand are overlain by Pleistocene sandy loam which rests unconformably against it. The sandstone contains large numbers of fossil leaves well preserved. As the rock does not split well the leaves are hard to get out in perfect condition. (Collection No. 181). I was informed of the whereabouts of the fossil plant locality just described by Mr. T. B. Applewhite, whose address is R. F. D. No. 7, Box 33, San Antonio, Texas. (The fossil leaves from this locality have been described by E. W. Berry in Prof. Paper 91, pp. 8-20, pls. 1-3, 1916).

Corpus Christi Road, crossing of Losoya Creek, half a mile south of Medina River crossing.

Section

	Feet
Surficial-alluvium:	
Reddish brown sandy loam with accumulation of pebbles at base in places. Contains land shells	4-15
(Great unconformity)	
Eocene (Wilcox?):	
Laminated, finely sandy, gray clay, and partings and thin layers of gray to brownish fine sand, some layers 6 or 8 inches thick. Some vegetable particles. Max.	20
Layer of ferruginous earthy sandy limestone, apparently of concretionary origin, cemented, on top of which is a thin conglomeratic layer composed of coarse pebbles, most of which appear to be fine ferruginous sandstone and sandy iron carbonate concretions. Among those pebbles were collected a few poor prints of Venericardia. Also some silicified wood	1
Irregularly bedded sandstone and loose sand, some showing ripple marks, with subordinate gray laminated clay	4

CARRIZO FORMATION

The Carrizo sandstone was named and described by Owen in the First Report of Progress of the Texas Geological Survey, published in 1889. The Carrizo formation of the Cambrian system exposed in the Carrizo Mountains of the Van Horn

Quadrangle, was named by Von Streeruwitz in 1891.* If, therefore, the Carrizo of the Eocene is recognized as of formation rank, the name as applied to this sandstone takes precedence over the Carrizo formation of the Cambrian. The Queen City member of the Wilcox formation, which is usually regarded as the northeast Texas equivalent of the Carrizo sandstone, was named by Kennedy in 1896.† The Carrizo sandstone is regarded by some as a member of the Wilcox formation.

A belt of sand hills extends across the southernmost part of Bexar County, representing country underlain either by the Carrizo sandstone or by very sandy phases of the Wilcox. This area is referred to locally as the "sand hills". The approximate location of this belt of country is indicated on the map.

Some of the hills near the county line in the southwestern part of the county, thickly strewn with concretionary ironstone fragments, may represent outliers from the Mt. Selman formation.

PLEISTOCENE

No marine formations are found in this county of later date than the Eocene period, the late Cenozoic being represented only by non-marine deposits, including river flood-plain, and to some extent chemically formed, sediments. Presumably, as indicated by the absence of marine formation, this area has been subjected to surface erosion during the latter part of the Tertiary and all of the Pleistocene. In this long interval there has been formed a complicated and extensive series of river flood plains. The earliest or oldest of these have themselves been more or less completely destroyed and removed by erosion. Of those that remain some are as old as the early Pleistocene, or possibly older, while others were formed during the middle and latter part of the Pleistocene period.

For a part only of this county are topographic maps available, and it has not been practicable to make a detailed study of the successive flood plains. It is important, however, to indicate

*Second Annual report of the Geol Surv. of Texas, p. 683, 1890

†The Eocene Tertiary of Texas east of the Brazos River. By Wm. Kennedy. Proc. Acad. Nat. Sci. Phila. for 1895, p. 135, 1896.

the general characteristics of the flood plain deposits, and to map the larger areas.

The flood-plain deposits of the county may be divided into two main groups, each of which is distinctive. The first of these groups includes the older and hence higher terraces of the county which are not obviously associated with the existing streams. The second group includes the low or late terraces whose relation to existing streams is sufficiently evident. Data on which to determine the age of the older terraces are wanting, but they may safely be placed as early Pleistocene or older. The late terraces are recognized as belonging to the latter part of the Pleistocene period.

The older and higher flood-plains, of which there are at least two and probably several, have some characteristics in common. As already stated they are not obviously associated with the existing streams. The sediments of these older terraces are locally more or less firmly cemented by calcium carbonate thus differing from the materials of the recent terraces, which are largely uncemented. Paleontologically, the older terraces present the negative characters of a complete or almost complete absence of fossils, while the more recent terraces contain fresh water land snails and in places vertebrate remains. Concretionary or pisolitic calcium carbonate pebbles subsequently more fully described, are occasionally found in the older flood-plains and in places are abundant, making up locally the greater part or all of the formation.

UVALDE FORMATION AND UVALDE PLAIN

(Pliocene or Pleistocene)

The oldest and highest flood plain deposits of this area are probably contemporaneous in age with those which have elsewhere been referred to the Uvalde formation. The materials of this formation as developed in Bexar County include limestone and flint boulders often imbedded in a softer matrix of finer material, clay or silt, or in some instances soft calcareous material resembling caliche. Approaching the Balcones Escarpment, the limestone boulders, as would be expected, increase both in relative abundance and in size. Southward from this escarp-

ment the relative amount of flint pebbles, although of smaller size, are in proportionately greater abundance. The flints of this formation were derived largely from the Edwards formation The limestone boulders came originally from this or from other limestone formations, having been moved in many instances probably no great distance. Well to the south where this flood plain overlies Upper Cretaceous formations, there are undoubtedly extensive inclusions from these formations. Under these conditions the Uvalde may contain beds of clay and marly deposits which are with difficulty separated from the immediately underlying Upper Cretaceous formations. Many of the flint pebbles of this formation are coated with calcium carbonate. The amount of this coating varies from mere films surrounding large flints to calcium carbonate concretions of varying sizes ateund fragments of flints as a nucleus. These concretions are more fully described subsequently. The gradient of the streams being reduced in passing coastward from the hills, the coarse materials of all these flood plains grade to fine silts and loams which are non-resistant to erosion and are finally lost.

The gravels of the Uvalde formation are utilized in road building and for concrete.

Thickness: The Uvalde plain, being the oldest of the flood plains of this area, has been cut into and largely destroyed by erosion, and hence persists as hardly more than a remnant of its former extent. In thickness the formation probably varied greatly depending upon the irregularities of the top surface of the underlying formations. In those areas where the formation now persists there is observed a thickness varying from a few feet to as much probably as 70 feet, although more commonly the gravels of this formation are between 15 and 30 feet in thickness.

Surface exposures and local details: Originally the Uvalde flood plain must have occupied an extensive area immediately south of the Balcones Escarpment, grading from very coarse materials near the hills to silts and loams farther south. The softer materials of the formation probably were first removed by erosion, the gravels and heavy conglomerates having been more persistent. Some of the areas occupied by this formation are indicated on the map, although for reasons elsewhere stated it has

not been possible to represent all of the flood plains deposits of the county.

The range of Austin Hills crossed on the Fredericksburg Road eight miles from San Antonio are overlaid by a remnant of the Uvalde formation. The formation is well exposed on this road 7.8 miles from San Antonio, where it consists of flint and hard limestone gravel imbedded in a chalky matrix. In a cut on the Altgelt-Wurtzbach road near its union with the Fredericksburg Road, 8.7 miles from San Antonio, is another good exposure of the formation. The lower part of the exposure here is chiefly very soft white marly material overlain by about eight feet of gravel including some very heavy limestone boulders. This area of the Uvalde formation continues with some interruptions as far to the southeast as the Waring estate between the Bandera and Culebra roads. The elevation of these exposures varies from about 1010 feet at the Fredericksburg Road crossing to 850 or 900 feet at the Waring estate.

No fossils are known from the Uvalde gravels except possibly some invertebrates that have washed into the formation from the older formations.

Physiographic expression: The Uvalde formation makes a plain now much cut into by erosion. The slope of this plain is more pronounced than that of the next later plain. Thus the Uvalde plain, if correctly identified, slopes south at the rate of about 20 feet per mile, while the lower plain on which Kelly field is located, slopes south at about 15 feet per mile. Locally the materials of this formation have become firmly cemented forming hard calcareous rocks. Under these conditions rocky thin soils are found, clothed with a mixed vegetation, chiefly oaks; more commonly, especially toward the southern part of the area, occupied by the formation, the soils are very gravelly and the prevailing timber growth is mesquite.

Surface exposures and local details: On the west side of Leon Creek west of San Antonio is found a considerable remnant of a flood plain which may be either an extension of the Uvalde plain or probably may be a plain at a slightly lower level. The plain here lies at the Castroville road crossing at an elevation of from 750 to 800 feet above sea level. To the south this plain

may be recognized to about the Frio Road crossing where it terminates by surface erosion although probably remnants may be found somewhat farther south. The plain may be traced to the north where it seems to pass without any very appreciable break onto the plain adjacent to Culebra Creek. On the uplands between Medio and Potranca creeks are terrace plain remnants which apparently lie at about the same level, and originally perhaps were parts of the same plain.

At the north side of the Castroville Road, about one-fourth mile beyond Leon Creek, deep gullies have washed into the gravel beds of this plain, affording a good exposure. The formation here rests on the Navarro and the lower three feet in this exposure consists of a very heavy pebble conglomerate in which are found large masses of glauconitic sandstone derived from the Navarro formation. These green sandstones of the Navarro are now exposed as elsewhere noted in the same bluff. Above this level is seen white marly material. Near the top of the exposure pebble beds again come into the section.

An exposure of gravel which is probably to be referred to the Uvalde formation is seen in a cut in the public road on New Braunfels Avenue, about 0.7 mile north of the north city limits of San Antonio. In this cut there are exposed about ten feet of clay, white chalky marl, and gravel. The gravel beds are strongly cross-bedded. The clay of this exposure, although probably included within the gravel series, closely resembles the clay of the Taylor formation which is exposed on River Avenue nearby. Similar gravel beds underlie the high lands north and northeast of Alamo Heights, lying at elevations of from 750 to 800 feet.

Heavy gravel deposits overlie the highlands in the northeastern part of the city of San Antonio and are well exposed in the cut made by the Missouri, Kansas and Texas Railway as well as in pits opened up for road material. The gravel beds at this exposure rest upon the Midway clays and are variable in thickness from a few feet to a maximum of 25 feet. The upper 3 or 4 feet are in places caliche cemented and form a very hard rock. At lower levels the gravel is less firmly cemented and is frequently cross-bedded. Lenses of clay like-

wise are observed, one of which is a foot thick and 50 or 60 feet in lateral extent. Many of the flints are coated with a thin covering of calcium carbonate; on some of the flints, especially the smaller ones, this coating is thicker and shows concentric or concretionary layers. Concretions consisting wholly of calcium carbonate, or with merely a nucleus of flint or other material, are present in this exposure, although not particularly abundant. In a pit opened for road material on the Sulphur Springs Road near this cut, the deposit consists almost wholly of small calcareous concretions. These are more fully described later in connection with the description of similar concretions from other localities.

LEONA (?) FORMATION AND PLAIN

(Mid-Pleistocene?)

The term Leona was proposed in 1900 by Dr. T. W. Vaughan, and was applied to a well developed flood plain in the Uvalde quadrangle lying at a lower level than the Uvalde plain* In Bexar County there is a well developed flood plain which very possibly is contemporaneous in time with the flood plain to which the name Leona has been applied, and which is therefore tentatively correlated with that formation. In Uvalde County, according to Vaughan, the position of the Leona formation is intermediate between that of the present flood plain and the Uvalde plain. In Bexar County the conditions are more complicated, in that there are three Pleistocene flood plains, the Leona being intermediate between the older and the younger.

The relation of the Leona flood plain to the existing streams is perhaps less obvious in Bexar than in Uvalde County. However, the writer offers the tentative suggestion that this flood plain as developed on the broad plains on which Kelly Field is located, is associated with the Leon Creek drainage. In the chapter on structure it is shown that the plunge of the structures underlying this area is to the southwest. Leon Creek in cutting across these structures has therefore tended to shift its course to the southwest. The effect of the south-

*U. S. Geol. Surv., Uvalde Folio, p. 3, 1900.

west shifting is seen at the present time in the high bluffs of this creek all of which in this part of its course are found at the right, or southwest, side of the stream. The tentative explanation offered is that the Kelly Field plain as now developed was built up chiefly by Leon Creek or its predecessor which has gradually shifted and is still shifting its course in a southwestward direction. The plain east of San Antonio may in the same way be associated with the Salado Creek drainage. The high bluffs of the Salado, like those of the Leon, are on the right bank, the plain being entirely to the east of the stream. That the San Antonio River has taken so small a part in the development of this plain may be explained by the fact that its drainage system scarcely extends back to the Balcones escarpment and the flood waters which it carries are less effective than are those of some of its tributaries.

The materials of this formation are extensively used for road building. Water is obtained from the gravel beds of the formation, chiefly through shallow dug wells.

At the Castroville Road crossing on Leon Creek this plain stands at a level of from 700 to 710 feet above sea, or from 50 to 100 feet below the level of the plain on the west side of Leon Creek already described. The slope of the plain is to the south or southeast and amounts to between ten and fifteen feet per mile. Its southern margin on the Somerset and Corpus Christi roads, six or seven miles south of San Antonio, approximates six hundred feet above sea level. The part of this plain lying to the east of Salado Creek has a slope from north to south amounting to an average of about 15 feet per mile.

The materials of this plain are largely gravel, and loam, although over a considerable area adjacent to the San Antonio River and Salado Creek, the deposits consist largely of concretionary calcite pebbles. At an excavation on the Quintana Road, 7 miles southwest of San Antonio, there is exposed of the formation 15 or 18 feet. The materials of the formation as seen in this exposure are stratified and consist of alternating layers of heavy gravel and calcareous sand. The deposits are here sufficiently well indurated to require blasting in working.

Thickness: Numerous pits for road material have been opened into gravel deposits of this plain. In these pits the

formation as a rule has a thickness of from 20 to 30 feet. In some of the wells dug into these gravels they have been found to be from 40 to 45 feet thick. Since the gravel rests upon an eroded surface of the Upper Cretaceous and Tertiary formations, they may be expected to vary greatly in thickness from place to place.

Physiographic expression: The plain formed by these deposits has a very gradual south or southeast slope amounting on an average to about fifteen feet per mile. The soils include gravels and loams. The vegetation on the uncleared lands is chiefly mesquite. The elevation of this plain at its northern limit is about 750 feet while its gradual slope carries it to a level of about 650 or 600 feet at its southern limits.

Common fossils: No fossils have been found by the writer in this formation, although the presence of vertebrates, particularly large proboscidians, has been reported from excavations within the city of San Antonio. Inasmuch, however, as the locality in question is near the headwaters of the San Antonio River where this plain merges with the later Pleistocene alluvial plain, an exact record of the fossils in the excavation is necessary in order to make sure of their place in this formation. In the absence of fossils the plain is referred doubtfully to about the middle part of the Pleistocene period. This reference is based on the fact that this plain lies above the late Pleistocene plain, to be described, and on the fact that the materials of the formation are not infrequently quite well cemented. Awaiting a more detailed study of these deposits, or the discovery of indigenous fossils, the age of the formation can scarcely be more accurately determined.

Surface exposures and local details: The largest continuous development of this plain is that extending from Leon Creek to the San Antonio River. The northern margin of this plain is found at the foot of the hills of the Austin and Taylor formations near or south of the Culebra Road. At its southern margin the plain terminates probably by surface erosion some six or seven miles south of San Antonio, although near the San Antonio River remnants of the plain, too limited to map, are found several miles forther to the south. Another large development of this plain is that found east of Salado Creek

and extending from just south of the Austin Road crossing to about the Goliad Road crossing.

Good exposures of the gravels of this plain are afforded in the pits opened for road materials. In these pits the gravels are seen to be irregularly stratified or cross-bedded, often with alternated bands of coarser and finer materials. Most of the gravel is flint, although in this plain, as in the higher Uvalde plain, there are local areas in which the materials are made up entirely of small calcium carbonate concretions. On this plain such concretions are seen in numerous pits on the west side of the San Antonio River and on the east side of the Salado River. In the valley of the San Antonio River this plain apparently merges into the late Pleistocene and recent plains within the city of San Antonio. The concretionary gravels are subsequently described.

LATE PLEISTOCENE ALLUVIAL DEPOSITS

The flood plains here regarded as of late Pleistocene age are those which border on, and have an obvious relation to, the existing streams and which lie above the present flood plain. The most pronounced development of the plains of this kind are those of the Medina River. The inorganic materials of this plain are chiefly silts and loams. The maximum width of this late Pleistocene plain is found on the Medina west of the central part of the county where that river lies near the boundary between the Cretaceous and Tertiary deposits. Farther to the east where the river is cutting through the Tertiary formations, the plain, although conspicuous, is not as a rule so wide. The next best development of this plain is that which borders Salado Creek. Here also the maximum width of the plain is found where the creek is cutting through the soft upper Cretaceous formations, the Taylor and Navarro. In the Tertiary formations the plain is noticeably narrowed. On the San Antonio River there is but a slight development of this plain.

Thickness: The late Pleistocene flood plain deposits attain a maximum thickness on the Medina River of about 50 feet. On the smaller streams they are of lesser development.

Physiographic expression: The late Pleistocene plains are seemingly very level, although as a matter of fact they slope

very gradually downstream, the rate of slope amounting to about 15 feet per mile. The soils are calcareous loams, and the timber growth includes considerable hardwood deciduous trees.

Common fossils: The late Pleistocene and the Recent deposits of this area are characterized by an abundance of the small land snail, *Bulimulus dealbatus mooreanus** which is common throughout this region at the present time. The presence of this snail in the late Pleistocene deposits and its absence so far as observed in the older formations, suggests changed climatic or environmental conditions in the late Pleistocene.

In addition to the land snails, proboscidian remains have been found in this formation at a number of localities. From the lower plain on the east side of Salado Creek, Baker secured the tooth of a mammoth, *Elephas* (Mss. notes). From the loam deposits at the Frio Road crossing on Medina River, Mr. C. H. Vogt collected some years ago a number of teeth of the elephant together with other large bones probably of the same animal.

Surface exposures and local details: The exposures of this late Pleistocene plain are found bordering all the larger streams lying from 25 to 35 feet above the present flood plain. The formation is readily recognized where typically developed by the presence of calcareous loams, containing a great abundance of the small land snail.

In mapping, it has not been practicable on the scale used to represent this formation on the smaller streams, nor to show its full extent upstream. In all cases, however, it narrows in width and approaches and gradually merges into the present flood plain. Probably the maximum thickness of the formation is seen on the Medina River near the Pleasanton Road crossing, where typical exposures are seen.

CAVE DEPOSITS

Numerous caves exist in the Cretaceous and Comanchean limestones of this county. One of these caves on the property of Mr. A. Friesenhahn, about 20 miles north of San Antonio, has been found to contain vertebrate fossils. The presence of

*Kindly identified from Bexar County specimens by Dr. Paul Bartch.

fossils in this cave was discovered some years ago and a small amount of collecting from the cave has been done by those locally interested. The entrance to this cave at the present time is through an opening extending vertically downward for about 25 feet. Formerly, however, there was another and different opening through which the debris that partly fills the cave has been washed in. In addition to bones of small animals, this cave contains teeth and bones of the elephant. The sabre-tooth tiger has also been reported. With these bones there is associated a number of specimens of the land snail, *Bulimulus dealbatus*. The presence of this fossil suggests that the cave deposits probably are not older that the deposits of the Medina flood plain which this snail, so far as present observations have shown, first appears in the stratigraphic succession. The presence of the snail together with the elephant remains suggests that the cave deposits are probably contemporaneous with the flood plain deposits of the Medina river.*

RECENT

The Recent deposits of this area are chiefly those in the flood plains of the streams. Near the foothills of the Edwards Plateau, the streams, although for the most part intermittent in flow, have great volume and velocity for a short time following heavy rains. For this reason the beds of the streams near the foothills contain a large amount of flint and limestone boulders and rock fragments, derived from the limestones of the Balcones fault zone and of the Edwards Plateau. In passing southward away from the foothills, the materials of the flood plains are found to contain relatively less of the heavy rocks and boulders and relatively more of the silts and clay loams derived from other formations through which the stream flows. In the southern part of the county the materials of the flood plain of the streams are chiefly silt, loam, and gravel.

The gravel in the stream beds is relatively free from objectionable silt and for this reason is much used in road building especially in that part of the county just south of the Balcones escarpment where the largest bodies of clean gravel are found. Some of the higher flood plains are utilized in farming, since

*Dr. O. P. Hay states that he has obtained sixteen species of fossils from this cave (Letter of Nov. 6, 1919).

only occasionally are they overflowed. On the Medina River the high recent flood plain has frequently been utilized in pecan growing.

In mapping, the flood plains of the streams have been included with the late Pleistocene flood-plain. The flood plains of all of the streams are narrow and could not well have been successfully represented on a map of the scale used for this report.

CALCAREOUS CONCRETIONS OF THE PLEISTOCENE OF BEXAR COUNTY (Pl. 1, p. 72)

In connection with the description of the Pleistocene flood plain deposits it has been noted that calcareous concretions are present and in places are very abundant. Concretions of this nature are particularly numerous in the deposits referred to the Leona formation where they make up, over considerable area, the greater part of the formation, especially in areas adjacent to the San Antonio River and Salado Creek. Similar concretions are found locally in deposits that, judged by their present elevation above the stream levels, are to be referred to the Uvalde formation.

In the literature the writer has been able to find only two references to these concretions, both of which unfortunately are merely abstracts of more extended papers. The earliest of these is a brief reference in an informal communication on various kinds of concretions made before the Geological Society of Washington at the meeting of January 25, 1911, by C. W. Hayes. The abstract of this paper given in *Science* is very brief, that part of it referring to the concretions from Bexar County being as follows:

> Calcite concretions from San Antonio, Texas. These occur in great abundance in the "tepetate" or "caliche," a widespread chalky limestone formation, produced at or near the surface in semi-arid limestone regions by the ascent of water through capillary action and evaporation with deposition of the dissolved salts. Ordinarily the deposit has a platy structure, but in places, as at San Antonio, it is strongly concretionary.*

A paper on these concretions was read by Alexander Deussen at the California meeting of the Geological Society of America,

*Sci. New Ser., Vol. XXXIII, p. 550, April 7, 1911.

1915. The abstract of this paper, published in Volume 26, No. 4 of the Bulletins of the Geological Society of America is very brief and does not include the author's conclusions.

However, in reply to an inquiry by the writer, Deussen has stated that his investigations led him to the conclusion that these concretions were formed from thermal springs.*

The suggestion that these concretions were formed from thermal springs appeals to the writer as both reasonable and probable. It is probably not accidental that these concretions lie down stream from the location of the pronounced breaks or faults from which springs now issue supplying the present streams of San Antonio and Salado. It is true that these faults cross other creeks, as for instance Leon Creek, but in the case of Leon Creek the faults are so nearly sealed as to allow very little water to emerge at the surface, and on Leon Creek there is found no accumulation of these concretions such as are found near San Antonio and Salado Creeks. That the water of these springs during the Pleistocene period was thermal or at least somewhat warmer than at present is probable. If the deep waters emerging at that time were thermal, the continued circulation of water through the rocks, emerging at the springs during and since the Pleistocene would tend to reduce both the temperature and the amount of solids carried in solution by the water. It may be noted in this connection that the waters of the Comanchean formations at the present time are found to be warm and to carry a heavy load of solids in solution in wells drilled a few miles southeast, that is down the dip, from the existing springs.

The area occupied by these concretions includes a narrow belt on either side of the San Antonio River for several miles south of San Antonio, and a much larger belt lying at the northeast side of the Salado Creek. This belt on Salado Creek has a width of two or three miles and extends for five or six miles south of the Seguin Road crossing.

*Letter of August 18, 1919.

STRUCTURAL GEOLOGY

The formations in Bexar County, both those of the Cretaceous and Tertiary, dip toward the Gulf Coast. The rate of dip, however, is changed and the county is divided both structurally and physiographically into two very distinct provinces along the line already referred to, known as the Balcones Escarpment, which in this county faces south-southeast. The structural conditions are very different in these two provinces. North of the Balcones Escarpment, the formations depart but little from the horizontal position, the rate of dip south of the Colorado River having been estimated by Hill and Vaughan to be not more than 10 feet per mile.* The structure in the coastal plains area of this county is much more complicated than is that north of the Balcones Escarpment, being affected both by faulting and by folding. At the inner or north margin of the Coastal Plains area are large faults, while farther to the south are other faults varying from small to large, accompanied by folds. The downthrow in most, although not in all, of the faults, and in the largest faults, is to the southeast or coastal side. The structures are in some, perhaps all, instances asymmetrical, the longer slope being on the southeast side. The combined effect of faulting and dipping, although varying from place to place, results on the whole in carrying the formations rapidly to a lower level in passing toward the coast.

The lines of faulting and folding in the coastal plains area either approximately parallel the main or first large fault of the Balcones fault zone, or they diverge to the south, and plunge to the southwest. The southwest plunge of the formations, as well as the divergence to the south from the line of the main fault, are possibly incident to the change of direction of the fault zone in this and the adjoining county, to which reference has already been made.

LOCATION OF PRINCIPAL FAULTS

The first large fault of the fault zone is that which brings the Edwards formation against the Glenrose. Helotes Creek at the Bandera Road crossing flows in this fault; the downthrow side of the fault, the Edwards limestone, being exposed in the

*U. S. Geol. Surv., 18th Ann. Rpt. Part 2, p. 258, 1898.

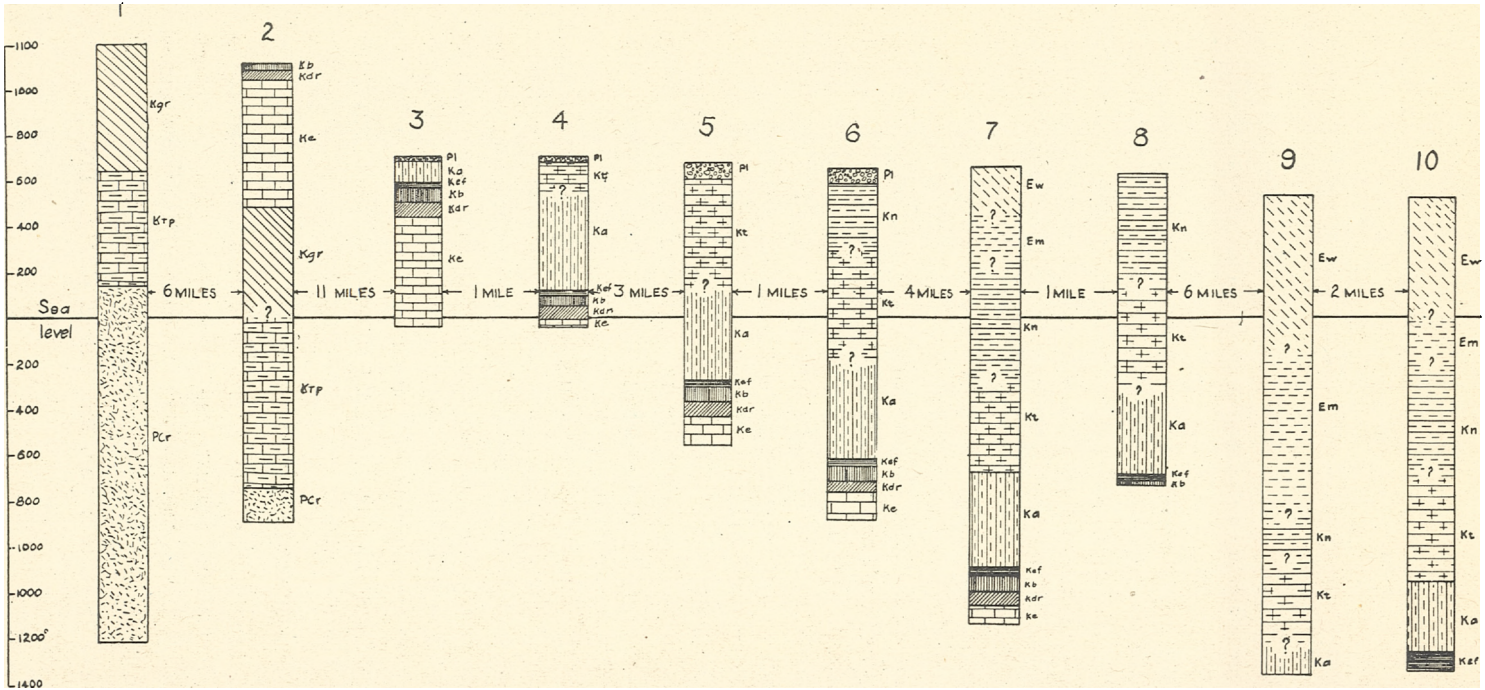

Fig. 4. Graphic representation of well logs. Wells arranged in order from northwest to southeast, on and near the Fredericksburg and Pleasanton Roads. The approximate distance between wells is indicated. No. 1, Government well on Leon Springs Military Reservation; 2, Government well on Camp Bullis Military Reservation; 3, San Antonio City well, Brackenridge Park; 4, Government well, Fort Sam Houston Military Reservation, San Antonio; 5, well at Steves Gardens, San Antonio; 6, San Antonio City Water Supply well, near Conception Mission; 7, Hill and Roby well, about seven miles south of San Antonio; 8, Wolfe and Elder well, Alta Vista field, about eight miles south of San Antonio; 9, Mathey well of the Bexar Petroleum Company, near Losoyo; 10 Park Oil and Gas Co. J. K. Lamb well south of Medina River.

Pcr, Pre-Cretaceous; Ktp, Travis Peak; Kgr, Glenrose; Ke, Georgetown-Edwards; Kdr, Del Rio; Kb, Buda; Ket, Eagleford; Ka, Austin; Kt, Taylor; Kn, Navarro; Em, Midway; Ew, Wilcox; Pl, Pleistocene.

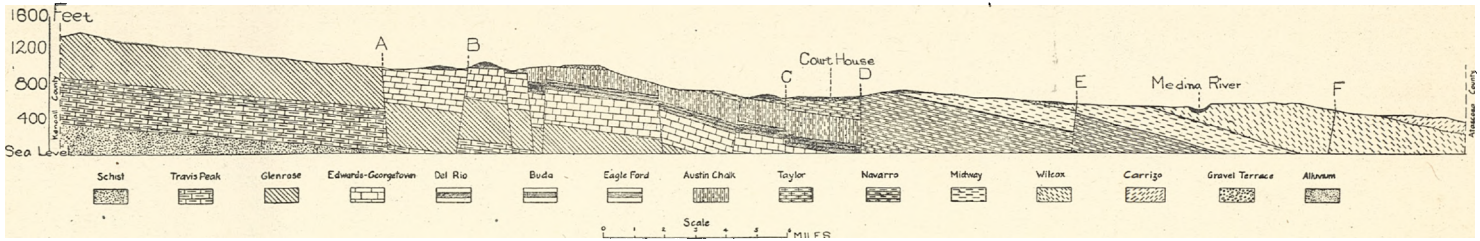

Fig. 5. Schematic representation of structure on an approximately north-south cross section following the Fredericksburg and Pleasanton public roads. In this reduced sketch no attempt is made to indicate folding which to some extent at least accompanies faulting. A, location of the first large fault of the Balcones fault zone, downthrow to the south; B, small fault seen on the S. A. P. Ry. about 14 miles north of San Antonio, downthrow to the north; C-D, location of principal large faults within the city of San Antonio. E, fault with downthrow to the north (or abrupt reverse dip) believed to exist north of the Alta Vista Oil field; F, approximate location of a fault with downthrow to the north, or of abrupt reverse dip south of the Medina River.

left bank of the stream. The following data afford an approximate estimate as to the amount of throw of this fault:

The surface elevation at the deep well on the Leon Springs Reservation is about 1156 feet above sea level. In this well the pre-Cretaceous schists were entered at the depth of 1015 feet or at the actual level of about 140 feet above sea. The elevation of the second deep well located on the Camp Bullis Reservation about six miles farther south, is less definitely known, but is probably about 1050 feet above sea. In this well, which is one or two miles east of the first or main fault of the Balcones fault zone, the pre-Cretaceous schists were entered at the depth of 1799 feet, or at the actual level of about 750 feet below sea. The difference in elevation of the top surface of the schist at these two localities, amounting to about 890 feet, is doubtless due in part to irregularities of the top surface of the schists, but a part and probably the greater part of this difference in elevation is accounted for by faulting, since the wells, as already stated, are separated by the large fault of the Balcones fault zone.

A second and probably more nearly exact measurement of the throw of this first large fault is obtained by comparing the records of these two wells. At the Leon Springs well the Glenrose formation rises in the hills to an elevation of 1350 feet or more above sea. In the well on the Camp Bullis reservation this formation is first recognized by characteristic fossils at the depth of 584 feet below the surface, or at the elevation of about 466 feet above sea level. There is therefore an interval of between 600 and 800 feet representing the downthrow of this fault, together with dips incidental to the faulting.

South of the first large fault are numerous others, small and large. The amount of throw of these faults varies from a few feet to between 400 and 500 feet; the downthrow of some of the faults is to the north side but the usual downthrow and the maximum downthrow is to the south side. A study of the well records indicates that in addition to numerous small faults there are several heavy faults or narrow zones of multiple faulting. One of these faults or fault zones passes north of and approximately parallels the Castroville Road west of San Antonio and in some way seems to involve the formation of the basin of Elmendorf Lake and possibly also of West End Lake. Well records in the vicinity of Elmendorf Lake in particular are very

unusual and discordant, giving results that can be accounted for only by complicated faulting, breaking, and displacement of the formations. Across this zone of faulting there is a change of level in the formations, as indicated by well records, amounting to about 400 feet within a mile or less. In the western part of the county this fault zone may be located both by topography and surface exposures. The line of hills seen north of the Castroville Road in the western part of the county is formed from the Austin formation. The more or less dissected plain crossed by the Castroville Road lies chiefly on the Navarro formation. Exposures near the fault line are seen on the Masterson ranch north of the Castroville Road on Lucas Creek.

A large fault with the usual northeast-southwest trend passes through the northwestern part of San Antonio. This fault is readily located by topography, surface exposures, and well records. From San Antonio to the east county line the upthrow of this fault brings the Austin formation to the surface while on the downthrow side is the Taylor formation. The surface topography revealing the upthrow side is the range of Austin Hills extending northeast from San Antonio. The exposures which reveal the fault have already been mentioned and include the exposures of the Austin formation seen in Brackenridge Park at the north city limits, and on Salado Creek and tributaries at the Austin Road crossing already described. The exposures of the Taylor formation on the downthrow side of the fault are seen on River Avenue. An approximate measurement of the amount of throw of this fault is obtained from two wells in the northeastern part of San Antonio. In a well located in Brackenridge Park at the north city limits, the Comanchean was reached at the actual level of 554 feet above sea. In the well drilled for Fort Sam Houston water supply, on Hackberry Street, about one mile farther south, these formations were entered at the actual level of 124 feet above sea. There is thus a drop in elevation of 430 feet within a mile. Whether this change in level is due to a single large fault, or to a succession of smaller faults, or to combined faulting and dipping, has not been determined.

Near the southern limits of San Antonio is another zone of

faults or rapid dips where, as indicated by well records, the formations pass in going southeast to a level about 350 feet lower in a distance of three-fourths of a mile or less. North of the fault zone the Comanchean is entered at from 900 to 950 feet from the surface, while south of the fault zone these formations are entered at from 1200 to 1250 feet from the surface. This zone of faulting is located chiefly by wells the location of which is indicated by map entries —322 and —338 (north of the fault), and —680 and —679 (south of the fault).

These several fault lines do not seem to be continuous as equally strong faults entirely across the county. On the contrary, some of them appear to pass from strong dips into faults and again into dips or a succession of small faults, a few of which have been located either by exposures or by well records, but many of which are obscured at the surface. At least two small faults cross the Fredericksburg Road within two or three miles south of the main Balcones fault. One of these may be seen in a cut in the San Antonio and Aransas Pass Railway about 14 miles north of San Antonio. The trend of this fault at this exposure is north 30° east. The upthrow in this instance is at the south side, the Buda formation at the south side of the fault being thrown against the Eagleford formation at the north or downthrow side. Faults near the Austin Road crossing on Salado Creek have already been described. In the cut made by the Southern Pacific branch line to Camp Travis, near the east limits of San Antonio, is a fault which trends about north 50° east. The downthrow of this fault is probably to the south. Two wells drilled at Conception Mission indicate the location of a small fault having a downthrow to the south of about 50 feet. A small fault or very abrupt dip is seen at an exposure on the Pleasanton Road, eight miles south of San Antonio and near the southern margin of the Alta Vista oil field. The trend is here north 60° east.

STRUCTURALLY HIGH AREAS

Associated with and more or less definitely limited by the faults are well marked structurally high areas, lifted blocks, or

folds, the location of which is recognized both on surface exposures and on well records. Three such pronounced structures have been recognized in the north part of the county, which for convenience of reference may be known as the Culebra, San Antonio and Alta Vista structures. Aside from or within these larger structures are smaller structures, the location of which requires more detailed mapping than is attempted in this report. In the southern part of the county it becomes difficult to interpret structural conditions, owing to the few well records and limited surface exposures available. It seems probable, however, that another structure similar to those described is found south of the Medina River, its position being indicated by the J. K. Lamb well, elsewhere described.

THE CULEBRA STRUCTURE

The first of the pronounced high areas is a relatively broad structure, the axis of which lies some six miles south of the Balcones Escarpment. This high area is recognized both on surface exposures and on well records. On the crest of this structure in the western part of the county the Austin formation lies at the surface, while both to the north and south the Taylor formation lies at the surface. The structure is equally well indicated by well records. The actual level of the Del Rio formation on the north side of this structure near the west county line is about 150 feet above sea (well of J. Benke). The same formation three miles southeast of this place lies about 300 feet higher (well of H. Uhl). The axis of the structure appears to lie another one or two miles farther south and hence somewhat higher than in the Uhl well. At the east side of the structure the Del Rio has again dropped to about 170 feet above sea level (well at fuller's earth plant). Several well records are available on and near the Culebra Road, which crosses this structure obliquely in passing from the west county line to San Antonio. The axis of the structure is crossed on this road about 14 miles northwest of San Antonio. Here the Del Rio formation lies at the actual level 730 feet above sea (well of Mrs. A. Voight). Passing southeast, this formation drops down to 170 feet above sea level in a distance of six miles (well of A. Skolout). Beyond this well to the southeast is the fault with

a downthrow of as much as 400 feet to which reference was made earlier in this paper.

It is difficult to determine whether this structurally high area represents an anticline in the usual sense of the term, or a fault block. If the latter, the block is limited at either side not by a single large fault, but by a succession of small or step faults. That there are faults at the north side of the area with the downthrow to the northwest is shown by the fault already referred to seen in the railway cut near the north side of the structure. It is probable that this structurally high area is produced by a combination of faulting and folding.

The wells from which data have been obtained and used in mapping this structure include those indicated by map entries 150, 360, 369, 455, 496, 555, 730, 715, 685, 560, 545, 580, 492, 270, 188, 170, 85, 16.

THE SAN ANTONIO STRUCTURE

A second notably high area having a northeast-southwest trend passes through the northwestern corner of the city of San Antonio. From San Antonio northeast the surface exposures on this structure are those of the Austin formation, forming the range of Austin Hills already described. Near the western limits of San Antonio, owing to the southwest plunge the Taylor comes to lie on the structure while exposures probably of the Navarro are seen at the north side on the Culebra Road, 5.4 miles from San Antonio. From near the west limits of San Antonio to Leon Creek the structure is concealed by the flood-plain deposits, and when again seen at and beyond Leon Creek, the Taylor formation has been carried by the southwest plunge below the surface, the exposures being largely if not entirely those of the Navarro formation. The gas field west of Leon Creek appears to be located within this structure. Beyond Medina Creek the structure has not been located either by surface exposures or by well records, and it is not known whether it flattens out or its position is merely in doubt from lack of suitable data.

The best exposures of this structure are those seen in the right bank of Leon Creek which crosses the structure south of

Kelly Field from the Castroville to the Quintana Road crossings. At the Castroville Road and for at least two miles farther down Leon Creek, the dips are to the northwest. From near or west of the Pearsall Road to the Quintana Road, the dips, often strong, are to the southeast. A green glauconitic sandstone ledge which serves as a horizon marker in these sections is seen both at the west and the east sides, but is wanting on account of erosion from the central part of the structure at the Leon Creek crossing. The exposures east of San Antonio which best locate this high area are seen on the Perin-Beitel Road from Fratt to Wetmore. At Fratt, exposures are seen on this road which probably represent the upper marly phase of the Austin formation. On the hills one and a half miles north of Fratt are seen exposures representing the hard limestones of the lower half of the Austin formation, while in the valley next northwest of these hills are exposures of either the upper part of the Austin or the Taylor formation. Near Elmendorf Lake at the west limits of San Antonio, this stucture is interrupted by a break or fault in which the formations are displaced as much as about 400 feet.

The wells by which this structure is located include those indicated by map entries 250, 485, 568, 317, 306, and 69.

THE ALTA VISTA STRUCTURE

Three of the oil fields of Bexar County, namely the Alta Vista, Mission, and Somerset fields, are so placed with respect to prevailing structural lines in this county as to suggest that they are possibly located on the same structure. If this is true, in this structure as in the two already described, there is a distinct southwest plunge. The heavy oils of the Alta Vista and Mission fields are obtained from the Austin formation at the actual level of from 450 to 550 feet below sea level. In the Sommerset field the lighter oils are obtained from either the Taylor or the Navarro formations at the actual level of from 400 to 700 feet below sea. To the northeast of Salado Creek, this structure, if we may rely on the rather limited well records available, turns more to the north, resembling in this respect the Culebra structure. It seems also to be interrupted near the

Seguin Road crossing by a fault. On this, however, the well records available are limited, and the mapping of this break is provisional. It is similar, however, to the interruption of the San Antonio structure already described. See wells No. 57, p. 138; 94, p. 140; 120, p. 165; 124, p. 167; and 160, p. 197.

THE GEOLOGIC MAP

On the geologic map are represented the surface exposures of the formations of this county in such detail as is practicable on a map of this scale. One of the problems to be met in mapping this area is the disposition to be made of the flood-plain deposits which more or less completely mantle the whole of the coastal plains division of the county. Since the chief object of this report is to describe the general geology, these flood-plain deposits have been disregarded in mapping, except where sufficiently well developed to completely obscure the underlying formations over considerable areas. The low and relatively recent flood-plains have been shown where best developed bordering the larger water courses; of the next older and higher deposits, the Leona formation, there have been shown on the map the large areas lying southwest, south, and southeast of San Antonio; of the highest plain, referred to the Uvalde formation, there have been shown some areas in which the formation occupies uninterruptedly several square miles. All of these flood plains are more extensive than is here shown.

Because of the presence of these surface materials, the boundary between the successive marine formations is necessarily placed in parts of the county on data from limited exposures, supplemented by well records. Where the surface is entirely obscured, the approximate boundary of the underlying marine formations has in some instances been indicated by broken lines, the data for placing the boundary being obtained chiefly from well records. As information is accumulated on the geology of this and the adjoining counties, the boundary lines of the formations can be more exactly determined.

In mapping structure the Del Rio has been used as a key horizon and the contours are drawn as on the top surface of this formation. In using well records and reducing elevations

to sea level it has been necessary to determine the approximate surface level of the wells from the topographic map. In that part of the county for which there is no topographic map the elevations for wells near the public roads have been obtained from the profiles of public roads made by the County Engineer of Bexar County, kindly made accessible for this purpose. In a few wells not on the area topographically mapped and remote from the public roads, an estimate of the elevation has been secured by data showing the level to which the artesian water of the **Georgetown-Edwards formations** will rise in wells. The static head of this water brings it to an actual level usually between 665 and 685 feet above sea, affording an approximate basis for estimating the surface elevation at the well. These methods of determining levels have introduced a possible small error. A much larger possible error is found in the well records themselves. As is well known, many well records afford only approximate data as to the depth at which formations are entered. While the wells of Bexar County afford unusually reliable data, yet it has been found in a number of instances that two logs of the same well, derived from different sources, differ to some extent. However, the limit of error both from approximate levels and from well logs, when carefully checked, is not large as compared to the contour interval of 100 feet used in making the sub-structure map.

INDEX TO LEVELS ON THE DEL RIO FORMATION

The numbers entered on the geologic map give the level of the top of the Del Rio formation above or below sea, the levels below sea being indicated by a minus sign preceding the number. In the following list the map entry numbers are arranged serially and for each entry there is given the name of the owner of the well and also the number which will serve as an index reference to the more complete data given in the chapter on well records. The question mark following certain of the numbers on the map indicates that the record is in doubt, the level of the Del Rio having been in some instances estimated from the level at which some of the overlying formations were reached.

Map Entry Number	Owner	Well Number*
5	Southern Ice Co.	111
6	Bexar County Courthouse	17
16	F. Masterson well	80
25	Geunther Milling Co.	41
30	Roy Hearne	51
60	Lone Star Brewing Co.	76
69	Government well, Hackberry St.	45
74	Artesian Ice Co.	8
82	Southwestern Land Corporation	114
–82	T. F. Brady	22
85	Medina Fullers Earth Co.	82
88	Salado Water Supply Co.	98
88	Southwester Land Corporation	113
90	Geo. Brackenridge	23
–100	G. F. Trice	133
–110	H. Van Dale	136
115	H. Heine	54
–115	San Antonio Steam Laundry	105
–120	Shattuck well	109
150	Mrs. Kate Benke	14
120	Roy Hearne	52
170	A. Skolaut	110
188	Ed Peffman	88
–190	J. H. Quinn	90
200	Mrs. Mackintosh	76
210	Paul Hartman	50
213	St. Louis College	97
215	Southern Pacific Ry. Schertz (Guadalupe Co)	
–215	Oscar Kreutch	71
226	Roy Hearne	33
227	H. Brendle	24
237	Chas. Matyear	81
239	J. D. Stephenson	116
–245	Community well, Cuppers Lane	31
250	Ross Davis	32
254	M. K. T. Ry., Landa	86
257	A. Koeps	70
260	Ed. E. Basse	55
260	L. M. Hubble	64
270	Chas. Hease	75
–270	S. A. and A. P. Ry.	100
–280	Collins Gardens	30
–285	H. J. Ackerman	3
306	H. Benz	15

*The wells to which these numbers refer are described on pages 129 to 197.

Map Entry Number	Owner	Well Number
–310	Acme Irrigation Co.	4
–315	R. H. Hofheintz	59
317	Government well, Aviation post	44
–320	D. G. Allen	6
–322	Artesian Water Co.	11
–323	J. H. Terrell	125
–328	D. J. Allen	7
–338	Steves Garden	118
–339	Gates and Co.	40
350	Southern Pacific Ry.	112
–350	Glen Carney	26
353	Dickenson well	33
–355	Dr. Sullivan	122
360	N. Kallison	63
367	H. H. Statte	115
369	Mrs. C. Hoffman	58
–369	Lady of the Lake Academy	72
–405	L. S. Toft	130
–410	C. C. Clamp	27
–415	West Gardendale	140
–418	H. Herff	56
435	H. Schumeier	108
440	J. Locke	75
449	H. Prinz	89
–453	J. T. Blank	15
455	H. Uhl	134
460	Waring Estate	139
470	Chris Weir	142
470	Hohnenberger well	62
–472	W. F. Leigler	74
485	Alex Lorenz	77
492	H. Steubing	117
496	A. E. Goforth	43
497	San Antonio City well	113
498	Joe Friesenhahn	39
520	O. J. Worsbach	144
545	A. Boerman	20
555	J. Widener	141
560	D. Boerman	21
568	F. Grote	46
580	E. J. Altgelt	11
620	H. Bruhn	25
655	Jud Harris	49
–679	San Antonio City Water Supply	101
680	August Pumper	95
–680	R. Tommins	131
685	Pete Tezel	128

Map Entry Number	Owner	Well Number
715	Louis Tezel	127
730	A. Voight	138
735	E. J. Altgelt	10
–750	Terrell Hot Wells	124
–800	Wolfe & Elder	160
–816	A. J. Ridder	93
–841	Kearney Oil & Pipe Line Co.	67
–870	Hot Wells Hotel	63
–880	Wm. Voght	137
–888	Superior Oil Co.	123
–888	Anton Ripps	94
–915	Holz well	60
–920	Medina Oil Co.	83
950	H. T. Biering	16
–1000	Perrinot well	156
–1005	Winters and Kreugel	143
1050	Government well, Camp Bullis	2
–1070	Hill and Roby	51
–1130	Steves well	120
–1380	Townsite well	132
–1500	J. K. Lamb	149
–1685	Blue Wing Club well	19
–1827	Mathey well	151

NOTES ON EXPOSURES SEEN ON THE PUBLIC ROADS

It has seemed worth while to place on record here certain data accumulated in connection with the field work and used in the preparation of the geologic and other maps. These notes were for the most part taken while traveling the several main roads of the county, and for convenience of reference are reported in the order of roads out from San Antonio to the north, east, south, and west. Mileage in all instances refers to distance from the Court House in San Antonio. Presented in this form the notes will perhaps be of service to the people of the county who travel these roads, as well as to the large number of visitors who come each year to this part of the State.

Blanco Road: The Blanco Road runs approximately due north from San Antonio to the county line. From the Bexar County court-house this road lies within the valley of the San Antonio River for a distance of about 1.4 miles. Underlying the stream deposits of this valley at this crossing is chiefly the Taylor formation. In the western part of San Antonio, from 1.4 to 2.5 miles

from the courthouse, the road passes over the San Antonio structure previously described; the formation, beneath the surface gravels, being the Austin chalk. From 2.5 to 3.7 miles is a gravel-covered and partially gravel-filled valley, the underlying formation being probably the Taylor as indicated by exposures on other roads. Between 3.7 to 4.7 miles from San Antonio this road passes onto the large zone of exposures of the Austin formation and continues chiefly or entirely on this formation to the valley of Salado Creek, about 10 miles from San Antonio. In the bluffs of Salado Creek, the Austin, Eagleford, and Buda formations are exposed as already described. These formations are again seen on the hill north of Salado Creek. Exposures of the Del Rio were not observed on this road but the formation is crossed over probably between 11 and 12 miles out from San Antonio, its zone of outcropping being represented by a valley beyond which are seen the Georgetown-Edwards limestones. The Glenrose formation comes in on this road about 19 miles from San Antonio.

For the first 18 or 19 miles north of San Antonio, the water supplies are obtained chiefly from the Georgetown-Edwards limestones, which are reached at depths varying from 600 to 700 feet in San Antonio to surface exposures north of the north fork of Salado Creek. Beyond about 19 miles from San Antonio, the wells enter the Glenrose-Travis Peak formations.

Bulverde Road: The Bulverde Road passes northeast from San Antonio to Wetmore, thence approximately north to the county line. From the courthouse to the north city limits, this road lies in the valley of San Antonio Creek. Near the north city limits it crosses the zone of faulting elsewhere described and passes onto exposures of the Austin formation. At the north side of the road about 6¾ miles from San Antonio is a deep sink hole in the Austin chalk. From Wetmore to the top of the range of hills 1½ miles north, the road again crosses the Austin exposures. At the north slope of this hill, as already noted, are exposures of the Eagleford and Austin formations, beyond which are the hills of the Georgetown-Edwards formations. The Glenrose-Edwards contact is apparently crossed about 21½ miles from San Antonio.

Nacogdoches and Austin roads: The Nacogdoches and Austin roads almost parallel the structural lines in this county. The Nacogdoches road which branches from the Bulverde Road one mile south of Wetmore affords exposures of the Austin formation. The Austin road lies toward the south side of the structurally high area described as the San Antonio structure. From the county line at Selma to Salado Creek the exposures seen on this road are chiefly, if not entirely, those of the Austin formation. Beyond the valley of

Salado Creek to the city limits are exposures some of which may represent the Taylor formation.

St. Hedwig Road: The St. Hedwig Road runs about due east from San Antonio. In the eastern part of San Antonio this road crosses the high gravel deposits mapped as the Uvalde formation. The valley of the Salado at this crossing includes alluvial deposits referred to the late Pleistocene flood-plain. About ¾ mile east of the crossing on Salado Creek the road ascends a pronounced terrace and passes onto the very level plain referred to the Leona formation, which continues to the break to Rosillo Creek, where exposures are seen of the Midway formation. The gravels of this formation as seen in the exposures on this terrace are largely pisolitic. From Rosillo Creek to the east county line the exposures on this road are interpreted as representing the Tertiary formations. The contact line between the Midway and Wilcox formations is placed about 14 miles from San Antonio.

Pleasanton Road: The Pleasanton Road runs about due south from San Antonio. For the first six miles from San Antonio this road passes over the level plain of the Leona formation. The gravels of this formation east of the Pleasanton Road near the San Antonio River are chiefly pisolitic, while west of this road they are largely flint pebbles deposits. The formations underlying the plain as indicated by well records are the Taylor and Navarro, with probably more or less of the Tertiary toward the southern part of the plain. About seven miles from San Antonio the road passes onto the Midway formation. Near the Alta Vista oil field, about 8½ miles from San Antonio, is the fault in the Tertiary formations to which reference has been made. From near Mitchell's Lake to about three miles beyond the Medina River, the exposures on this road are mapped as Wilcox. Within about 4 miles of the county line, the road enters the belt of sand hills representing the Carrizo formation.

Somerset Road: The Somerset Road runs in a general southwest direction from San Antonio into Atascosa County. From San Antonio to Leon Creek the road passes over the Pleistocene plain (Leona formation). The surface elevation rises very gradually to near the middle of the plain, and again drops gradually toward Leon Creek. Near this creek, the road descends to a lower plain forming a well marked terrace. Flowing artesian water is obtained on this road from the Georgetown-Edwards limestones which are reached at a depth of from 900 to 1000 feet, the top of the Comanchean being reached at about 850 to 900 feet. However, the water from these formations, from about six or seven miles from San Antonio on to the southwest as far as tests have been made, is a warm sulphur water not desirable for drinking purposes, although used

to some extent for irrigation. From Leon Creek to the Medina River is a plain which is gravel-covered. The timber growth is chiefly mesquite. In the bed of the Medina River are seen large concretions of the Tertiary formations. The late terrace deposits of the Medina River valley at this crossing have a thickness of as much as 50 feet. They consist of loams in which are found many land snails, chiefly **Bulimulus.** On the south side of the Medina, this plain continues for about one mile, beyond which to the county line the road passes over the Tertiary. Beyond Somerset are several exposures of thinly laminated sands of the Wilcox formation.

Pearsall (Frio) Road: The Pearsall Road runs southwest from San Antonio. From San Antonio to Leon Creek this road leads across the level plain on which Kelly Field is located, mapped as the Leona formation. The gravel, silt, and loam deposits of this plain have a depth of from 25 to 50 feet and are utilized in places for road material. The native vegetation, now largely cleared, is mesquite. The formation underlying the plain is probably chiefly Navarro as indicated by exposures on Leon Creek. The Comanchean is reached in wells drilled in this plain on the Pearsall Road at between 900 and 950 feet, being one or two hundred feet nearer the surface here than on the Castroville Road two or three miles northwest. This difference is due to structural features elsewhere described. Artesian water is obtained in these deep wells from the Georgetown-Edwards formations which are reached at about 1050 feet, and are penetrated in drilling a variable depth. In some of the wells on the lower lands the artesian water flows at the surface, although in wells located on higher lands the water is non-flowing.

In the bluffs of Leon Creek at the Pearsall Road crossing are exposures of the Navarro formation elsewhere described. From Leon to Medina Creek the road passes over rolling lands with gravelly soils indicating remnants of flood-plain deposits. The underlying formation is largely concealed but is probably the Navarro formation. From Media Creek to the Medina River, on this road, is a late Pleistocene flood-plain deposit, mapped as the Medina flood-plain. From the Medina River to the county line, this road passes over the Tertiary probably chiefly, or entirely, on the Wilcox formation. In the cut in the public road west of the Medina, are exposures of the Wilcox already described.

Castroville Road: The Castroville Road (West Commerce Street, in San Antonio) passes to the south of the termination of the range of Austin Hills, originating in San Antonio. By turning north on Zalzamora Street, a distance of about one-half mile, an exposure of the upper part of the Austin formation may be seen. On the other hand, by turning south on West 19th Street an exposure of what is probably the Taylor formation may be seen near the east

end of Elmendorf Lake. After passing Elmendorf Lake the road goes onto a level plain representing the Leona formation, which continues to Leon Creek. Well records indicate that the base of the Upper Cretaceous lies at a depth of between 1050 and 1100 feet from the surface. Hence, as the flood-plain deposits are only from 25 to 50 feet deep, the formation on this part of the plain next below the Pleistocene is probably the Navarro. Water is obtained on this plain from shallow wells entering the Pleistocene and from deep wells entering the Comanchean formations. The deep wells give artesian water, which rises to within from 25 to 50 feet of the surface, depending upon the elevation at the well. Near Leon Creek the road passes down to a lower and later small terrace bordering the present stream. The gravels of this late terrace and of the stream bed are used in road construction.

At the Leon Creek crossing on this road are seen exposures of the Navarro formation elsewhere described. Beyond the creek the road passes onto the high terrace mapped as Uvalde formation. From Leon Creek to Media Creek the exposures are chiefly of these high terrace deposits. This formation, however, is thin and small streams have cut through in places to the underlying clays, probably of the Navarro formation, as indicated by an exposure seen in a small stream channel about one mile beyond Leon Creek in which many **Exogyra costata** are found. The timber growth of this upland is chiefly mesquite with some oak on lands underlaid by caliche-cemented terrace gravels. The water supply here is chiefly from deep wells entering the Comanchean limestones. The top of the Comanchean on this plain is reached at a depth of about 575 feet and the water-bearing limestones at about 700 feet from the surface. (Well of A. Skolout).

From Media Creek to the county line this road passes over an undulating country in which the chief timber growth is mesquite, and which is underlaid throughout probably by the Navarro formation. At the surface are found remnants of gravel terrace deposits which were formerly perhaps extensive, having been largely removed by erosion. Turning south on the Cagnon cross road about one mile there is seen at the slope to the valley of the Medina River an exposure of yellow clay containing many **Exogyra costata.** To the north of the Castroville Road and near the Cagnon cross road is the fuller's earth plant elsewhere described. To the north from this road, near the west line of the county, may be seen the pronounced range of Austin Hills while to the south a few miles is seen the broad valley of the Medina River. One of the lines of heavy faulting approximately parallels this road from near the Leon Creek crossing to the county line separating the dissected plain over which the road passes from the Austin Hills to the north.

Potranca Road: From Leon Creek to the west county line, the

Potranca Road lacks but little of paralleling the structural lines of the Cretaceous formations. The road runs a few degrees south of west while the lines of structure are more nearly due southwest. For somewhat less than a mile beyond Leon Creek the road leads across a hill formed of Austin chalk. Beyond, for about one and a half miles, is a broad valley covered by gravel deposits. Although not shown on the map, this terrace plain extends north to Culebra Creek and possibly represents the location of a former valley. From this valley to the county line the road lies continuously on the Upper Cretaceous formations with frequent exposures. For the most part the soft marly phases of the Austin are represented, the oyster, **Exogyra ponderosa** being very abundant, although at the Media Creek crossing and at several places beyond there are seen the hard limestones of the Austin formation. The vegetation includes a dense growth of live oak on many of the hills, and mesquite in the valleys.

Culebra Road: The Culebra Road extends northwest from San Antonio. On this road 5.4 miles from San Antonio, exposures are seen at the south of the road containing **Exagyra costata,** probably indicating the Navarro formation. At the Zalzamora Creek crossing are seen exposures of the Austin formation, while at a somewhat higher level on the hill slope facing the valley of Leon Creek is an exposure 8.7 miles out, interpreted as representing the Taylor formation. Beyond the Leon Creek crossing for about 8 miles, aside from surface materials, the underlying formation is the Austin chalk. In this part of its course the road passes over the structurally high area elsewhere described. For the last 3 or 4 miles before reaching the county line, the road passes over a high gravel-surfaced plain, underlaid, as indicated by well records, by the Taylor formation.

The Bandera Road: This road extends northwest from San Antonio. In a stream bed ¼ mile north of the Bandera Road, 5 miles from San Antonio, is an exposure of yellow clay containing **E. ponderosa,** probably representing the Taylor formation. From 6.6 miles to about 13.6 miles, the exposures on this road aside from surface materials are those of the Austin formation. At the Leon Creek crossing are the bluffs of this formation with an abundance of fossils to which reference has previously been made. From 13.6 to about 15 miles is relatively level land in which are occasional exposures of the Buda limestone, the Eagleford shales being obscured. At 15.5 miles, the Del Rio is seen exposed at a pond in a stream bed ¼ mile north of the road; this formation is again seen near Helotes Creek. At the Helotes Creek crossing the Edwards formation lies at the surface, while beyond this crossing the road passes over the Glenrose formation to the county line. The large

fault of the Balcones fault zone is crossed on this road at Helotes Creek.

Babcock Road: Although lying close to and paralleling the Bandera and Fredericksburg roads, the Babcock Road affords a few exposures that should be mentioned. At 5.4 miles from San Antonio on a small tributary to Martinez Creek is seen an exposure of yellow clay containing **E. ponderosa** and probably representing the Taylor formation. From 5.8 miles to 10 miles the exposures aside from surface materials are chiefly those of the upper part of the Austin formation, including possibly some exposures of the lower part of the Taylor formation. The hard limestones representing the lower part of the Austin are first seen on this road 10.7 miles from San Antonio. The Eagleford and Buda formations are first seen on a small stream 11 miles out. The Del Rio is first seen on this road about 12 miles from San Antonio, and from 12 to 13 miles the road passes over repeated exposures of the Buda and Del Rio formations, the alternating exposures being due apparently chiefly to small faulting. At the Leon Creek crossing on this road is seen the flint-bearing phase of the Edwards formation. Beyond the crossing for a mile or so the Del Rio continues to be seen occasionally and is used in the construction of a pond near the Hausman cross road 14.8 miles from San Antonio. The limestone hills of the Edwards formation where crossed by this road are two or three miles wide, beyond which the road passes onto the Glenrose formation.

Fredericksburg Road: From San Antonio the Fredericksburg Road runs west of north to the county line, and thence to Fredericksburg. Within the city of San Antonio, at a distance of from 1.5 to 2.5 miles from the court-house, this road crosses the structurally high area elsewhere described as the San Antonio structure. Although not seen immediately on this road, Austin exposures have been seen both north and south of the road. A cut in the public road at a stream crossing about one mile from the north city limits affords an exposure of yellow clay in which no fossils were found but which on lithologic appearance would seem to represent the Taylor formation. Beyond this stream for several miles is a broad valley the surface of which is gravel covered. This valley is probably underlaid by either the Taylor or the Austin formation. From 5.4 miles to 9.3 miles, the exposures, except those of the Uvalde gravels, are interpreted as representing the Austin formation. From 9.3 to 9.7 miles are exposures of yellow clays containing **E. ponderosa,** apparently representing the Taylor formation. From 9.7 to 10 miles exposures of the Austin formation are continuous. The hard limestones of the lower part of the Austin are first seen on this road at 10 miles from San Antonio, where

they are underlaid by the Eagleford shales. From 10 miles to 13 miles from San Antonio this road crosses the belt of repeated exposures of the Buda and Del Rio and other formations to which reference has already been made, the succession of exposures being due in part to small faulting and in part to folding. At the Leon Creek crossing and for a mile or so beyond exposures are seen of the Edwards formation. About 16 miles from San Antonio the road passes onto the Glenrose formation and continues chiefly or entirely on that formation to the county line.

ECONOMIC GEOLOGY

The mineral resources of Bexar County include artesian and other ground waters, cement, concrete, clay, fuller's earth, greensand, lignite, limestone, petroleum, natural gas, and road materials. On the accompanying map is shown the location of some of the principal mineral deposits of the county (Fig. 6).

ARTESIAN AND OTHER UNDERGROUND WATER SUPPLIES

The underground waters are one of the very valuable natural resources of Bexar County. In parts of the county flowing artesian wells of large volume are secured. In some other areas non-flowing waters are secured from wells of moderate depth; while in some limited areas difficulty has been met with in securing sufficient water. The relation of the geology to the water supply is very close, some of the formations containing but little water, while others afford an abundant supply. The principal water-bearing formations are the Glenrose-Travis Peak limestones, the Georgetown-Edwards limestones, the limestones of the Austin formation, and the sands and sandstones of the Tertiary formations. The formations in which the water supply is frequently found to be limited are the Del Rio, Buda, Eagleford, Taylor, and Navarro, and the upper part of the Austin in which the rocks are of such close texture as to retain and yield very little water. Since the formations pass through the country, as already explained, in belts having a general northeast-southwest direction, it follows that the county divides itself, with respect to water supplies, into similar belts, depending upon the character of the underlying formations reached by wells.

PRINCIPLES OF ARTESIAN WELLS AND GROUND-WATER ACCUMULATION

Since the principles underlying the accumulation of ground waters, including flowing artesian wells, have been fully set forth in numerous publications, they need not be discussed

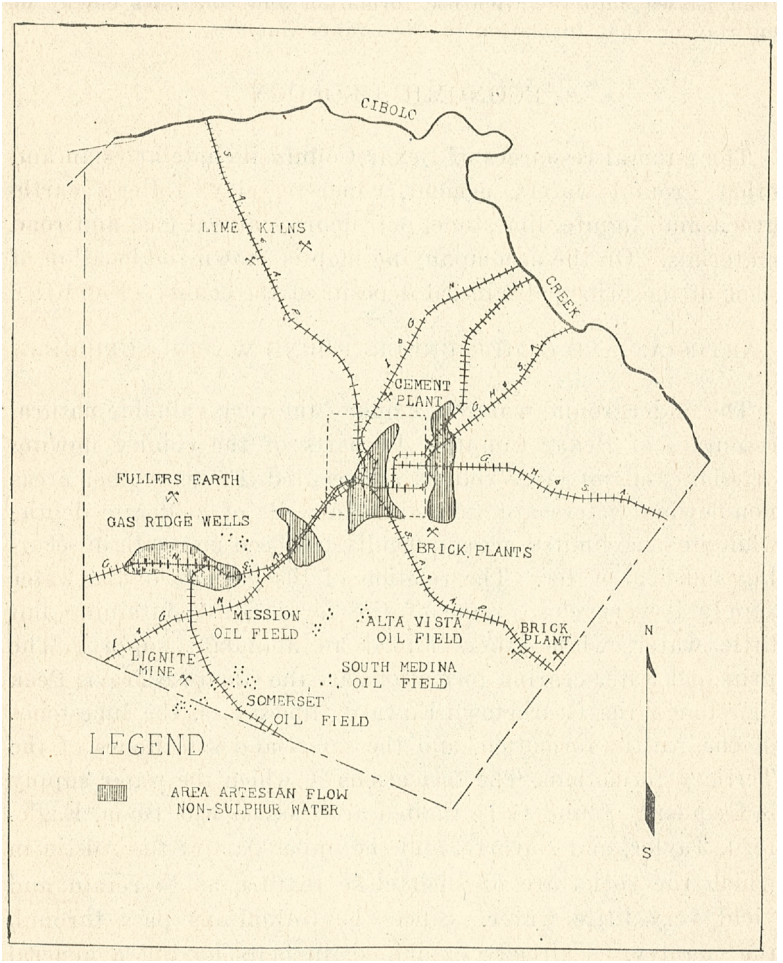

Fig. 6. Sketch map indicating the brick, cement and fuller's earth plants, lime kilns, lignite mine, oil and gas fields and areas of flowing artesian water.

here. It is therefore sufficient to state that for the coastal plains area of this county the principal intake area for the ground water is through the surface exposures of the formations on their outcropping margins, chiefly south of the Balcones Escarpment. The flowing artesian waters obtained from the Georgetown-Edwards limestones enter those formations chiefly within a few miles of the Balcones Escarpment.

The pores and cavities in the rock become completely filled with water up to limits which vary appreciably between dry and wet seasons. In the case of some of the formations, especially the limestones referred to, the pores and cavaties are so numerous that the quantity of water contained in the formation is very great, so that the supply is not appreciably affected by pumping.

With regard to the artesian waters, the conditions are admirable for securing flowing wells from the water-bearing strata where the elevation is not greater than the effective head of the water. Thus water entering the Georgetown-Edwards formation follows the dip of the formation through the cavities and openings of the limestones to a lower level, and when tapped by wells will rise in the boring. The height to which the water will rise, however, varies with the seasons. Thus, following a long period of dry weather or a succession of dry seasons, the water line has been known to drop at San Antonio to the actual level of 659 feet above sea. On the other hand, following extremely wet seasons, the water has been known to rise to the level of 694 feet above sea, giving a maximum recorded variation of 36 feet.* As a rule, the static head of the water varies between seasons within much smaller limits. At San Antonio, the static head of the water of the Georgetown-Edwards formations is close to an average of 670 feet above sea level. While exact measurements are not available, the water of these formations seem to be under a very close approximation to this same static head throughout the county. The only departure that would be expected from this head is that due to the friction of flow through the rock, which apparently is not great in this formation.

*Records supplied by San Antonio Water Supply Company.

Water obtained from the Austin formation has been found to be under a static head in this area which differs more or less from the Edwards formation. Water obtained from the Travis Peak formation, where reached by wells in the coastal plain, has been found to be under a greater static head than is greater than that of the overlying formations. This fact is indicated by water obtained in the Waring well, subsequently described (No. 139, of the section on well records).

WATER OF THE GLENROSE-TRAVIS PEAK LIMESTONES

The Glenrose formation, as shown on the geologic map, and as stated in the discussion of the geology, lies at or near the surface in that part of the county north of the Balcones escarpment. Although not exposed at the surface, the Travis Peak formation underlies the Glenrose and is reached by some of the deeper wells. In the Glenrose formation water is usually found in sufficient quantity for household and stock purposes within the moderate depth of 200 or 300 feet. A few wells have failed to get water in the Glenrose, and some have obtained a moderate supply by going through the Glenrose into the Travis Peak formation beneath, while two wells within this area, one on the Leon Springs Reservation and one on Camp Bullis Reservation, have passed entirely through the Travis Peak formation without securing a supply of water sufficient for the needs of the Government camps. The wells passing through these two formations encountered a succession of hard and soft limestones, marls, clays, and sands.

East of the Balcones Escarpment these formations pass by faulting and dipping to a much lower level and are overlaid by later formations. At the Waring estate, about eight miles northwest of San Antonio, a deep well has been drilled through the overlying formations, and into, if not through the Travis Peak. In this well water is said to have been obtained at the depth of 2699 feet. This water is probably from sands near the base of the Travis Peak, or the equivalent of the Trinity sands farther north. The water rose to within about 46 feet of the surface or to about the actual level of 874 feet above sea. From the record secured in this well, it

seems probable that the Travis Peak formation in this immediate area may be found to give an important water supply, the artesian head of which is much higher than that of the later formations.

WATER OF THE GEORGETOWN-EDWARDS LIMESTONES

The Georgetown-Edwards limestones afford the largest reservoirs for underground waters of any of the formations of this area. The surface outcropping of these formations which is their intake area, forms a relatively narrow belt lying immediately south of the Balcones Escarpment and forming the line of hills elsewhere described as the Edwards Flint hills. Within the area in which these formations lie at the surface they supply non-artesian water to wells at the moderate depth of from 100 to 300 feet. Farther to the south and southeast these limestones pass under later impervious formations and the cavities of the limestones, becoming filled, contain very large quantities of water, which by reason of the eastward dip of the formations is under pressure and hence becomes artesian water.

AREA OF ARTESIAN FLOW

The area of flowing wells from the Georgetown-Edwards limestones is indicated on the accompanying map (Fig. 6). Toward the north the flowing area is limited by the increased elevation of the country, the land rising to a level higher than the static head of the artesian water. To the south, on the other hand, the limitation of this belt for practical purposes is due in part to the increased depth of the water-bearing formations, but more particularly to a change in the quality of the water. South of the area indicated on the map, the water of these formations contains hydrogen sulphide gas, and also increases notably in temperature, becoming a warm sulphur water. The amount of salts in solution likewise increases until the water becomes undesirable for household use.

WELLS LOCATED IN THE AREA OF SURFACE EXPOSURES OF THE GEORGETOWN-EDWARDS FORMATION

Wells located immediately south of the Balcones main fault line and within the area of surface exposures of the Georgetown-

Edwards formations encounter in drilling chiefly hard limestones, with, in places, layers or masses of flint. Records of several wells within this area have been obtained in which the depth varies from 100 to about 300 feet. The water obtained is usually sufficient to supply household and ranch purposes. The Government test well on the Bacon Ranch in the Camp Bullis Reservation passed entirely through these limestones as well as the Glenrose and Travis Peak formations beneath, without getting sufficient water to supply the Government camps.

NON FLOWING ARTESIAN WELLS OF THE GEORGETOWN-EDWARDS FORMATIONS

Immediately north of the belt of flowing artesian wells is another belt in which artesian water is obtained from those formations, but in which it is non-flowing because of the increased elevation of the ground. Since this belt of country lies to the north of the flowing artesian belt and hence nearer the surface outcropping of the formations the formations are reached and the artesian water obtained at a more shallow depth than farther south.

FLOWING ARTESIAN WELLS OF THE GEORGETOWN-EDWARDS FORMATIONS

The number of flowing wells within the artesian belt obtaining water from the Edwards and Georgetown limestones is so large that it is impracticable to record more than a relatively small number of them. The succession of formations in these wells, however, is very definite and by reference to the map a reasonably definite idea may be obtained of the formations to be expected in drilling in any part of the flowing area. Most of this flowing area lies within the natural divisions of the county designated as stream terrace deposits and Taylor-Navarro Plain (Fig. 2). The succession of formations to be expected in a well within this area therefore is about as follows from the surface to the artesian water horizon.

1. Surface materials, soils, gravel, and other terrace deposits, variable, although of moderate thickness.
2. Clays, marls, and shales representing either the Taylor forma-

tion or the combined Navarro and Taylor formations; thickness variable with the location from a few hundred to one thousand or more feet.

3. Soft marl and chalk beds passing below into harder limestones representing the Austin formation; thickness, between 300 and 400 feet. Some of the light-colored limestones near the middle of this formation are called "magnesian" by the drillers in this county. The limestones near the base of the formation are often quite indurated. Some water usually containihg more or less hydrogen sulphide gas is often obtained in the Austin formation.

4. Dark colored calcareous shales, more or less sticky in drilling, representing the Eagleford formation, and commonly known in this county as the "lignite" or as the "first mud;" thickness from 30 to 40 feet.

5. A uniformly very hard limestone often characterized by black specks, representing the Buda formation; thickness quite uniformly from 60 to 65 feet.

6. Clay usually blue or yellow in color and often containing small twisted "ram's horn" shells; thickness in this county quite uniformly from 65 to 70 feet. This formation, the Del Rio clay, is very generally referred to by the drillers as the "mud hole" or as the "big mud" or as the "second mud."

7. The Georgetown and Edwards limestones lie immediately beneath the clays of the Del Rio formation. After reaching the limestone the drilling is continued until a sufficient quantity of water is obtained. In some wells the drilling is continued into these formations for only a few feet while in other wells it is continued to a considerable depth. In general, it is reported that the amount of water secured is increased with increased depth in these formations.

WATER OF THE DEL RIO AND BUDA FORMATIONS

The Del Rio and Buda formations supply relatively little water. The Del Rio consists of clays chiefly while the Buda is a close-grained limestone, neither being sufficiently porous to be well adapted as water reservoirs. A few strong flowing wells are reported as terminating in the Buda formation. Probably, however, in these instances the drill enters fracture zones in the rock, the water obtained being derived from the underlying water-bearing limestones. These formations, however, particularly the Del Rio, form the overlying impervious stratum which confines the artesian waters within the Georgetown-Edwards limestones.

WATER OF THE EAGLEFORD AND AUSTIN FORMATIONS

As a water-bearing rock, the Austin formation is somewhat unreliable. A considerable number of wells have obtained good water in moderate quantities from this formation, but on the other hand, a large number of wells drilled into this formation have secured water containing too much hydrogen sulphide gas to be desirable. The formation contains considerable quantities of pyrite and doubtless the hydrogen sulphide in the water is incident to the oxidation of the pyrite. The water is obtained chiefly from the limestones of the lower part of the formation.

The Eagleford formation, which lies below the Austin, is relatively thin in this county and consists of calcareous shales. It contains as a rule relatively little water.

WATER OF THE TAYLOR AND NAVARRO FORMATIONS

The Taylor and Navarro formations, which consist chiefly of compact marls, clays, and shales, nearly a thousand feet in thickness, are essentially non-water-bearing. Wells drilled through these formations in the Leon Creek gas field, the Alta Vista and the Somerset oil fields, report very little water until within the middle or lower part of the Austin formation. There are, therefore, very few water wells terminating in these formations.

WATER OF THE TERTIARY FORMATIONS

The sand lenses which are often numerous in the Tertiary formations afford moderate supplies of good water. Wells terminating in these formations supply water in sufficient quantities for household purposes at Somerset, Elmendorf, and elsewhere in the southern part of the county.

For the record of numerous wells in this county, see the section on well records.

SPRINGS

The permanent surface waters of this county are derived from springs, the largest springs of the county being those in

San Antonio at the headwaters of the San Antonio River, and on the Salado River a few miles east of San Antonio, and in San Pedro Park. These springs are located near fault lines and without doubt are supplied from the underground artesian reservoir, the water escaping to the surface through breaks in the rock incident to faulting. The following observations have been recorded, which seemingly establish the connection between the artesian reservoir and the water from these springs: "A few years ago a series of stakes was driven in the still waters of the head lake (of San Antonio River) and the height of the water marked thereon. The artesian wells were then all turned on and let run for twenty-four hours. The level of the water in the head lake or pond of the river had fallen 2 inches. The wells were then checked and in about one day the water in the head lake was at its former level. Then again the artesian wells were by survey connected in a system of levels. An excavation was made on the land of the observer below the water line. It was possible by observing the height of the water in this hole to obtain the height of water in any artesian well in the city".*

WARM SULPHUR WATER IN THE COMANCHEAN LIMESTONES

Numerous wells drilled in Bexar County have shown that from a few miles south of San Antonio the water obtained from the Georgetown-Edwards limestones is warm sulphur water. The transition from non-sulphur to sulphur water in these formations, in passing to the south, is probably not as abrupt as some of the well records seem to indicate. The somewhat gradual transition from the non-sulphur to the sulphur water areas is indicated by the slightly sulphurous waters of several wells near the dividing line between the two areas.

No very satisfactory explanation has been offered to account for this change from non-sulphur to sulphur water in these formations. However, in passing to the south or south-

*The Water Powers of Texas, by Thomas U. Taylor. U. S. Geol. Surv., Water Supply and Irrigation Paper No. 105, p. 25, 1904.

east, the water-bearing formations drop rapidly to lower levels and hence are more deeply buried beneath the surface It is reasonable to assume also that there is less circulation of water in these formations where deeply buried than in the same formations lying near the surface, especially within the general region of the location of fissure springs which probably have permitted the escape of water and consequently circulation in the formations since as early at least as sometime in the Pleistocene period. The boundary line of the sulphur water area conforms in general with the lines of structure, and is approximately coincident with one of the lines of heavy faulting. Increased depth and increased chemical activity together with reduced circulations may account for an increased temperature in these waters.

SOURCE OF HYDROGEN SULPHIDE IN UNDERGROUND WATER

The probable sources of the hydrogen sulphide in ground waters may be summarized as follows: The decay of organic matter, containing sulphur; the reaction of organic matter upon sulphides or sulphates; the reaction of acids upon sulphides; the partial oxidation of sulphides.

Hydrogen sulphide is formed during the decay of both animal and vegetable matter, and is obviously a possible source of hydrogen sulphide in underground waters. The hydrogen sulphide found in shallow waters in particular is doubtless very frequently from organic sources. Thorpe states that the decay of organic matter in contact with sulphates results in the formation of H_2S.* The reaction in this case probably results from reducing properties of decaying organic matter, the sulphates being first reduced to sulphides according to the following reaction: $Na_2SO_4 + C_2$ (carbon of organic matter) $= 2CO_2 + Na_2S$. The sulphide is then acted upon by the carbonic acid to form H_2S as follows: $Na_2S + H_2CO_3 = H_2S + Na_2CO_3$. The reaction of organic matter upon the suphides is regarded by Van Hise as another important source of H_2S in underground water.†

The formation of hydrogen sulphide as a result of action of

*Dictionary of Chemistry, Vol. III, p. 697, 1900.

†A Treatise on Metamorphism, Mon. XLVII U. S. Geol. Surv., p. 1112, 1904.

acids upon metallic sulphides is one of the most familiar of laboratory experiments. This suggests the possibility of the formation of this gas as the result of the action of acids upon metallic sulphides contained in the rocks. Sulphides, especially those of iron, are widely scattered in the earth's crust and occur in sufficient quantity to account for the formation of H_2S gas in water. Hydrogen sulphide is a weak acid and its salts are decomposed by a stronger acid. Sulphuric and other mineral acids should certainly react upon sulphides liberating H_2S. Carbonic acid when abundant reacts upon alkali sulphides to produce hydrogen sulphide. It is true that the alkali sulphides are normally not abundant in the crust of the earth. Stokes has shown, however, that the reaction of sodium carbonate within the earth upon pyrite or marcasite produces sodium sulphide. The reaction given by him is as follows: $8FeS_2 + 15Na_2CO_3 = 4Fe_2O_3 + 14Na_2S + Na_2S_2O_3 + 15CO_2$.*

It is a well known fact that the carbon dioxide which unites with water to form carbonic acid is abundant in the deep waters, especially in the limestone formations, the pressure existing at considerable depth enabling the water to hold great quantities of carbonic acid. The series of reactions given by Stokes accounts for the presence of alkali sulphides in solution in the deep waters. It may be added that all sulphides are soluble to some extent in water, and in that condition may be acted upon by carbonic acid.†

The partial oxidation of sulphides is, according to Van Hise, a possible additional method of the formation of hydrogen sulphide, the reaction being as follows:‡

$3FeS_2 + 4H_2O + 4O = Fe_3O_4 + 4H_2S + 2SO_2$

The oxidizing processes are the most rapid near the surface, especially above the underground water level, and H_2S derived from this source probably supplies relatively shallow, rather than deep waters.

Since iron sulphide (pyrite) is known to be present in the

*From Van Hise, loc. cit., p. 1107.

†Inorganic Chemistry. International Library of Technology. Sec. 12, p. 11.

‡Inorganic Chemistry. International Library of Technology. Sec. 12, p. 1113.

water-bearing formations it seems probable that the hydrogen sulphide of the deeper formations in Bexar County is very largely from this source.

CEMENT

The one cement plant in operation in this county at the present time is that of the San Antonio Portland Cement Company, located on the International and Great Northern Railway two miles north of the north city limits of San Antonio, at the north side of the range of Austin Hills already referred to as originating at San Antonio and extending northeast (Fig. 2). The location appears to be near the contact of the Austin and Taylor formations. The materials from which the cement is made accordingly include the uppermost strata of the Austin formation together with more clayey material overlying this rock, which may represent the Taylor formation. The rock of the Austin formation is here of a light yellow color and of medium hardness. Upon partial disintegration, it breaks by exfoliation and upon further exposure crumbles to small fragments. The rock as seen in the face of the quarry is much broken by jointing, including small faulting. The dividing line between this rock and the more clayey material above is distinct and well marked.

Overlying the clay and rock is a surface accumulation of gravel and pebble deposits. The gravel overburden is removed and the underlying clay and rock after being loosened by blasting is loaded into tram cars by steam shovel and in the case of the harder rocks, by hand. The thickness of the clay stratum overlying the rock probably increases as the quarry is worked back into the hill. In practice, however, it is found necessary to use only a limited amount of clay mixture with the rock of this locality. The product of the quarry is marketed under the name of the Alamo Portland Cement.

An analysis of the limestone and clay utilized in this plant was made some years ago by the Bureau of Economic Geology under the direction of Dr. W. B. Phillips, and is recorded on

page 65 of Bulletin 365 of the University of Texas. The analyses are as follows:

	Limestone per cent	Shale (clay) per cent
Silica	7.80	55.30
Alumina	3.45	13.56
Oxide of iron	1.35	4.50
Lime	46.64	9.48
Magnesia	None	None
Carbonic acid	36.65	7.45
Loss on ignition	3.35	8.85
	99.24	99.14

Formerly, the limestone of the Austin formation exposed in what is now Brackenridge Park at the north city limits of San Antonio was utilized in cement manufacture. Remnants of the old plant are still to be seen, and the sunken garden of Brackenridge Park marks the location of the pit from which was removed material for cement manufacture and to some extent for other purposes, such as road material and ballast. The firm operating at this locality, the Alamo Portland Cement Company, was the predecessor of the present San Antonio Portland Cement Company.

UNDEVELOPED PORTLAND CEMENT RESOURCES

In addition to the plant now operating in Bexar County, it is probable that other localities are found within the county capable of development for Portland cement manufacture. In selecting such localities, however, it is important to give careful attention both to transportation and to raw materials. The location should be easily within reach of rail transportation and should, of course, be favorably located with regard to raw materials.

Since in the manufacture of Portland cement there are required both limestone and clay, it is essential that a location for a plant be selected where these ingredients are both readily available. Approximately three times as much limestone is used as clay; or more, if the limestone contains clayey impurities as it often does. Favorable localities, therefore, are those in which clays and limestones may be obtained from the same pit, such as are to be found on the contact line between limestone and

clay formations. One such contact is that between the Austin and Taylor formations on which, as already stated, the plant of the San Antonio Portland Cement Company is located. By reference to the map showing surface outcroppings of the formations, the approximate line of separation between these formations may be located in the county, thus aiding in the search for such favorable localities.

Another geologic horizon worthy of attention in this connection is that of the Del Rio clay together with the underlying Georgetown-Edwards limestones and the overlying Buda limestone. The Del Rio clay in this county has an average thickness of from 65 to 70 feet. The Buda limestone, which lies above this clay, is a very close-grained, quite pure limestone, having a thickness when fully developed of about 60 or 65 feet. The Georgetown-Edwards series of limestone below the Del Rio clay has a thickness of several hundred feet.

The Del Rio clay, as noted in the description of that formation, contains in places considerable pyrite and gypsum. In considering this clay for cement manufacture it will be necessary to make sure that these ingredients are not present at the locality selected. Nodules of calcium carbonate such as are sometimes present in this clay are, according to Eckel*, also to be avoided. The Buda limestone is a dense and usually very pure limestone rock, having a thickness of from 60 to 65 feet. Following is an analysis of the limestone of this formation as developed in the Chisos Mountains of Trans-Pecos Texas. The formation as developed in Bexar County probably differs to some extent from that used in this analysis, but the test is nevertheless illustrative of the chemical composition of the rock of this formation.

Analysis of Buda limestone from the Chisos Mountains. From the Buda Horizon, one mile east of Boquillas.†

	Per cent
Silica	2.35
Alumina	.21

*Cement Materials and Industry of the United States. U. S. Geol. Surv. Bull. 243, p. 38, 1905.

†A Sketch of the Geology of the Chisos Country, Brewster County, Texas. By J. A. Udden, Bull. 93, University of Texas, p. 28, 1907.

	Per cent
Ferric oxide	.24
Lime	53.90
Magnesia	.15
Carbonic acid	42.23
Water (hygroscopic)	.18
Water (combined)	.33
Sulphur	Trace
	99.59

The Georgetown-Edwards series of limestones lying beneath the Del Rio clays has a combined thickness of several hundred feet. The Edwards limestone contains at some horizons large masses and layers of flint such as would render it undesirable for cement making. The upper part of this limestone series, however, probably chiefly in that part of the section representing the equivalent of the Georgetown formation, contains relatively little flint. Hence there is an opportunity of finding limestones suitable for cement-making underlying, as well as overlying, the Del Rio clays.

By referring to the map it will be seen that the San Antonio and Aransas Pass Railway crosses the formation referred to in the northern part of the county.

Another formation that should receive consideration in a search for cement materials is the Eagleford. This formation, which consists of calcareous shales with interbedded thin limestones, lies between the Buda and Austin formations. In Bexar County the Eagleford formation as already stated is but little developed, having a thickness of about 30 or 35 feet only. Its distribution is such that surface exposures are numerous in which this formation is found lying upon the Buda Limestone, or underlying the hard limestones at the base of the Austin formation. No chemical analyses of the Eagleford shales of Bexar County are at hand, and so far as the writer is aware, no attempts have been made to utilize this formation in this county in cement manufacture. In Dallas County, the shales of this formation are combined with the

limestones of the overlying Austin formation in the manufacture of cement.*

CLAY

The clays of Bexar County are found chiefly in the Del Rio, Taylor, Navarro, Midway and Wilcox formations. The clays of the Del Rio formation are referred to under the discussion of cement materials. The clays of the Midway and Wilcox formations are utilized in the manufacture of building bricks. The clays of the other formations are undeveloped in this county.

BUILDING BRICK

Three plants in this county are producing building brick. These are: the Bem Brick Company, San Antonio; the Star Clay Products Company, Elmendorf; the San Antonio Sewer Pipe Works, Saspamco.

In the plant of the Bem Brick Company the clay used is that of the Midway formation. According to unpublished notes of C. L. Baker, the clay of this pit is a dark blue-gray, easily slaking clay, carrying much fibrous and platy selenite, and weathering light yellowish and drab, containing large brown cone-in-cone concretions and small nodules of limonite. The fossils recognized were *Turritella mortoni, Venericardia, Volutilithes,* and *Dentalium.* The clay of this pit is very similar to that exposed in the cut of the Missouri, Kansas and Texas Railway nearby. The bricks made from this clay burn to a light red color. Up-draft kilns are used, with mesquite wood as fuel. The bricks burn to a light red.

The clay used by the Star Clay Products Company is from the Wilcox formation. The manufacturing plant is at Elmendorf, but the clay pits are on the south side of the San Antonio River, about four miles from Elmendorf, the clay being transported from the pit to the plant by aerial tram. The following description of these clays is from notes made by Mr. Baker.

*The Geology of Dallas County. By Ellis W. Shuler. Univ. of Tex. Bull. No. 1818, p. 35, 1918.

In the clay pit the dip (perhaps not greatest) is 8° in the direction south 20° west. The Wilcox here consists of coarsely-laminated clayey sands. The sand is medium-grained and contains flakes of muscovite, some layers being more clayey, while others are laminated with thin seams of limonite. The clay is taken just as it occurs without sorting. The clay contains many leaf impressions. Layers of bluish white clay six to eight inches thick occur in the upper half of a fifteen foot section. These clay layers, if thicker, would probably make pottery clay.

The overburden at the pit consists of alluvial material amounting to from four to fifteen feet. This covering is often cemented with iron oxide indicating a near approach to the Mt. Selman formation. After removing the overburden the clay is plowed and dumped into tramway cars and hauled a couple of hundred feet by mule, and then attached to aerial tramway. Mexican labor is used.

This company formerly made jars, crocks, jugs, and flower pots, both glazed and unglazed, out of picked blue clay. At the present time this firm is making hollow tile and some brick. The tile and brick are wet-molded, then dried in kilns. Crude oil is used for firing the kilns, lignite being used for the boilers.

One of the pits of the San Antonio Sewer Pipe Works is in Bexar County near the south boundary, while the manufacturing plant and other pits are just across the line in Wilson County. The clay used is from near the top of the Wilcox formation. The following description of this plant is from the notes taken by Mr. Baker:

The overburden at the pit in Bexar County is a cross-bedded sand from 10 to 12 feet thick. The upper six to eight inches are light gray, below which is found four feet of light brick red sands, while the remainder beneath is a light brownish red. The sands are often mottled with red, the mottling being sometimes bordered with limonite or other cement. This overburden is removed by steam shovel. The dip in this pit as indicated at the contact between these sands and the underlying clay is one degree to the south.

The total thickness of the clay worked at this pit is about 18 feet. The clay is blue-drab in color and slakes on long exposure to the weather. It weathers in bedding planes and joint cracks with a rusty to brick red coating of limonite. It contains small nodules of limonite and stains of yellow alum. It contains also many well preserved fossil plant impressions, especially leaves of dicotyledonous plants.

At the manufacturing plant the clay from this pit is mixed with sandy clay from another pit. This company, which has been in

operation for twenty-two years, originally made stoneware, but is now making sewer pipe, drain tile, and wall copings. The beehive type of kiln is used. The clay burns dark brown.

FULLER'S EARTH

The fuller's earth deposits of Bexar County are being exploited at the present time by but one firm, the Medina Fullers Earth Company. The deposit that is being mined is located near the headwaters of a small stream north of the Castroville Road and west of the Cagnon cross road about 16 miles from San Antonio. The plant at which the earth is dried, ground, and prepared for market is located in San Antonio, the crude earth being hauled from the pit by trucks. In the pit at the present time there is seen an exposure of as much as 35 feet of workable fuller's earth. The overburden is moderate consisting of a few feet of soil and gravel.

The fuller's earth is of a light gray or drab color, becoming lighter colored upon drying. Upon fresh fracture, the clay breaks in a very characteristic manner which suggests at once the resemblance to the divisions of shells of ammonoids. The clay is seemingly entirely free from sand, and contains little if any calcareous material. When placed in water, or upon long exposure, the clay slakes into very finely-divided material. The soils derived from it are sticky, and with the inclusion of organic matter become dark in color.

The fuller's earth beds themselves contain no fossils, so far as observed. Their relation to the overlying fossil-bearing beds indicates, however, that they are either of the Navarro or Taylor formations of the Upper Cretaceous. From the record of the well drilled at the pit the place of the fuller's earth bed appears to be about 600 feet above the base of the Upper Cretaceous. Of this interval, the Eagleford and Austin formations occupy between 335 and 400 feet. While the records are less exact than could be desired, the fuller's earth bed of this pit is placed provisionally with the Taylor formation probably near its top. In the cut at the entrance to the plant a short distance northeast of the pit and also on the hills near the pit, are found exposures of the yellow clay containing an

abundance of the oyster *Exogyra costata.* These exposures lying at a slightly higher level probably indicate the Navarro formation.

The fuller's earth produced by this company is crushed into pieces of moderate size, not exceeding two or three inches in diameter and is then passed through a rotating drying cylinder to remove the excess of moisture. The clay is then ground and sacked for market. It is said to be chiefly used in clarifying vegetable oils including cottonseed oil, for which purpose the present practice is to grind the earth to pass a 200-mesh sieve. It is used also in clarifying lard. Aside from the finely ground earth, a part of the product is ground to a mesh of 16-32-60, the earth of this grade being used for mineral oils.

BENTONITE

In addition to the fuller's earth there is found in this county also in the Upper Cretaceous formations the material known as bentonite. The bentonite deposits of this county have been described in a circular previously issued by the Bureau of Economic Geology, which for convenience of reference is here reprinted. The circular was based on the work of Mr. C. L. Baker.

In the course of work in Bexar County, the Bureau of Economic Geology and Technology of the University of Texas has discovered a bed of the peculiar clay called bentonite, heretofore known only from Wyoming. Bentonite has the property of absorbing large quantities of various liquid substances. When freshly exposed, it is generally light yellowish-green or creamy white in color and has the appearance of wax. It often appears as a joint clay, breaking with a conchoidal fracture into roughly rectangular blocks. On surfaces exposed to the weather the outcrop looks much like that of ordinary clay, so it is necessary to dig in and expose the fresh material in order to be certain that bentonite really occurs. Bentonite has a soft, soapy feel, has very little or no grit, and is brittle. Mixed with the proper amount of water, it becomes very plastic; it differs from all ordinary clays or kaolins in being easily fusible at moderate heat. When placed in water it rapidly swells up and slacks, like quicklime. It completely absorbs over three times its weight or seven times its volume of water, and twice as much glycerin as diatomaceous earth will absorb.

Bentonite has been put to various uses. It is used for the manufacture of hoof-packing, a dressing for the inflamed hoofs of horses; and also in the manufacture of the medical dressing, antiphlogistine. Its chief use is to give body and weight to paper. It is also used as soap filler, in the manufacture of high grades of soap; to dilute powerful drugs in powdered form; and as an adulterant in candy. It is a good retarder for use with the hard cement plasters and would probably make a better absorbent of glycerin in the manufacture of dynamite than the diatomaceous earth now used for that purpose. Owing to its peculiar properties, it is likely to find more extensive and varied use in the future.

Bentonite has so far been found in commercial quantities in two widely distant localities in Bexar County. Probably further work will show up a number of other localities or perhaps a continuous bed outcropping across the country in an east-west direction. One of the known localities is in a long white bluff on the east side of Lucas Creek about ¼ mile northeast of the oil derrick on the B. F. Masterson ranch, north of the Castroville road in the western part of the county. The other locality is on Salitrillo Creek on the F. Siebold land, in the eastern part of the county. The bentonite has been found in a low north bank, a short distance downstream from the old road crossing the Salitrillo Creek.

CONCRETE

The concrete materials of Bexar County are obtained from the hard limestones, flints, cherts, and from the pebble and boulder deposits of the stream beds and valleys. The limestones best adapted for crushing for concrete are of the following formations: the Georgetown-Edwards limestone series; the Buda limestone; the basal strata of the Austin Formation; and the heavy limestone concretions of the Midway and Wilcox formations. In addition there are certain hard limestone ledges in the Glenrose and in the Eagleford and probably in some other formations that will serve this purpose. By reference to the map the general distribution of the surface outcroppings of these formations may be located.

The flint and cherts that may be used for concrete are chiefly those of the Edwards formation. The gravel and boulder deposits of the stream beds include material derived from the other formations, especially from the heavy Comanchean limestones. The stream deposits contain as a rule a mixed accumulation of flint and limestone pebbles and

boulders. The deposits of this kind are best developed in the Recent and Pleistocene stream beds for several miles south of the Balcones Escarpment. In all the central and northern parts of the county concrete materials may be obtained locally or at least by transportation for no more than a few miles.

GREENSAND

The Navarro formation as developed in Bexar County is characterized by beds of greensand, the distinguishing feature of which is the presence of the green-colored mineral, glauconite; a mineral containing a small amount of potassium. Numerous exposures of the greensand strata of this formation are found in the county. Of these perhaps the best known is an exposure at the south bank of Leon Creek between the Castroville and Pearsall road crossings. An analysis of this greensand has been given by Dr. Wm. B. Phillips in Bulletin 365 of the University of Texas, Page 69, 1914. The account of this phosphatic greensand deposit given by Dr. Phillips is as follows:

On Leon Creek, about 7 miles west of San Antonio, on the Castroville Road, there is a heavy deposit of phosphatic greensand of the following composition:

	Per cent
Silica	35.18
Alumina	5.30
Lime	16.00
Oxide of iron	17.25
Magnesia	Trace
Soda	1.39
Potash	1.69
Carbonic acid	8.00
Loss on ignition	10.10
Phosphoric acid	3.30
	98.21

This deposit contains rounded phosphatic pebbles, from 1/8-inch to ¼-inch in diameter, of the following composition:

	Per cent
Silica	7.50
Alumina	31.03
Oxide of iron	4.58
Lime	18.08
Carbonic acid	4.60
Phosphoric acid	18.19
Loss on ignition	12.60
	98.34

The larger pebbles are not abundant. For the most part, the pebbles are very small, less than 1-20 inch in diameter.

An examination of 10 feet of this phosphatic green sand foot by foot gave the following results, from above downward:

	Phosphoric acid Per cent
First foot	3.09
Second foot	2.38
Third foot	3.22
Fourth foot	3.07
Fifth foot	4.00
Sixth foot	2.73
Seventh foot	4.32
Eighth foot	2.60
Ninth foot	3.70
Tenth foot	3.97
Average	3.30

The total thickness of the deposit is about 20 feet, and it sets in at from 4 to 6 feet below the surface.

Taking the deposit as a whole, it carries enough lime, potash and phosphoric acid to make it a good fertilizing agent. The rock is soft and easily pulverized. It could be finely ground and used with distinct advantage on many farm lands in south Texas, especially those in the vicinity of San Antonio. With the exception of some "stray" phosphate in Fayette County, the exact locality of which is somewhat uncertain, the phosphatic pebbles from Leon Creek carry considerably more phosphoric acid than any other known deposit in the State.

LIGNITE

Lignite is found in commercial quantities in Bexar County in the Wilcox formation of the Tertiary system. The areal

distribution of the surface outcropping of this formation is indicated in a general way on the accompanying map. In the well logs, lignite is frequently reported in this formation*. These strata lie at varying depths below the surface and are of varying thickness from one to several feet. The individual lignite beds are doubtless of relatively local development, but the frequency with which they are reported indicates the possibility of beds of commercial value at places in the part of the county occupied by the Wilcox formation.

At the present time, a lignite mine is being opened up about 1½ miles west of Somerset. The company operating here is the Brackenridge Coal Company. The test pits indicate a lignite bed having a thickness of from 5 to 9 feet, lying about 44 feet below the surface, and including a sufficient areal extent to justify development. A branch line is now being built to the mine from the Artesian Belt Railway.

LIMESTONE

The limestone resources of this county are extensive. The Comanchean system in particular contains a great succession of thick limestones, particularly those of the Glenrose, Edwards, Georgetown and Buda formations. In the Upper Cretaceous the Austin formation is the chief limestone member. The distribution of these formations is indicated on the geologic map. The limestone formations are crossed by several of the railroads, particularly by the San Antonio and Aransas Pass Railway north of San Antonio.

The limestones suitable for cement and lime manufacture, and for building stone and road materials are separately discussed. Another possible use for the limestones is to grind and apply to acid soils. As is well known many of the soils of

*It is necessary to distinguish in well logs between the term "lignite" as used by drillers operating in the central part of the county, and the same term as used by drillers in the southern part of the county. The latter refer to the true lignite of the Wilcox formation, while the former refer to the dark carbonaceous shales of the Eagleford formation.

the Gulf Coastal Plains are acid in reaction and are benefitted for some crops by the application of ground limestone. For this purpose a pure limestone is desirable, thus reducing the amount of inert matter that it is necessary to transport

Analyses of the limestones of the Austin and Buda formations have already been given. The following test of a sample of the limestone of the Edwards formation has previously been published in University of Texas Bulletin 365, p. 66, 1914:

Analysis of limestone from San Antonio Lime Company.

	Per cent
Silica	0.70
Alumina	0.28
Oxide of iron	0.72
Lime	55.05
Carbonic acid	41.90
Loss on ignition	2.10
	100.00

Physical qualities:

Crushed at pounds per square inch	6,666
Weight of cubic foot	167.60
Per cent of cells by volume	0.20
Volume of cells in a hundred parts by weight	0.07
Pounds of water absorbed per cu. ft.	0.11

LIME

The limestones suitable for the manufacture of lime in Bexar county are extensive. The Edwards formation is a very pure calcium carbonate and several quarries have been opened in this formation for the manufacture of lime. Owing to unfavorable labor conditions no one of these quarries was in actual operation during 1918, although it is expected that this industry will be resumed as soon as conditions will permit. The San Antonio Lime Company located on the San Antonio and Aransas Pass Railway 14 miles from San Antonio use rock from this formation. The analysis of the limestone rock used by this company has already been given.

With large quantities of limestone rock available for lime manufacture the success of a plant of this kind will be de-

termined by the location with respect to markets, convenience and cost of transportation.

BUILDING STONE

The limestones of the Comanchean system offer very attractive stone for building, and are of service especially where conditions are such that they can be used without being transported and great distance. The Glenrose, Edwards, Georgetown and Buda formations are all capable of furnishing desirable building-stone. In the Upper Cretaceous the indurated ledges of the Eagleford formation have been used locally for building. These hard layers have the advantage of uniform thickness The basal members of the Austin formation likewise include ledges of hard limestone available locally for building purposes.

PETROLEUM AND NATURAL GAS

Petroleum in Bexar County was probably first produced in commercial quantities from the Dulnig wells about eight miles east of San Antonio. Subsequently oil and gas have been discovered at other localities, and at the present time there are perhaps between 60 and 70 producing wells in the county.

The oil has been obtained chiefly in the southern part of the county, south and southwest of San Antonio. Although somewhat scattered, the producing wells, all of which are small in production, may be grouped as the wells are now known into four or five more or less well defined fields or areas. The location of these areas is indicated on the key map to the resources of Bexar County (Fig. 6). They are as follows: Alta Vista, Mission, South Medina, Gas Ridge, Somerset, and some oil wells southeast and southwest of the Somerset field.

The Alta Vista field lies about eight miles due south of San Antonio on the west side of the Pleasanton Road. The Mission field lies about three miles west of the Alta Vista field, or about twelve miles slightly west of south of San Antonio. The Somerset field is near the Bexar-Atascosa county line 18 miles southwest of San Antonio. A gas and oil field lies between Leon

and Media Creeks from eight to twelve miles southwest of San Antonio. To this field no name seems to have been applied although it is referred to locally as the "Gas Ridge". South of the Medina River, three or four miles south of the Mission field, several wells have been brought in recently, located on the Kimbley-Brown lease chiefly on the Swearingen property. A few additional wells are found in the county not included within any one of the areas mentioned.

At the present time (1918) five wells are producing in the Alta Vista field, of which one flows and four are pumped. In and near the old Mission field there are about seven wells producing. In and near the old Somerset field within Bexar County, about fifty small wells are now producing. All of the wells at present producing in these three fields are small, making from two or three to five or six barrels per day. In the Atascosa County extension of the Somerset field, better wells are obtained some of which are reported to make fifteen barrels or more per day.

All of the wells thus far obtained in this county obtain oil from the Upper Cretaceous formations; in the Alta Vista and Mission fields, from the Austin formation; and in the other fields chiefly from the Taylor and Navarro formations. The oil from the Austin formation is a heavy oil, reported to be about 14 or 15 degrees Baumé, while that of the Taylor and Navarro formations is much lighter, averaging about 36 degrees Baumé. Some of the oil from the Somerset wells may come from the Midway formation.

THE ALTA VISTA FIELD

The first showing of oil in the Alta Vista field is said to have been in a well drilled for water. This led subsequently to other wells being drilled, and in September, 1915, the Mars Discovery well was brought in, the initial production of which was reported at the time to be as much as 125 barrels per day. The impetus given to drilling by this and by subsequent successful wells led to very active development in this field for a short time. Subsequently the wells rapidly dropped off in production.

THE MISSION FIELD

The Mission oil field may be regarded as essentially the southwestward extension of the Alta Vista field. The first well indicating oil drilled in what subsequently became known as the Mission oil field is said to have been drilled for water in June, 1901. This well showed oil at the depth of 275 feet. Following the discovery of this showing of oil, drilling was undertaken in this field by Nash and Fitzgerald who finally completed, in 1907, a 2900 foot well on the Linn farm. This deep well, a record of which is given under the section on well records, yielded a flow of sulphur water and was non-productive of oil. In this field after passing through showings of light oil, heavy oil similar to that of the Alta Vista field is obtained at the depth of about 1000 feet. Sulphur water is encountered below the heavy oil as in the Alta Vista field.

GAS RIDGE OIL AND GAS FIELD

The Gas Ridge oil and gas field lies west of Leon Creek and north of the Pearsall (Frio) road, and is located chiefly on what is known as the Hamilton-Swain and Cohen lands. Two wells were drilled in this field some years previous to 1916. Additional wells yielding gas and some oil were drilled during 1916 and at the time of the preparation of this report several additional wells were being drilled. This field was visited in 1916 by Mr. E. L. Porch, Jr., and the following extract is from the report made to the Bureau of Economic Geology by him at that time on the new wells then being drilled or recently completed.

> These wells are all within a few hundred feet of two gas wells which were drilled here several years ago. The gas from one of these wells is used as fuel for the present work, the other well being connected up so that it can be used if needed. There is a third well, about a half mile south of these two gas wells, which is said to have also been a gas well. . . . .
>
> Sarber well No. 1, in which oil was first struck, is located on the Hamilton-Swain tract, while Sarber No. 2 is located on the Abe Cohen tract, and is about 500 feet east of No. 1. Well No. 1 was

drilled with a standard rig, and is 492 feet deep. No. 2 was drilled with a rotary rig, to a depth of 1035 feet.

At the time of my first visit on Friday, a packer was being placed in No. 1, and I could hear the gas bubbling in it. No. 2 was down about 1000 feet and was showing some oil and gas.

I took a sample of the oil said to have come from No. 1, and samples of all of the cuttings from known depths. There was a barrel of the oil near the derrick, and it had been standing some eighteen hours, but notwithstanding this fact, it smelled something like gasoline, and had a specific gravity of 29.1° Baumé. The oil sand in No. 1 is said to be 22 feet thick.

On the afternoon of the next day (Saturday) oil was struck in No. 2 at a depth of 1035 feet, it being estimated that the drill penetrated the "oil sand" less than a foot. On Sunday afternoon I made my second trip, but could not obtain a sample of the "oil sand," and all the oil I could secure was some skimmings from the slush pit. This oil has a specific gravity of 12.8° Baumé, and appears very similar to the oil obtained in the Alta Vista field, which is about 8 miles southeast of this field.

These gas wells were said to have had an initial pressure of 350 lbs. per square inch, and they still have sufficient pressure (judging from observations of the one I saw tried) to shoot a flame out about forty feet from the mouth of a four inch pipe, with a roar that could probably have been heard over a mile away. . . .

The logs of the wells in this field indicate a succession of clay shale and gumbo. Chalky rock is noted in some of the deeper wells. There is little or no water in the higher formations although water is doubtless to be expected in wells drilled somewhat deeper. The wells start, aside from the surface materials, in the Navarro formation. The shallow oil and gas with little doubt comes from the Taylor formation. The deeper oil, which is much heavier than the shallow oil, may come from the Austin formation. The gas is probably from the Taylor formation at the depth of about 800 feet.

THE SOMERSET OIL FIELD

As in the case of the Alta Vista and Mission fields, the Somerset field was discovered as the result of drilling for water. About 1913, Mr. C. Kurz while drilling for artesian water on his property two miles east of Somerset encountered oil which led to other wells being drilled by himself and others.

The field in Bexar County now has about 50 small wells. In this field the oil immediately east of Somerset is reported as being obtained from hard shale at from 850 to 900 feet. South and southwest of Somerset, however, the wells are deeper, reaching in this county a maximum of about 1250 feet. In the extension of the field into Atascosa County, somewhat deeper wells are required to reach the producing horizon.

On the Kurz property boulders are reported as being encountered occasionally to the depth of about 300 feet. Below this level is chiefly shale and gumbo. On the Witherspoon lease adjoining the Kurz property similar conditions are encountered. The generalized log of the wells on this property is given by Mr. Kurz as follows: Alternating beds of sand and rock from the surface to the depth of 270 feet. Water in the formation at intervals to about 300 feet. Below about 270 or 300 feet is alternating shale and gumbo strata with little or no water.

The wells on the Harrison property, Slimp and Davidson lease, south of Somerset, reach the producing sand at about 800 feet. The wells of the Crosby lease, on the other hand, near the county line, reach a producing horizon at the depth of about 1250 feet.

THE SOUTH MEDINA OIL FIELD

Several oil wells were brought in south of the Medina River during 1918 by Kimbley and Brown. These wells reach the producing horizon here at the depth of from 1250 to 1350 feet. The materials passed through are indicated by the logs of the wells kindly supplied by Mr. Brown, and published in the chapter on well records. The wells start in the Tertiary formations and probably terminate in either the Navarro or Taylor formation. In the Park Oil and Gas Co. test well, Applewhite No. 1, located less than one mile southeast of Kimbley and Brown, Swearingen No. 4, the Austin formation appears to have been reached at 1896 feet from the surface.

RELATION OF THE BEXAR COUNTY OIL FIELDS TO STRUCTURE

In the Alta Vista field the producing horizon lies more than 100 feet nearer the surface at the north side of the field than

at the south side. A part and perhaps the greater part of this difference in elevation is accounted for by the small fault or abrupt monoclinal fold which passes through this field to which reference has already been made. The following data on the depth to the producing horizon in this field were secured chiefly from Messrs. Ross, Mull and Raborn, operators and drillers in this field.

Wells of Alta Vista field arranged approximately in order from north to south.

Name of well	Elev.	Depth to Prod. Horizon	Actual level Prod. Horizon
Ingram well	615	1020	405
Fuchs No. 2	615	1020	405
Aiken	605	1020	415
Mars Discovery	600	1070	450
National Oil Co.	585	1120	585
Busby Well	555	1150	595

The most striking feature of these records is the apparent change in level of more than a hundred feet between the last two wells and those which precede. This change in the level of the producing horizon appears to be essentially in the line of the fault already referred to.

In the Somerset field the data on structure are unfortunately very limited. In that part of the producing area lying from ½ to 1½ miles southeast of Somerset, the dip in the strata is pretty definitely shown to be to the southeast. On the Kurz property near the Artesian Belt Railway about 1½ miles from Somerset, the dip was found from well records to amount to 40 feet in about one-third of a mile. In addition to a southeast dip the structures in the vicinity of Somerset plunge to the southwest as is indicated by the increased depth of well in passing from Bexar to Atascosa County.

On the Swearingen property south of the Medina River the dip in the producing horizon in a direction slightly east of south, as shown by the wells of the Kimbley-Brown lease, is as much as 115 feet in a little more than a mile in a direction slightly east of south.

It is thus seen that the producing wells in the fields on which

definite data are available are located on the southeast slope of the structures. On other data already presented it is shown that these structures are asymmetrical, having a long southeast slope and a more abrupt northwest slope or limb; some of the structures possibly being at the northwest side by abrupt dips or by dips and faults. In extending explorations it appears reasonable, therefore, to anticipate the possibility of similar structures with, in general, a northeast-southwest trend farther to the southeast from those already known.

QUALITY OF THE BEXAR COUNTY OIL

As has already been stated the oil obtained from the Austin formation is much heavier than that from the overlying Taylor or Navarro formations. The following gravity tests of the Bexar County oils have been made at various times in the testing laboratory of the Bureau of Economic Geology. The first three oils are probably from the Taylor or Navarro formations; the others are probably from the Austin formation. The gravity was taken at 60° F.

No. 1. Crude petroleum from near Somerset, 18 miles south of San Antonio; gravity, 35.8 ° B.

No. 2. From a well at Somerset, Bexar County; gravity, 30.7 ° B.

No. 3. Said to have come from Sarber well No. 1, Hamilton Swain Tract, about 9½ miles southwest of San Antonio, at a depth of 492 feet; gravity 29.1 ° B.

No. 4. Collected from scum of pit on H. Cohen Tract, Sarber No. 2 well, about 500 feet east from Sarber No. 1, at a depth of 1035 feet; gravity, 12.1 ° B.

No. 5. From National Oil Company No. 1, 1115 feet below surface, in Alta Vista field, Bexar County; gravity, 14 ° B.

No. 6. From Marr's No 1 well, Bexar County; gravity, 14 ° B.

No. 7. Crude oil from Kelso well No. 1, 8 miles south of San Antonio; gravity, 14 ° B.

GENERAL CONSIDERATIONS

The oil fields of Bexar County are located on structures which lie within and are a part of the disturbed area of the Balcones fault-zone, the structure approximately paralleling

the Balcones Escarpment. The location of this county near the turn of this fault zone from the northeast-southwest to an east-west direction accounts possibly for the very heavy faulting as well as for the southwest plunge of the structures. The structurally high areas appear to be limited at either side in part by faults and in part by abrupt dips, the longest slopes being to the southeast. It is probable that the producing wells are located chiefly on the southeast slope of the structures. This is true at least for the Alta Vista, South Medina, and Somersat fields, the data on the Mission and Gas Ridge fields being at present less definite. Production in this county is from the Upper Cretaceous, the Lower Cretaceous not having been found to be producing. Wells drilled to test formations below the Cretaceous, if located in the central or southern part of the county, must expect to drill through 3500 feet or more of sediments before reaching formations older than the Cretaceous. Near the Balcones Escarpment the formations next beneath the Cretaceous have been found to be schists. Whether or not the Pennsylvanian or other formations come into the section farther to the south, between the Cretaceous and the schists, has not been determined. If wells are drilled in search of production below the Cretaceous, the more promising locations are on structures as far removed, the required drilling depth being considered, as practicable from the Balcones Escarpment. In the further development in the Upper Cretaceous and Tertiary formations it is suggested that structures already known may be followed in their southwest trend, and that other similar structures may be looked for to the south or southeast of those already known.

ROAD MATERIALS

The road materials in Bexar County include gravel, limestone rock and sandy clays. Of these materials the gravels are the most generally utilized, and are found in the stream beds and in the flood plain deposits of the Leona and Uvalde formations. The distribution of the limestones and clays has already been indicated.

WELL RECORDS

In this section will be found records of the wells that have been utilized in making the contour map showing structure and in describing the water supply conditions in the county. Since in the structural map the key horizon used is the Del Rio formation, the actual level of the top of this formation is given for all wells as nearly as this can be determined or estimated from the well logs. The wells are numbered for convenience of reference and are entered according to the formations in which they terminate, those reaching the oldest formations being first listed.

WELLS ENTERING THE PRE-CRETACEOUS FORMATIONS

As has already been stated, two wells in this area enter the pre-Cretaceous formations. The description of the cuttings of these wells will subsequently be published by Dr. J. A. Udden in connection with the destription of samples from other wells in the State. The two wells are as follows:

1. Well on Leon Springs Military Reservation, about 2 miles northeast of Leon Springs Station; elevation about 1156 ft. above sea level; log made from the driller's records and submitted to the Bureau of Economic Geology by Alexander Deussen.

	Depth in feet
Quaternary:	
Black soil	0- 4
Gravel	4- 15
Glenrose:	
Yellow limestone	15- 25
Blue limestone, a little water	25- 44
15″ casing set at 44,	
Blue clay	44- 50
Blue limestone	50- 58
Blue clay	58- 70
Blue clay and yellow lime mixed	70- 95
Yellow limestone	95- 125
Blue limestone	125- 140
Blue clay	140- 155
Gray limestone	155- 160
Yellow limestone	160- 180

Glenrose:	Depth in feet
Yellow limestone honey-combed	180- 199
Blue clay	199- 210
Gray limestone	210- 247
When 600′ was reached, water dropped to 300′ of surface. Water struck at 230′ appeared to be a strong vein; rose 50′	
Blue clay	247- 254
Gray limestone	254- 309
Crystallized limestone	309- 315
Blue limestone	315- 366
Gray limestone	366- 375
Hard white crust limestone	375- 382
Gray limestone clay in seams	382- 400
Yellow limestone	400- 433
Blue clay	433- 487
Gray limestone	487- 535
Travis Peak formation:	
Dark gray sandstone	°535- 570
Blue clay	570- 620
Blue sandstone	620- 690
10″ casing set at about 635′	
Brown stone	690- 708
Blue stone	708- 775
Blue clay	775- 790
Red clay	790- 792
Brown stone	792- 800
Light blue clay	800- 842
Red clay	842- 847
Blue clay	847- 855
Green and red clay mixed	855- 865
Gray stone	865- 875
Red clay	875- 950
Red clay	950- 975
Red sandstone	975- 985
Gray sandstone	985-1010
Conglomerate rock, small vein of water struck	1010-1015
Pre-Cretaceous:	
Brown clay	1015-1045
Slate	1045-1077
Slate	1077-1184
Slate seamed with quartz	1184-1244
Slate mixed with quartz	1244-1305

Pre-Cretaceous:	Depth in feet
Slate and oil	1305-1344
Vein opened in cleaning out well. Water rose to 280′ of surface	
Slate mixed with quartz	1344-1645
At 1645′, casing reduced from 8″ to 6″.	
Slate mixed with quartz	1645-2035
At 1728′, 8″ casing from surface	
Slate	2035-2500
No water. 6″ casing	

2. Well on Camp Bullis Reservation, east of S. A. P. Ry., about 14 miles northwest of San Antonio. Benkendorfer, driller. Elevation, about 1050 feet. Record based on examination of samples by Dr. J. A. Udden and V. V. Waite.

The surface exposure at the well shows remnants of the Buda limestone underlaid by the Del Rio clay which is recognized as extending to a depth of 53 feet. Beneath the Del Rio is found the thick series of Comanchean limestone including presumably the Georgetown, Edwards, Comanche Peak, Walnut clays, Glenrose, Travis Peak and Basement sands. The Glenrose fossil Orbitulina was recognized in samples from 584 feet and deeper, indicating that the Georgetown, Edwards, and Comanche Peak formations are included in the interval from 53 to 594 feet, or less, from the surface. Orbitulina continues to the depth of 1036 feet. From about 1270 to 1770 the cuttings show numerous layers of blue clay and shale alternating with limestones and marls together with red calcareous clays and shales and some quartz sand this part of the section presumably being within the Travis Peak formation. At 1799 feet and below to the bottom of the well, 1905 feet, the cuttings indicate shists similar to those of the deep well on the Leon Springs Reservation. The formations encountered in this well may be tentatively given as follows: Buda, 0-14 feet; Del Rio, 14-53 feet; Georgetown, from about 53 to about 95 feet; Edwards, (including Comanche Peak and Walnut clays if present) from about 95 to 580 feet; Glenrose and Travis Peak (not inclusive of basement sands) 580 to about 1710 feet. Basement sands 1710 to 1790 feet. Below 1790 feet to the depth of the well (1910 feet) is pre-Cambrian schist.

With regard to schists Dr. Udden states: The two dark schists seen in the lowest one hundred feet of this boring were carefully tested by J. H. Stullken and found to contain four per cent of fixed carbon, but practically no combined carbon. This fixed carbon is graphite. Tests for manganese were negative. The formation represented is probably the Pack Saddle schist.

This well is of especial interest as giving practically the full section of the Comanchean, and also as indicating the presence of schists beneath the Comanchean immediately south of the Balcones Escarpment. Of the Comanchean formations there is wanting at

this well only the upper part of the Buda. The actual thickness of Comanchean drilled through is 1770 feet. To this should be added about 50 feet to account for the full thickness of the Buda limestone. Thus the Comanchean at this locality is about 1820 feet thick.

Log of well at Camp Bullis Reservation, San Antonio, Bexar County, Texas, August, 1919. Furnished by F. G. Chamberlain, Constr. Q-M., Camp Travis.

Buff colored limestone	0-	7
Buff colored limestone, lighter than above	7-	14
Buff colored marl	14-	38
Yellow marl	38-	50
Yellow clay	50-	53
Straw colored limestone	53-	65
Yellow limestone, fine texture	65-	68
White limestone	68-	72
Yellow limestone	72-	78
White limestone	78-	89
Cream colored limestone	89-	93
White limestone	93-	113
Cream and light gray limestone	113-	118
Light gray limestone with gray flint	118-	124
Cream and light gray limestone	124-	129
Compact gray limestone	129-	146
Cream colored limestone, some flint	146-	158
Cream colored and light gray limestone	158-	170
Compact cream colored limestone	170-	186
Cream and light gray limestone	186-	194
Cream colored and some yellow limestone	194-	197
Grayish white limestone	197-	207
Compact cream colored limestone	207-	221
Light cream colored limestone	221-	230
Yellow foraminiferal limestone	230-	232
Yellow limestone red blotches	232-	237
Yellow and gray limestone, red streaks	237-	244
Blue limestone	244-	246
Bluish gray limestone	246-	255
Yellow limestone	255-	260
Yellow and gray limestone	260-	277
Yellow limestone	277-	288
Yellow limestone and light gray sandstone	288-	292
Light gray dolomite	292-	302
Gray limestone	302-	315
Gray dolomite	315-	325
Gray limestone	325-	331
Dolomitic gray limestone	331-	348

Oolitic foraminiferal gray limestone 348- 352
Gray marly limestone 352- 360
Gray impure limestone 360- 387
Gray fine grained limestone 387- 392
Light blue gray limestone 392- 397
Fine-grained gray limestone 397- 415
Gray soft marly limestone 415- 456
Gray oolitic foraminiferal limestone 456- 472
Gray marly limestone 472- 493
Gray soft organic limestone 493- 515
Gray dolomite, limestone, some shale 515- 520
Gray foraminiferal limestone 520- 530
Gray dolomite, limestone, some quartz sand 530- 535
Gray organic fragmental limestone 535- 608
White foraminiferal limestone 608- 612
White fine-grained limestone 612- 617
White porous organic fragmental limestone 617- 626
White limestone, some quartz sand 626- 630
Light gray foraminiferal and organic fragmental limestone 630- 641
Gray limestone, some bluish gray marly shale..... 641- 646
Gray limestone 646- 655
Fragment of stalactite 655- 660
Gray foraminiferal and organic fragmental limestone.. 660- 679
Gray marly limestone and bluish gray marly shale.... 679- 683
Light gray foraminiferal and organic fragmental limestone 683- 707
Bluish gray marl 707- 737
Light gray marly limestone 737- 743
Light gray limestone 743-1090
Gray limestone 1090-1100
Dark gray limestone 1100-1112
Dark gray limestone and gray marl 1112-1119
Gray limestone and white marl 1119-1120
Gray limestone and gray marl 1120-1125
Gray limestone, organic fragmental 1125-1144
Gray limestone, some gray marl 1144-1150
Dark gray marl and some dark gray limestone.....1150-1161
Gray marl 1161-1167
Gray limestone, white limestone, blue marl 1167-1173
White and dark gray marl, some yellow limestone....1173-1179
Light gray limestone 1179-1186
Light gray marly limestone 1186-1209
Blue and white marly limestone 1209-1219
Light gray marly limestone 1219-1232
Gray and cream colored limestone 1232-1240

Greenish gray marl, some fine gray sandstone.....1240-1247
Light gray and marly limestone.....1247-1253
Light blue marly clay 1253-1255
Fragment of echinoid spine, cytherea 1255-1258
Gray limestone 1258-1259
Light buff colored limestone, some marl, pyrite and sand 1259-1262
Gray marl 1262-1269
Buff colored limestone, gray limestone, gray marl, some calcite, sandstone, and chert 1269-1270
Blue and white marl 1270-1279
Light blue shale, some white marl 1279-1284
Blue marly clay 1284-1303
Dark gray organic fragmental limestone 1303-1310
Blue marly shale, some white marl and fine buff colored limestone 1310-1316
Blue marl with gray limestone 1316-1322
Blue marly shale 1322-1334
Dark gray organic fragmental limestone 1334-1345
Gray organic limestone 1345-1475
Blue marly shale, some quartz and sand.....1475-1479
Blue marly shale and some gray limestone.....1479-1484
Blue marly shale and some sand.....1484-1501
Soft blue marl 1501-1528
Dark olive green and some light gray marl.....1528-1533
Bluish green marl and some light gray marl.....1533-1539
Bluish gray marl, some marly shale, and quartz.....1539-1549
Blue marly shale 1549-1623
Soft blue calcareous shale 1623-1625
Light red marly shale 1625-1647
Soft light green marl 1647-1654
Bluish gray marl 1654-1657
Brownish gray marl 1657-1660
Light gray marl 1660-1666
Light greenish gray marl 1666-1673
Light brownish colored marl, much sand 1673-1675
Light brownish colored marl and less sand.....1675-1689
Light colored marl.....1689-1703
Light buff colored siliceous limestone.....1703-1711
Light buff colored calcareous sand 1711-1766
Light buff colored limestone with fine and coarse sand.1766-1770
Dull yellowish gray schistose shale.....1770-1779
Yellowish gray schist, part purple 1799-1802
Dirty brownish gray and bluish gray schist 1802-1808
Dark and light brownish gray schist.....1808-1816
Slightly micaceous schist, white and gray quartz.....1816-1822

Dark gray schist, some quartz 1822-1830
Dark gray, dull red and purplish schist, some quartz..1830-1835
Dark gray schist, some greenish and reddish.....1835-1847
Dark with little pinkish gray schist.....1847-1856
Dark gray schist with reddish and light greenish gray.1856-1869
Very dark almost black graphitic schist.....1869-1875
Schist, dark gray, reddish, and greenish gray.....1875-1895
Like preceding but more green.....1895-1900
Blackish gray graphitic schist, some quartz.....1900-1910

WELLS TERMINATING IN THE COMANCHEAN

The term "non-flowing" is used for wells in which the water rises in the boring but does not reach the surface. "Flowing" wells are those in which the water overflows at the surface. The head of the water above or below the surface is given for some of the wells; however, the head varies considerably, as already stated, with the season, and the record for any well is likely to vary according to the season in which the measurement was made. In the well records, the following data are given in order, so far as available: Name of owner; location of well; depth; elevation at the well; water, whether flowing or non-flowing; elevation of the top surface of the Del Rio formation above or below sea level. These data are followed by the log of the well if available. The approximate location of most of the wells is indicated on the contour map by the entry showing the level of the top surface of the Del Rio formation.

With the elevation of the top of the Del Rio recorded, the level of the other Comanchean and Cretaceous formations can be approximately determined. The top of the Comanchean (base of the Upper Cretaceous) lies about 65 or 70 feet higher than the Del Rio; the Georgetown-Edwards series of limestones, the principal water reservoirs of this county, lie immediately below the Del Rio or about 70 feet lower than the elevation given. The Upper Cretaceous formations are 1200 or 1300 feet thick. An asterisk placed after the number of the well in the table indicates that a log or other data are given following the tabulated record.

WELLS TERMINATING IN THE COMANCHEAN (LOWER CRETACEOUS) FORMATIONS.

No.	Owner	Location with Reference to San Antonio Courthouse	Depth	Elev.	Water	Depth of Del Rio from Surface	Elev'tion Top of Del Rio	Marine Formations Penetrated
3*	Ackerman, H. J.	6 miles east†	1409	665	Non-flowing	950-1000	—285	Taylor to Edwards.
4	Acme Irrigation Co.	N. E. of Kelly Field†	1480	685	Non flowing	995-1045	—310	Taylor to Edwards.
5*	Alamo Waterworks	Alamo Heights	540	815	Non flowing —149	430- 500?	385?	Austin to Edwards.
6*	Allen, D. J.	Kelly Field†	1595	680	Non flowing —5	1000-1054	—320	Navarro to Glenrose.
7	Allen, D. J.	South of Kelly Field†	1488	662	Flowing	990-1045	—328	Navarro to Edwards.
8	Artesian Ice Co.	807 Avenue B†		660	Flowing	586- 646	74	Taylor to Comanchean
9	Artesian Water Co.	4 miles south†	1206	673	Flowing +10	995-1053	—322	Navarro? to Edwards.
10	Altgelt, E. J.	10 miles noth†	355	1000	Non-flowing	265- 325	735	Austin to Comanchean.
11	Altgelt, E. J.	9½ miles north†	560	1060	Non-flowing	480- 540	580	Austin to Comanchean.
12*	Basse, Ed. F.	5 miles north†	590	760	Non-flowing	500- 555	260	Taylor? to Edwards.
13	Baysan, Gus	Cupper's Lane	1146	685	Non-flowing	1040-1100	—355	Navarro to Georgetown.
14*	Bencke, Mrs. Kate	22 miles northwest†	1000	1030	Non-flowing —360	880- 940	150	Taylor to Edwards.
15	Benz, H.	8 miles northeast†	1500	695	Non-flowing —36	389- 446	306	Austin to Glenrose.
16*	Biering, H. T.	15.6 miles northwest†	359	950	Non-flowing —278	At surface	950	Del Rio to Edwards.
17	Bexar County	Courthouse†	872	656	Flowing +20	650- 700	6	Taylor to Edwards.
18*	Blank, J. T.	6 miles west†	1483	710	Non-flowing —47	1163-1228	—453	Navarro to Edwards.
19*	Blue Wing Club	12 miles south†	2440	490	Flow. sulphur water	2140-	—1685±	Wilcox to Edwards.
20	Boerman, A.	10.5 miles northwest†	351	815	Non-flowing	270- 330	545	Austin to Georgetown.
21*	Boerman, D.	11 miles northwest†	403	880	Non-flowing —178	320- 385	560	Austin to Edwards.

22	Brady, T. F.	Cervalo street†	1500	668	Non-flowing —4.5	750- 800	—82	Taylor to Glenrose.
23	Brackenridge, Geo.	Northeast of Country Club†	1018	630	Flowing +34	540- 585	90	Taylor to Edwards.
24*	Brendle, H.	527 Bandera Street†		720	Non-flowing	493- 583	227	Taylor? to Comanchean.
25	Bruhn, H.	8 miles north†	665	1010	Non-flowing	390- 460	620	Austin to Edwards.
26	Carney, Glen	7 miles east†	1226	650	Flowing	1600±	—3502	Navarro? to Edwards.
27*	Clamp, C. C.	6 miles west†	1452	700	Non-flowing —24	1110-1162	—410	Navarro to Edwards.
28*	Collins Mfg. Co.	½ mile northeast†		660	Flowing	720- 800	—60	Taylor to Comanchean.
29	Collins, F. F.	San Antonio	906	660	Flowing +28	840- 890	—180	Taylor to Georgetown.
30*	Collins Gardens	Southwest†		650	Flowing	930-1000	—280	Taylor? to Comanchean.
31	Community Well	Cupper's Lane†	1005	685	Non-flowing, near surface	930- 995	—245±	Taylor? to Georgetown.
32	Davis, Ross	5 miles north†	568	750	Non-flowing	500- 555	250	Taylor? to Georgetown.
33*	Dickenson	8 miles west†	602	850	Non flowing —180	497- 567	353	Taylor? to Georgetown.
34	Doboralski, Wm.	San Antonio	1405	670	Flowing?	995-1049	—325	Navarro? to Edwards.
35	Edgewood Water Co.	Edgewood, San Antonio†	1005	680	Non flowing	925- 975	—245	Navarro? to Georgetown.
36	Electric Light Co.	San Antonio	1000	620	Flowing +42	838- 900	—218	Taylor to Edwards.
37	Epps, J.J.	Frio road near city limits	950	665	±	830- 880	—165	Taylor to Edwards.
38	Frey, Carl		1140	700	Non-flowing —13	1000-1050	—300	Navarro to Edwards.
39	Friesenhahn, Joe	13 miles northeast†	410±	850±	Non-flowing	352- 408	498±	Austin to Edwards.
40	Gates & Co.	West Gardendale†	1413	690	Non-flowing —27	1029-1084	—339	Navarro to Edwards.
41*	Geunther Milling Co.	902 Morales street†		675	Non flowing	650- 700	25	Taylor to Comanchean.
42	Gibbs Building	Houston and Alamo streets	860	665	Flowing +20	675- 725	—10	Taylor to Edwards.
43	Goforth, A. E.	18 miles northwest†	564	940	Non flowing —330	444- 504	496	Austin to Edwards.
44*	Government Well	At Aviation post†	874	735	Non-flowing	418- 494	317	Taylor? to Edwards

WELLS TERMINATING IN THE COMANCHEAN (LOWER CRETACEOUS) FORMATIONS—Continued.

No.	Owner	Location with Reference to San Antonio Court-house	Depth	Elev.	Water	Depth of Del Rio from Surface	Elev'tion Top of Del Rio	Marine Formations Penetrated
45*	Government Well---	Hackberry St. near Ave. C†	729	689	Non-flowing —3----	620- 673	69	Taylor to Edwards.
46*	Grote, F.----------	6.5 miles northeast†-------	339	840	Non-flowing —159---	272- 332	568	Austin to Georgetown.
47	Gunter Hotel------	Houston and St. Mary sts	1018	658	Flowing +24-------	675- 725?	—22?	Taylor to Edwards.
48	Haag's Store-------	0¼ miles north----------	325	845	Non flowing --------	245-	600?	Austin to Edwards.
49*	Harrison, Jud------	8.5 miles north†---------	328	900±	---------- ----------	245- 300	655±	Austin to Georgetown.
50	Hartman, Paul------	9 miles west†----------	680	770	Non flowing —80----	560- 620	210	Taylor to Edwards.
51	Hearne, Roy--------	Alameda Gardens†--------	1200	730	Non-flowing --------	700- 750	30	Taylor to Edwards.
52	Hearne, Roy--------	¾ mile northwest No. 51†	745	740	Non flowing —76----	620- 670	120	Taylor to Edwards.
53	Hearne, Roy--------	1 mile west of No. 51†------	809	739	Non-flowing —86----	513- 575	226	Taylor to Edwards.
54	Heine, H.----------	11.5 miles west†---------	715	710	?----------	595- 655	115	Taylor to Edwards.
55	Hease, Chas.-------	9 miles west†----------	620	770	Non-flowing —80----	500- 566	270	Taylor to Edwards.
56*	Herft, H.----------	4.5 miles west†----------	1266	682	----------	1100-1155	—418	Navarro to Edwards.
57*	Hill & Roby-------	7.5 miles south†---------	1890	625	Flow. sulphur water	1695-1750	—1070	Tertiary to Edwards.
58	Hoffman, Mrs. C.---	19 miles northwest†-------	736	975	Non flowing —315---	606- 666	369	Taylor to Edwards.
59*	Hofheintz, R. H.---	North of Kelly Field†-----	1453	680	?----------	995-1049	—315	Navarro to Edwards.
60*	Holtz, Well--------	9 miles southwest†-------	1665	610	Flow sulphur water	1525-	—915±	Tertiary to Edwards.
61	Hooge & Waters----	Zalzamora and Laredo sts.	1475	650	Flowing ----------	950-1000?	—300?	Navarro to Edwards.
62	Hornenberger------	9 miles northwest†-------	--------	870	Non-flowing --------	400- 470±	470	Austin to Comanchean.
63*	Hot Wells Hotel----	4.5 miles south†----------	-------	575	Flowing ----------	1445-	—870	Tertiary? to Comanchean

64	Hubble, L. M.	Menchaca Street†	490	670	Non-flowing	410- 470	260	Austin to Georgetown.
65	Kallson, N.	19 miles northwest†	786	980	Non flowing —330	620- 680	360	Taylor to Edwards.
66	Kearney, C. H.	4 miles east?	1225	650	Flow sulphur water	987-1034	—337	Navarro to Edwards.
67	Kearney O. & P. L. Company.	12 miles south†	2355	610	Flow. sulphur water	1451-1491	—841	Tertiary to Travis Peak.
68	Kirkpatrick, J. H.	Southwest?		650	Flowing	998-1048	—313	Navarro to Comanchean.
69	Koelben, Joe	?	1105	640	Flowing +40	1030-1080	—390	Navarro to Georgetown.
70	Koeps, A.	8 miles northwest†	620	751	Non-flowing —80	500- 569	257	Taylor to Edwards.
71	Kreutch, Oscar	5.5 miles east†	1000	675	Non-flowing —7	890- 940	—215	Taylor to Edwards.
72	Lady of Lake Acad.	West city limits†	1380	685	Non-flowing —25	1054-1104	—369	Navarro to Edwards.
73*	Lake View Addition	24th Street	591	678	Non-flowing			
74*	Legler, W. F.	5 miles west†	1565	695	Non flowing —20	1167-1220	—472	Navarro to Edwards.
75*	Locke, J.	5 miles north†	380±	750	Non flowing —95	310- 370?	440?	Austin to Georgetown.
76	Lone Star Brewing Company.	120 Jones Avenue†	805	670	Flowing	606- 660	60	Taylor to Edwards.
77	Lorenz, Alex	6 miles north†	420	830	Non-flowing	345- 400	485	Austin to Georgetown.
78	MacIntosh, Mrs.	7 miles east†	668	700	Non-flowing —10	500- 570?	200?	Taylor to Edwards.
79	Malone, W. D.	West City limits	1500	672	Non-flowing	985-1040	—313	Navarro? to Edwards.
80*	Masterson, B. F.	18 miles west†	1620	750	?	734- 817±	16±	Taylor to Glenrose.
81*	Matyear, Chas.	24th Street and Lakeview	609	678	Non-flowing —6	441- 494	237	Austin? to Edwards.
82*	Medina Fullers Earth Company.	16 miles west†	778	770	Non flowing	685- 750±	85	Taylor to Georgetown.
83	Medina Oil Co.	12 miles south†	1383	530	Flow. sulphur water	1450-1505	—920	Tertiary? to Edwards.
84	Menafee Bros.	Edgewood Addition		680	Non-flowing	925- 975	—245	Navarro? to Comanchean.
85	Mission Ice Co.	San Marcos and Rivas Sts	758	664	Flowing	660- 710?	4?	Taylor to Georgetown.
86	M. K. & T. Ry. Co.	Landa Station†	648	784	Non-flowing —115	530- 580?	254?	Taylor to Edwards.

WELLS TERMINATING IN THE COMANCHEAN (LOWER CRETACEOUS) FORMATIONS—Continued.

No.	Owner	Location with Reference to San Antonio Courthouse	Depth	Elev.	Water	Depth of Del Rio from surface	Elev'tion Top of Del Rio	Marine Formations Penetrated
87	Moore Building	Houston St. and Ave. C	760	665	Flowing +15	637- 687	28	Taylor to Edwards.
88	Peffman, Ed.	9 miles west†	722	790	Non flowing —135	602- 622	188	Taylor to Edwards.
89	Prinz, H.	7.5 miles northeast†	446	800±	Non-flowing	351- 406	449±	Austin to Georgetown.
90	Quinn, J. D.	Salado Creek, E. of S. A.†	975	640	Flowing	830- 840?	—190?	Taylor to Edwards.
91	Rechert, Wm.	Southwest	1165	680	Nonflowing	1010-1060	—330	Navarro to Georgetown.
92	Reichert, Wm.	Cervalo Street	1200	668	Non-flowing —4	890- 940	—222	Taylor to Edwards.
93*	Ridder, A. J.	13 miles southwest†	2911	628	Flowing +40	1444-1497	—816	Tertiary? to Travis Peak?
94	Rupps, Anton	7.5 miles south†	1884	610	Flow. sulphur water	1560-1616	—888	Tertiary to Edwards.
95	Rumper, Aug.	12 miles northwest†	230	830±	Non flowing —150	150- 180	680±	Austin to Georgetown.
96	St. Anthony Hotel	Travis and Navarro Sts.	831	653	Flowing	675- 725?	—22?	Taylor to Edwards.
97*	St. Louis College	5.4 miles west†	702	760	Non-flowing	547-	213	Taylor to Edwards.
98*	Salado Water Supply Co.	5 miles northeast†	702	628	Flowing +40	540- 585	88	Taylor to Edwards.
99*	S. A. & A. P. Ry.	Roundhouse†	1108	630	Flowing +52	900- 950	—270	Navarro to Edwards.
100	S. A. & A. P. Ry.	½ mile northwest Roberts†		850±	Non-flowing	267- 290	583±	Austin to Comanchean.
101*	San Antonio City Water Supply.	Concepcion Mission†	1440	608	Flowing	1287-1328	—679	Navarro to Edwards.
102*	San Antonio City Water Supply.	Market Street	880	650	Flowing	608- 654?	42?	Taylor to Edwards.
103*	San Antonio City Well	North City limits†	702	670	Flowing	173- 234	497	Austin to Edwards.

104*	San Antonio Portland Cement Co.	5 miles north	667	740	Non-flowing —70	587- 657?	153?	Taylor to Georgetown.
105	San Antonio Steam Laundry.	131 North Street†		660	Flowing	775- 825	—115	Taylor to Comanchean.
106	San Antonio Street Railway Co.	10th Street and Ave. D	1140	670	?	800- 850	—130	Taylor to Edwards.
107	Sauer, Geo.	6.5 miles northeast	370	830	Non-flowing	260- 330	570	Austin to Georgetown.
108*	Schumeier, H.	1 mile south of Wetmore†	420	760	Non-flowing	325- 375	435	Austin to Edwards.
109*	Shattuck	19th Street W.†		678	?	789- 856	—120	Taylor to Comanchean.
110	Skolout, A.	10.5 mile west†	715	810	Non-flowing —135	640- 700	170	Taylor to Georgetown.
111*	Southern Ice Co.	Durango and Frio Streets	822	655	Flowing	°650- 711	5	Taylor to Edwards.
112	Southern Pacific Ry.	1.5 mile west of Schertz†	450±	750	Non-flowing	400- 450	350	Austin to Comanchean.
113*	Southwest Land Corporation.	4 miles west†	1000	708	Non-flowing	620- 672	88	Taylor to Edwards.
114	Southwest Land Corporation.	4 miles west†	672+	750	Non-flowing	620- 672	82	Taylor to Edwards.
115	Statte, H. H.	21 miles northwest	813	1040±	Non-flowing —330	673- 753	367	Taylor to Edwards.
116	Stephenson, J. D.	24th Street†	1050	630	Non-flowing —30	441- 494	239	Austin to Edwards.
117	Steubing, H.	11 miles west†	400	800	Non-flowing —160	308- 396	492	Austin to Georgetown.
118*	Steves, Mrs. J.	Steves Gardens†	1185	645	Flowing	983-1041	—338	Navarro to Edwards.
119*	Stevens, Mrs. J	509 King William Street	758	645	Flowing +18	682- 734	—32	Taylor to Georgetown.
120*	Steves, Ed.	8.5 miles south†	1840	660	Flow. sulphur water	1790-?	—1130±	Tertiary to Comanchean.
121	Steves, Ed.	Edwards Street	1185	630	Flowing sulphur water +44	983-1041	—353	Navarro? to Edwards.
122	Sullivan, D.	1½ mile S. E.†	1100	620	Flowing	975-1040	—355	Navarro to Edwards.
123*	Superior Oil Co.	12 miles south†		612	Flow. sulphur water	1500-	—888	Tertiary to Comanchean.
124*	Terrell Hot Wells	5.2 miles south†	1956	630	Flowing	1380-1425	—750	Tertiary to Comanchean.

WELLS TERMINATING IN THE COMANCHEAN (LOWER CRETACEOUS) FORMATIONS—Continued.

No.	Owner	Location with Reference to San Antonio Courthouse	Depth	Elev.	Water	Depth of Del Rio from Surface	Elev'tion Top of Del Rio	Marine Formations Penetrated
125*	Terrell, Dr. J. H.	Southwest, near city limits†	1140	675	Non-flowing	998-1058	—323	Navarro to Edwards.
126	Tex. Steam Laundry	205 Losoya Street	748	665	Flowing +28	645- 703	20	Taylor to Georgetown.
127*	Tezel, Louis	13 miles northwest†	245	865	Non-flowing	150- 210	715	Austin to Georgetown.
128	Tezel, Pete	11.5 miles northwest†	235	825	Non-flowing —150	140- 200	685	Austin to Georgetown.
129	Tezel, Chas.	11 miles northwest	210	815	Non-flowing	120- 180	695	Austin to Georgetown.
130	Toft, L. S.	7 miles east†	1260	665	Non-flowing ?	1070-1125	—405	Navarro to Edwards.
131	Tommins, R.	South City limits†	1500	630	Flowing	1310-1370	—680	Navarro to Edwards.
132*	Townsite Well	Somerset†	2320	650	Flowing	2030-2100	—1380	Tertiary to Edwards.
133	Trice, G. F.	Cervalo St and 16th†	1449	675	Non-flowing —12	775- 825	—100	Taylor to Glenrose?
134	Uhl, H.	20 miles northwest†	675	1010±	Non-flowing —230	555- 615	455±	Taylor to Edwards.
135*	Union Meat Co.	Laredo and Ralph Streets	1400	640	Flowing +30	751- 820	—111	Taylor to Glenrose?
136	Van Dale, H.	Parrall and Brazos Streets	955	640	Flowing	750- 800	—110	Taylor to Edwards.
137*	Voght, Wm.	14 miles southwest†	1850	605	Flow. sulphur water	1485-1537	—880	Tertiary to Edwards.
138*	Voight, A.	14 miles northwest†	216	850	Non-flowing —177	120- 180	730	Austin to Georgetown.
139*	Waring Estate	7.5 miles northwest†	2853	920	Non-flowing —46	460- 510	460	Taylor to Travis Peak.
140	West Gardendale	5 miles west†	1284	710	Non flowing	1125-1184	—415	Navarro to Edwards.
141	Widener, J.	17 miles northwest†	533	970	Non-flowing —280	415- 475	555	Austin to Edwards.
142	Wier, Chris	14 miles northeast†		870	Non-flowing —100	400-	470	Austin to Comanchean.
143	Winter & Kreugel	9¾ miles south†	1825	595	Flow. sulphur water	1600-1639	—1005	Tertiary to Glenrose.
144	Wurzbach, O. J.	21 miles northwest†	620	960	Non-flowing —260	440- 500	520	Austin to Edwards.

*Log or other additional record given below under the heading "Supplementary Data."
†Location indicated on contour map.

SUPPLEMENTARY DATA ON WELLS TERMINATING IN THE COMANCHEAN

The following data including logs is supplementary to that given in the preceeding tabulated records.

3. H. J. Ackerman, 6 miles east of San Antonio, east side of the W. W. White Road, ½ mile south of St. Hedwig Road. This well is near the limits of the area of surface flow from the Georgetown-Edwards limestones. When first drilled, the well is said to have flowed slightly over the pipe but to have subsequently ceased to flow. The well is also near the south limits of non-sulphur water in these limestones.

5. Alamo Water Works, Alamo Heights. Lorenz Bros., drillers. Log by drillers from memory.

Yellow clay (Austin?)	0- 140
Yellow rock (Austin)	140- 350
(First) mud hole (Eagleford)	350- 380
White rock (Buda)	380- 430
Dark blue mud, caves (Del Rio)	430- 500
Yellow sand rock (limestone?)	500- 540

6. D. J. Allen, in Kelly Field south of Pearsall (Frio) Road, 1 mile S. W. of city limits. T. H. Little, driller, 1910.

Gravel and yellow clay (Pleistocene)	0- 60
Shale (Taylor and Navarro)	60- 600
White limestone (Austin)	600- 900
Lignite of shale (Eagleford)	900- 940
Hard rock (Buda)	940-1000
Mud hole (Del Rio)	1000-1054
Brown and white limestone	1054-1254
White and gray limestones	1254-1595

The gravel deposits of this well are those of the Pleistocene. Aside from these flood-plain deposits the materials to the depth of 600 feet represent the Taylor and a part of the Navarro. The Austin formation is recorded as "white limestone," 600 to 900 feet. The Eagleford, "lignite" is given as 40 feet; the Buda, "white rock," 60 feet; and the Rel Rio "mud hole" as 54 feet. The top of the Comanchean was reached at 940 feet. The water-bearing limestones were here reached at 1054 feet and were penetrated to 540 feet, thereby securing a very large flow of water, the well being reported to yield 3000 gals. per minute by pumping. Mr. Allen has several other similar wells on this property.

12. Ed E. Basse, west side S. A. & A. P. Ry., south side Olmus

Creek, 5 miles north of San Antonio. Alex Lorenz, driller. Log by driller from memory.

Surface materials	0- 30
Blue mud, thickness not recorded	30- 425
Lignite (Eagleford)	425- 450
Not recorded (Buda)	450- 500
Clay (Del Rio)	500- 555
Limestone (Georgetown)	555- 590

14. Mrs. Kate Benke, north side of Culebra Road near the west county line. A. E. Goforth, driller. Log by driller from memory.

Yellow clay and rock (Taylor)	0- 300
White magnesian limestone and blue medium hard limestone (Austin)	300- 785
Lignite (Eagleford)	785- 820
Buda limestone	820- 880
Clay (Del Rio)	880- 940
Limestone (Georgetown-Edwards)	940-1000

Although located within a mile or so of the Balcones Escarpment, the first 300 feet of this well with little doubt pass through the Taylor formation. This is followed by 485 feet most or all of which is to be referred to the Austin, representing the thickest recorded section of that formation. The Eagleford is assigned the usual thickness of 35 feet; the Buda, 60 feet; and the Del Rio 60 feet. The top of the Comanchean formations lies at the depth of 820 feet from the surface. The magnitude of faulting in this area is indicated by the fact that within two miles west from this well the Glenrose formation is seen lying at the surface at elevations of from 1200 to 1400 feet above sea level, while in this well the top of the Glenrose probably lies 300 feet or more below sea level.

16. H. T. Biering, west side Bandera Road, 15.6 miles from San Antonio. Record from owner.

This well is located in the Del Rio plain a mile or so from the Balcones Escarpment. The surface materials at the well are heavy stream washed gravel, although the Del Rio nearby lies at about the same level. The well starting at the Del Rio level terminates in the Edwards limestone.

18. J. T. Blank, south side Castroville Road, 6 miles west of San Antonio.

Surface materials, blue clay and rock	0- 928
Not recorded	928-1163
"Mud hole" (Del Rio)	1163-1228
Limestone	1228-1483

The principal water supply is reported to come from only 4 feet

below the surface of the Georgetown-Edwards limestones. Above this level are the formations of the Upper Cretaceous, the Eagleford, Austin, Taylor, and probably a part of the Navarro. The surface materials here are the gravel flood plain deposits.

19. Blue wing Club, west side of San Antonio River, 12 miles south of San Antonio. Drilled by cable. Jacob Wolf, driller. Showings of oil at 900 feet, and continuing more or less to 1200 feet.

Sand	1-	5
Clay, yellow	5-	85
Sand, white, with water	85-	90
Rock, hard, blue	90-	92
Clay, soft, blue	92-	112
Rock, hard, blue	112-	115
Clay, soft, blue	115-	133
Rock, hard, blue	133-	135
Clay, soft, blue	135-	150
Rock, hard, gray	150-	153
Clay, soft, blue	153-	170
Rock, hard, gray	170-	174
Clay, soft, blue	174-	191
Rock, hard, blue	191-	193
Clay, soft, blue	193-	211
Rock, hard, blue	211-	215
Clay, soft, dark blue	215-	231
Rock, hard, dark blue	231-	234
Clay, soft, blue	234-	250
Rock, hard, gray	250-	252
Clay, soft, blue	252-	270
Rock, hard, gray	270-	273
Clay, soft, dark blue	273-	289
Rock, hard, blue	289-	293
Clay, soft, blue	293-	311
Rock, hard, blue	311-	313
Clay, soft, blue	313-	320
Rock, hard, blue	320-	322
Clay, soft, blue	322-	334
Not recorded	334-	337
Rock, hard, blue	337-	357
Clay, soft, blue	357-	360
Rock, hard, blue	360-	383
Clay, soft, blue	383-	387
Rock, hard, gray	387-	405
Clay, soft, blue	405-	407
Rock, hard, blue	407-	425
Rock, hard, gray	425-	428

Clay, soft, dark blue	428- 445
Rock, hard, gray	445- 447
Clay, soft, light blue	447- 460
Rock, hard, gray	460- 464
Shale, soft, blue	464- 468
Rock, hard, gray	468- 470
Shale, soft, dark	470- 472
Rock, hard, white	472- 478
Shale, soft, dark blue	478- 567
Rock, hard, blue	567- 569
Shale, soft, blue	569- 728
Shale and boulders, soft, blue	728- 755
Shale, soft blue	755- 905
Sand rock, soft, gray	905- 925
Shale, soft, blue	925- 960
Shale, soft and hard, blue	960- 996
Rock, soft, blue	996-1006
Clay, soft, blue	1006-1050
Shale, hard, blue	1050-1072
Shale, hard, blue	1072-1092
Shale, hard blue	1092-1106
Sand rock, hard, blue	1106-1115
Shale, hard, blue	1115-1145
Rock, hard, gray	1145-1149
Shale, hard, blue	1149-1184
Rock, hard, blue	1184-1191
Shale, soft, blue	1191-1212
Clay, soft, light blue	1212-1300
Rock, hard, blue	1300-1306
Shale, soft, blue	1306-1356
Shale, hard, blue	1356-1387
Rock, hard, gray	1387-1390
Clay, soft, blue	1390-1409
Rock, hard, light blue	1409-1446
Gumbo, hard, dark	1446-1746
Rock, soft, white	1746-1850
Rock, soft, blue	1850-1910
Rock, hard, white	1910-1987
Rock, hard, blue	1987-2015
Rock, hard, gray	2015-2054
Rock, hard, light blue	2054-2080
Rock, hard, gray	2080-2140
Rock, soft, dark blue	2140-2152
Rock, hard, white	2152-2189
Rock, hard and soft, yellow; water	2189-2269
Rock, hard, white; no water	2269-2304

Rock, soft, yellow; water 2304-2374
Rock, soft, yellow, and hard; water 2374-2433
Rock, hard, flint; no water 2433-2437
Rock, hard, dark blue; no water 2437-2444

The log of this well is difficult to interpret. The driller states that he was unable to recognize either the Eagleford "lignite" or the Del Rio "mud hole." The water obtained from the well is reported to have had a temperature of 117° and to have had a head of about 75 feet above the surface. The water which was first obtained at the depth of 2189 feet, or at the actual level of about 1700 feet below sea, is derived with little doubt from the Georgetown-Edwards limestones. The Del Rio formation is placed provisionally in this well at 2140 feet from the surface or at the actual level of about 1685 feet below sea. This interpretation is permissible from the log.

21. D. Boerman, south side of Bandera Road, 11 miles northwest of San Antonio. Record from owner.

Chiefly limestone and shale (Austin-Eagleford)..... 0- 280
Hard limestone (Buda) 280- 320
Mud hole (Del Rio) 320- 385
Limestones (Georgetown) 385- 403

24. H. Brendle, 527 Bandera St., about one mile north of west of San Pedro Springs, San Antonio. Log published in 18th Ann. Rpt., U. S. G. S., p. 293.

Blue marl and clay described as sea mud in this well from 493-583 feet, is interpreted as the Del Rio formation, which accordingly lies at the level of from 227 to 317 feet above sea.

27. C. C. Clamp, south of the Castroville Road, east of Leon Creek, 6 miles west of San Antonio. Log by Mr. Fred Lewis.

Clays, mostly blue in color (Navarro-Taylor)..... 0- 662
White shale (Austin?) 662- 825
White lime rock (Austin) 825-1023
Lignite (Eagleford) 1023-1054
White limestone (Buda) 1054-1110
Mud hole (Del Rio) 1110-1162
Limestone 1162-1195
Water sand 1195-1196
Limestone 1196-1220
Crevice, water 1220-1221
Sandy limestone rock 1221-1275
Crevice, water 1275-1277
Limestone 1277-1292
"Sand" 1292-1308

Not recorded 1308-1395
Limestone rock 1395-1452

Aside from the surface materials the first 662 feet in this well probably represent the Taylor and a part of the Navario formations. The 361 feet recorded as white shale and white lime rock probably represent the Austin formation. The Eagleford lignite is assigned a thickness of 31 feet; the Buda, 56 feet; and the Del Rio, 52 feet. The water-bearing limestones lie at the depth of 1162 feet. As bearing on structural conditions it is of interest to note that the Comanchean formations here lie at a lower level than at the Allen well in Kelly Field, about 2½ miles farther south, the Allen well being nearer the axis of the San Antonio structure, already described.

28. Collins Manufacturing Company, 900 yds. northeast by north of Courthouse, San Antonio. Record from U. S. G. S. 18th Ann. Rpt., p. 293. At this well blue clays were passed through from about 720 to 800 feet which with little doubt represent the Del Rio formation. The Del Rio here lies at about 60 feet below sea level.

30. Collins Gardens, near I. & G. N. Ry. track below Union Stockyards, used for irrigation. Jacob Wolf, driller.

Yellow clay and gravel (Pleistocene)	0- 40
Blue clay, mostly soft and caving (Navarro-Taylor)..	40- 525
Limestone (Austin)	525- 855
Lignite (Eagleford)	855- 890
Hard limestone (Buda)	890- 930
Mud hole (Del Rio)	930-1000
Limestone	

The blue clays of this well from 40 to 525 feet represent the Taylor and probably a part of the Navarro formations. The limestones which may be assigned to the Austin formation have a thickness of 330 feet. The Buda limestone, the first of the Comanchean formations, is reported at 890 feet. In this well good water is reported to have been obtained while in the limestones of the Austin formation, at the depth of 638 feet.

33. Dickenson well, north side of Culebra Road, 8 miles northwest of San Antonio. Alex Lorenz, driller. Elevation of Del Rio, 353 feet.

Surface materials, blue clay and limestone (Taylor-Austin)	0- 420
Lignite (Eagleford)	420- 447
Hard rock (Buda)	447- 497
Mud hole (Del Rio)	497-567
Limestone rock (Georgetown-Edwards)	567- 602

The surface materials at this well include remnants of the gravels of the Uvalde formation. A part of the clays represent the lower part of the Taylor formation as indicated by exposures nearby. The limestones under the clays to the depth of 420 feet are of the Austin formation. The Comanchean is entered at 447 feet and the water-bearing Comanchean limestones are reached at 567 feet.

42. Geunther Milling Company, 902 Morales St., east side of I. & G. N. Ry., San Antonio.

Yellow clay and gravel (Pleistocene)	0- 50
Blue clay (Taylor)	50- 250
Soft gray rock (Austin)	250- 350
White limestone, water (Austin)	350- 550
Bluish black shale, lignite (Eagleford)	550- 600
Hard white limestone (Buda)	600- 650
Sea mud (Del Rio)	650- 700
Blue limestone	700- 750
"Sand" and black flint strata, water	750- 800
Hard sandstone	800- 850
Flint, gray (and limestone)	850- 875

The log of this well as preserved is evidently a somewhat generalized record. However, it serves to place approximately the top surface of the water-bearing limestones at 700 feet. Some part of the Taylor formation here lies above the Austin and Eagleford, although concealed at the surface by flood-plain deposits.

43. A. E. Goforth, north side Culebra Road, 18 miles northwest of San Antonio. Goforth, driller.

Surface materials and limestone rock, the lower part hard and blue in color (Austin formation)	0- 349
Lignite (Eagleford)	349- 384
Hard limestone (Buda)	384- 444
Del Rio clay (mud)	444- 504
Limestone rock (Georgetown-Edwards)	504- 564

44. Government well, at Aviation Post, on Austin Road, about 6 miles from San Antonio, Benkendorfer, driller.

Soil	0- 2
Yellow clay	2- 55
Blue clay (small vein good water at 190, rose within 100 ft. of surface)	55- 190
Magnesian limestone, soft, light blue	190- 210
Soft shale	210- 220
Light gray hard limestones	220- 240
Blue gray very hard limestone	240- 260
Hard white limestone	260- 280

Soft white limestone	280- 300
Blue and white hard limestone	300- 320
Not recorded	320- 330
Hard white and blue limestones	330- 340
(8″ casing rested at 340 ft)	
Very hard white limestone	340- 353
Lignite, black and soft (Eagleford)	353- 380
Gray shaly rock	380- 400
White hard limestone	400- 418
Del Rio "mud," soft, blue-gray	418- 494
(6″ casing rested at 494 ft)	
Limestone, slightly yellow, hard	494- 557
Limestone, light in color	557- 575
Porous limestone	575- 580
Hard brown limestone	580- 590
Soft limestone	590- 625
Hard brown limestones	625- 655
Flinty limestone	655- 657
Soft limestone	657- 671
White hard limestone	671- 680
Soft brown limestone	680- 690
Hard limestone	690- 748
Black flint	748- 750
Hard yellow limestone	750- 795
Very hard limestone	795- 835
Light brown soft sandstone	835- 855
Light brown limestone	855- 874

The formation penetrated in this well to the depth of 353 feet is chiefly the Austin including possibly some of the Taylor at the surface. The combined thickness of the Eagleford "lignite" and Buda "shaly rock and white limestone" is recorded as 65 feet. This is unusually thin for these formations unless a part of the Eagleford has been included with the limestones referred to the Austin. All wells between the east city limits of San Antonio and Salado Creek record a reduced thickness of the Eagleford, Buda, and Del Rio formations.

45. Government well, Fort Sam Houston, near west limits of Government Reservation between Pine Street and River Avenue, San Antonio. Judson, driller; 1903; depth 729 ft.; casing 10-in. to 630 ft. Elevation, 689. Non-flowing, although stood in well when completed within a few feet of the surface. Elevation Del Rio, 69.

Blue loam and flint boulders	0- 3
Yellow clay	3- 41
Blue clay	41- 258

Magnesian limestone. Small streak of good water at

350 ft.	258- 354
Gray limestone, sulphur water	354- 392
Gray limestone, hard	392- 429
Yellow limestone	429- 468
Gray limestone	468- 535
"Lignite" (Del Rio)	535- 566
Gray limestone (Buda)	566- 620
Blue clay with shells (Del Rio)	620- 673
Blue limestone	673- 688
Hard yellow limestone	688- 706
Calcareous limestone	706- 708
Struck water at 705 ft.	
Open cavity	708- 713
Hard limestone with fissures filled with clay	713- 729

This well may be compared with the new city well drilled at the north city limits in 1918. Although only about 1 mile farther north, the Del Rio at the city well is found at the level 497, or more than 400 feet higher than in this well, the two wells being separated by a large fault.

46. F. Grote, south side of Bulverde Road, 6½ miles from San Antonio. Alex Lorenz, driller.

Soft "adobe" lime	0- 17
Hard limestone (Austin)	17- 187
Lignite (Eagleford)	187- 222
Hard limestone (Buda)	222- 272
Clay (Del Rio)	272- 332
Hard limestones (Georgetown)	332- 339

This well starts in the Austin formation surface exposures of which are seen nearby. The Comanchean formations are entered at the depth of 222 feet. The water-bearing limestones were reached at 332 feet and were drilled into only 7 feet. The well is located on the structurally high area elsewhere described as the San Antonio structure.

49. Jud Harrison, west side Blanco Road south of Coker cross road, 8½ miles north San Antonio. Alex Lorenz, driller.

Not recorded (Austin)	0- 185
Lignite (Eagleford)	185- 190
Hard limestone (Buda)	190- 245
Clay (Del Rio)	245- 300
Limestone (Georgetown)	300- 328

56. Herff well, formerly the Werner property, north of Castroville Road, between Stephenson Road and West 34th St. Benkendorfer, driller. Record from driller's notebook. Del Rio mud

recorded at from 1000 to 1060 feet, the water-bearing Comanchean limestones thus lying at the level 350 below sea.

Surface clay and gravel (Pleistocene)	0- 31
Yellow clay (Navarro)	31- 81
Blue clay (Navarro-Taylor)	81- 621
Magnesian limestone (Austin)	621- 781
Blue limestone (Austin)	781- 811
White limestone (Austin)	811- 951
Lignite (Eagleford)	951- 969
Gray limestone (Buda)	969-1050
Clay (Del Rio)	1050-1110
Brown limestone	1110-1140
Porous limestone, water rock	1140-1286

The surface clay and gravel at this locality includes that of the flood-plain deposits. Aside from these surface materials the Upper Cretaceous is here recorded as having a thickness of over 900 feet, the Comanchean limestones (Buda formation) having been reached at 969 feet. Judging from the thickness of the Upper Cretaceous there are probably present here the Eagleford, Austin, Taylor, and lower part of the Navarro formations.

57. Hill and Roby, east side Pleasanton Road, 7¼ miles south of San Antonio. Jacob Wolff, driller. 1910. Depth, 1890. Elevation about 625. Flowing warm sulphur water.

In this well the Del Rio clay is said to have been passed through at from 1695 to 1750 feet, or at the actual level of from 1060 to 1125 below sea. The formation thus lies more than 300 feet lower than its estimated level in the Alta Vista oil field, a few miles farther southwest, and but little less than 200 feet lower than in the Ripps well a short distance southeast.

59. R. H. Hofheintz on Pearsall (Frio) Road between public road and railway, just north of Kelly Field, four miles from San Antonio. Benkendorfer, driller.

In this well the Comanchean formations were entered at 950 feet. The overlying Cretaceous includes probably the Eagleford, Austin, Taylor and the lower part of the Navarro formations, as well as the surface flood-plain deposits. The Del Rio formation was entered at 1000 feet, or at the level of 315 feet below sea. The water-bearing Comanchean limestones lie at the depth of 1054 feet and were drilled into to the total depth of 1453 feet. A log of this well is given in Bull. 298, U. S. G. S., p. 268.

60. Holtz well, on left bank of Leon Creek below the Somerset Road crossing, nine miles southwest of San Antonio. This well was drilled by rotary by Holtz to a depth of 1200 feet where hard rock

was reached and where the 6″ casing was rested. From this depth the well was drilled with cable tools by Benkendorfer. Temperature of water said to be 106.5 F.

63. Hot Wells Hotel, on San Juan Boulevard, 1¼ miles south of the south city limits of San Antonio, east side of San Antonio river. Robert Newton, driller.

Soil	0- 5
Yellow clay	5- 15
Black sand	15- 20
Sand and gravel, water	20- 30
Yellow clay	30- 52
Blue shale	52- 90
Streaks of lignite	90- 95
Gumbo and blue clay	95- 125
Sandy shale	125- 175
Gumbo	175- 323
Sand rock	323- 325
Gumbo	325- 337
Sand rock	337- 340
Gumbo	340- 351
Rock	351- 353
Sandy shale	353- 412
Gumbo	412- 506
Sandy shale	506- 577
Sand rock, oil show	577- 587
Gumbo	587- 597
Sandy shale	597- 710
Hard gumbo	710- 990
Lime rock, casing 8″ set	990-1003
Lime rock	1003-1445?
Gumbo and hard shale	1445-1454
Lime rock	1454-1740
Hard shale	1740-1748
Hard lime rock, pink	1748-1865
Sand lime, some water	1865-1875
Porous rock, sulphur water	1875-1878

This well having been drilled by rotary does not afford as definite information as the wells drilled by cable tools. The log is given as made out by the driller. While the interpretation of the log is in doubt, it is probable that aside from surface materials, the first 990 feet represents chiefly Navarro and Taylor formations; while from 990 to about 1445 represents the limestones of the Austin, Eagleford, and Buda formations. On this interpretation the Del Rio lies here at about 1445 feet from the surface or about 870 feet below sea level.

67. Kearney Oil and Pipe Line Company, No. 3, west side of Palo Alto Road about one mile south of Leon Creek crossing.

Yellow clay	0- 42
Blue clay	42- 125
Black sand, gas show	125- 161
Blue clay	161- 226
Sand rock	226- 234
Gumbo	234- 261
Sand rock	261- 262
Gumbo	262- 268
Soft rock	268- 269
Gumbo	269- 273
Soft rock	273- 275
Gumbo and soft rock	275- 392
Shale	392- 433
Hard rock	433- 449
Gumbo	449- 486
Gumbo and shale, oil show	486- 527
Gumbo	527- 569
Gumbo and shale, oil show	569- 621
Soft rock, oil show	621- 636
Gumbo	636- 703
Shale	703- 724
Gumbo	724- 745
Not recorded	745- 837
Rock (limestone)	837- 869
Gumbo	869- 872
Soft rock	872- 886
Gumbo	886- 890
Soft rock	890- 892
Gumbo	892- 957
Hard rock (limestone)	957-1063
Yellow rock (limestone)	1063-1151
Sand, heavy oil, about 2 bbls. per day	1151-1161
White limestone and water	1161-1211
Yellow limestone and water (sulphur)	1211-1221
White limestone	1221-1321
Lignite, kind of mud (Eagleford)	1321-1357
Black limestone (Buda)	1357-1451
Mud hole, sea shells (Del Rio)	1451-1491
Hard black limestone	1491-1591
Warm sulphur water	1591-1861
White rock, salty water	1861-1881
Cold water, brackish	1881-1991
Not recorded	1991-2355

This well, log of which has been given by Mr. Kearney, affords a very important and reliable record of the depth of the formations

at this locality. The well is located within the belt of Tertiary exposures, provisionally mapped as Midway. The interval from the surface to 957 is assigned to the Midway, Navarro and Taylor formations. The Austin formation apparently is represented by the interval from 957 to 1321 feet, 364 feet, consisting chiefly of limestones, with some slight production of heavy oil at 1151 feet. The record of the Eagleford "lignite", Buda limestone, and Del Rio clay is unmistakable. To the Eagleford is assigned a thickness of 36 feet, to the Buda, 94 feet; and to the Del Rio, 40 feet. The Georgetown-Edwards limestones were entered at 1491 feet. Warm sulphur water was obtained in these limestones. The drill hole was continued below the top of these limesones 964 feet, probably terminating in the Glenrose formation. Mr. Kearney believes that the water obtained below 1881 feet was neither so warm nor so salty as that from a somewhat higher level. Mr. Jacob Wolff believes that the cool non-sulphur water lies below 1900 feet from the surface. The interval between the oil sands in the Austin and the top of the Del Rio formation in this well is about 300 feet. The whole thickness of the upper Cretaceous as indicaed by this well is about, or a little more than, 1200 feet. The stratigraphic interval from the greensand horizon near the top of the Navarro to the top of the Del Rio is 1326 feet. The actual level of the Del Rio at this locality is 841 feet below sea level.

73. Well in Lakeview Addition, near 24th Street, west part of San Antonio, north of Elmendorf Lake.

Black soil	0-	4
Yellow clay	4-	31
Soft blue clay	31-	43
Not recorded	43-	187
Hard streaks at	187	
Not recorded	187-	190
Sand rock, six inches at	190	
Not recorded	190-	206
Hard lime rock	206-	281
Black lignite (Eagleford)	283-	291
Streaks black lignite at	349	
Not fully recorded	291-	441
Blue mud (Del Rio)	441-	494
Soft dark sandrock	494-	522
"Granite"	522-	586
Sand rock with water	586-	591

This log is very unusual and is difficult to interpret. If the blue clay at 441 feet represents the Del Rio, the formation lies here at about the actual level of 239 feet above the sea.

74. W. F. Legler, on north side Castroville Road, 5 miles west of San Antonio. Alex Lorenz, driller.

Soil	0- 5
Clay and gravel (Pleistocene)	5- 18
Yellow clay (Navarro)	18- 52
Blue clay (Navarro-Taylor)	52- 670
White shale (Austin)	670- 910
Limestone (Austin)	910-1080
Lignite (Eagleford)	1080-1108
Hard rock (Buda)	1108-1167
Clay (Del Rio)	1167-1220
Limestones, water bearing at successive horizons	1220-1555

The top of the Comanchean formation in this well is reached at 1108 feet below the surface, the upper Cretaceous formations present being probaly the Eagleford, 28 feet; Austin. 310 feet; Taylor and lower part of the Navarro, 618 feet; and the Pleistocene flood-plain deposits amounting to about 18 feet.

75. J. Locke, west side of Blanco Road, 5 miles north of San Antonio. Alex Lorenz, driller.

Yellow calcareous marl (Austin)	0- 50
Blue limestone rock (Austin)	50- 250
Lignite (Eagleford)	250- 265
Hard white rock (Buda)	265- 310
Sea mud (Del Rio)	310- 370
Limestone (Georgetown)	370- 385

77. Alex Lorenz, north side Bulverde Road, about 6 miles north of San Antonio.

"Adobe"	0- 25
Blue "mud" rock (Austin)	25- 150
White limestone rock (Austin)	150- 270
Lignite (Eagleford)	270- 295
Hard limestone (Buda)	295- 345
Clay (Del Rio)	345- 400
Limestone rock (Georgetown)	400- 420

80. B. F. Masterson, about 1 mile north of the Castroville Road, 18 miles west of San Antonio. Test well for oil. Record from Geo. B. Mechem Co.

In this well, according to a summary of the log supplied by the owners, the Del Rio formation is believed to have been entered at the depth of 734 feet from the surface, and to be 83 feet thick. The Georgetown-Edwards limestones were reached at 817 feet, and the drill hole was continued to 1620 feet probably terminating in the Glenrose formation.

81. Chas. Matyear, near 24th Street, in Lakeview Addition, San Antonio. Alex. Lorenz, driller. Elevation, 678. Elevation of Del Rio, 186.

Black earth	0-	4
Yellow clay	4-	31
Soft blue clay	31-	43
Not recorded	43-	187
Hard streaks	187	
Black sand rock	190	
Hard lime rock	206-	281
Like black lignite (Eagleford)	283-	291
Streak black lignite	349	
Blue mud (Del Rio)	441-	494
Soft dark sandrock	519-	522
"Granite"	584-	586
Sand rock, water	591	

82. Medina Fuller's Earth Company, about one mile north of Castroville Road, and west of Cagnon Cross Road, 16 miles west of San Antonio. Alex. Lorenz, driller. From the stratigraphic interval from the surface to the Del Rio formation it appears that this well starts in the Taylor formation.

Blue marl	0-	400
White soft rock	400-	600
Eagleford	600-	635
Buda	635-	685
Del Rio	685-	750
Georgetown	750-	778
Actual level, Del Rio	100±	

83. Medina Oil Company, south of Leon Creek, west of Applewhite Road. Jacob Wolff, driller. 4-inch casing set at 1530 feet; first flow of sulphur water at 1540 feet; second flow, 1800 feet; depth of well 1833 feet.

Yellow clay	1-	15
Gravel	15-	25
Black sand	25-	50
Blue clay	50-	100
Blue rock	100-	104
Blue clay	104-	124
Blue rock, showing oil	124-	129
Blue clay	129-	145
Blue rock	145-	153
Light blue clay	153-	165
Blue rock	165-	169
Blue clay	169-	176
Blue rock	176-	186

Blue clay	186- 200
Blue rock	200- 206
Blue clay	206- 217
Gray rock	217- 255
Clay and sand, gas	**255- 296**
Gray rock	296- 302
Blue clay	302- 348
Gray rock	348- 355
Light blue clay	355- 408
Blue rock	408- 416
Blue gumbo	416- 436
Dark blue clay	436- 496
Dark gray rock	**496- 500**
Hard blue clay	500- 548
Dark gray rock	548- 552
Dark gray shale, gas and oil	552- 564
Dark gray rock	564- 567
Dark clay and sand, gas and oil	567- 630
Gray rock	630- 633
Dark hard clay	633- 665
Hard gray rock	665- 671
Hard blue clay	671- 728
Gray rock	728- 736
Blue clay	736- 783
Black rock	783- 791
Dark clay	791- 806
Dark rock	806- 836
Gray shale with oil	836- 858
Hard dark rock	858- 912
Hard light blue rock	912- 922
Hard dark gray rock	922- 943
Hard white rock	943- 950
Hard light blue rock	950- 953
Yellow shale with oil	953- 957
White rock	957- 960
Light blue rock	960- 964
Yellow shale with oil	964- 982
Light blue rock	982- 986
White soft rock	986- 990
Light blue hard rock	990- 994
Yellow shale with oil	994-1012
White rock	1012-1014
Blue rock	1014-1015

In this well, the Del Rio formation is reported at 1450 feet from the surface, or at about 920 feet below sea level. At 25 feet there is reported a black sand which very possibly is the glauconitic

sand horizon of the Navarro formation. If so, the thickness of the Upper Cretaceous as recorded in this well is 1425 feet, which is somewhat greater than farther northwest as indicated by the Kearney, Vogt, and Ridder wells.

93. A. J. Ridder, east side of Medina River, 13 miles southwest of San Antonio, north of Pearsall Road. Several wells on this property. L. N. Knight, driller. In all of these wells the glauconitic greensand is noted, and the wells are of interest as indicating a south or southeast dip. They are as follows:

Deep well, north side Southern Pacific track; depth, 2911 feet; elevation 628; flowing artesian water.

In this well no water was found until below 1502 feet, the formations being entirely dry to that depth. Successive water horizons between 1557 and 1980 feet were found. A glauconitic greensand horizon was recognized at 165 feet from the surface, the greensand being 50 or 60 feet thick. The Del Rio formation was recognized at 1444 feet and continued to 1497 feet. The limestones below the Del Rio were drilled into 1413 feet. From this record it appears probable that the well terminated either near the base of the Glenrose or in the Travis Peak formation. In this connection it is of interest to note that the driller reports having drilled into fossil wood not petrified, but more or less lignitized, near the bottom of this well.

This deep well affords a record of practically the full thickness of the Upper Cretaceous. While the Buda is not recorded, its uniform thickness of 65 or 70 feet overlying the Del Rio makes it possible to place the top of the Comanchean at about 1374 feet from the surface. The greensands reached at 165 feet are with little doubt those of the Navarro formation as exposed on Leon Creek.

The Upper Cretaceous is therefore 1200 feet thick at this well, possibly a little more. This agrees closely with the thickness of these formations as determined from the Kearney well, about 6 miles farther southeast, where the Upper Cretaceous formations appear to have a thickness of about 1232 feet.

Another measurement obtained from this well and from the Kearney well, used in estimating the place of the Del Rio in some wells, is the stratigraphic interval between the glauconitic greensand and the top of the Del Rio formation. In this well this interval is 1279 feet; in the Kearney well, the same interval was found to be 1326 feet, or 47 feet greater.

Ridder well, near west line of property. Elevation 617. Greensand at 200 feet from surface, or at level of 417 feet above sea.

Ridder well, on north side of Pearsall Road, about ¾ mile from Medina River. Elevation 617. Greensand at 235 feet from the surface, or at level 382 feet above sea.

Ridder well, on east side of Medina River. Elevation 595. Some

water obtained at 1056 feet; additional water at 1410 feet. Greensand at 285 feet from the surface, or at level 310 feet above sea.

The dip in the formations from the deep well north of the railway to this well on the river, a distance of about one mile, according to these records is 150 feet. That this dip continues to the south is indicated by the Vogt well, subsequently recorded.

97. St. Louis College, between Culebra and Bandera roads, about 5.4 miles west of San Antonio. Elevation, 760.

Flint	0-	3
Adobe	3-	5
Yellow clay	5-	65
Blue clay	65-	215
Magnesian lime rock	215-	288
Hard blue lime	288-	392
Hard yellow rock	392-	402
Hard gray rock	402-	455
Lignite (Eagleford)	455-	485
Limestone (Buda)	485-	542
Blue clay (Del Rio)	542-	590
Dark blue limestone	590-	600
Yellow limestone	600-	636
Crystallized limestone	636-	680
Water rock	680-	702

The Del Rio in this well lies at 547 feet from the surface. Another well on this property located 375 feet west of the one reported reached the Del Rio at 590 feet or 43 feet lower than in the first well. Aside from this difference in level, the formations are much the same in the two wells. By reference to the structural map it will be seen that these wells are located but a short distance north of the large fault which passes between the wells and the Castroville Road.

98. Salado Water Supply Company, ¾ mile south of Austin Road, about 5 miles northeast of San Antonio, on Salado Creek. Jacob Wolff, driller. 6000 gallons water per minute.

Surface	0-	8
Dark blue clay	8-	108
Light blue clay	108-	215
White rock, soft	215-	330
Yellow rock, sulphur water	330-	350
White chalk, hard	350-	445
Lignite (Eagleford)	445-	470
White rock, hard	470-	510
White pearl rock	510-	520
Blue hard rock	520-	540

Sand hole	540- 585
White rock, hard	585- 610
Red sand rock, gas flow	610- 617
Hard white rock	617- 642
Brown flint	642- 647
Yellow water rock, white streaks	647- 702

99. San Antonio and Aransas Pass Railway, at "roundhouse" on railway near the intersection of Proban and Simpson streets, west of the San Antonio River, near intersection of S. P. Ry. and S. A. & A. P. Ry. south of San Antonio. Allen Burman, driller. **Sulphur** water was obtained from the Austin at 620 feet, from the surface; good water was obtained at 1065 and at 1090 feet. The water is reported to rise 50 feet above the ground level. The Del Rio clay in this well lies at 270 feet below sea level. Casing, 7½″ to 550 feet. The Del Rio is cased off by 70 feet of 6½″ casing.

Soil	0- 6
Soft white clay	6- 22
Sticky yellow clay	22- 30
Hard blue clay	30- 100
Soft blue clay	100- 250
Hard gray clay	250- 300
Soft white soapstone	300- 350
Hard blue clay	350- 400
Soft white clay	400- 500
Hard white rock	500- 550
Hard white rock	550- 600
Soft gray rock, sulphur water at 620′	600- 700
Hard gray rock	700- 750
Hard white rock	750- 850
Hard brown rock	850- 900
Hard blue sea mud (Del Rio)	900- 950
Hard white limestone	950-1103

101. San Antonio City Water Supply, about 400 yards west of Concepcion Mission, south San Antonio. A second well drilled about 200 feet north of this one records only about 7 feet of Del Rio, entered at 1270 feet. The reduced thickness of the Del Rio together with the abrupt dip probably indicates faulting at this locality with the downthrow to the south. Surface elevation of this well about 605 feet. Water in completed well rises 72 feet above floor of derrick, or to elevation of 680 feet.

Surface materials	0- 54
Blue clay	54- 780
"Magnesian" limestone	780- 900
10″ pipe rested at	800

Gray limestone	905-1197
Water at 1130.	
Lignite (Eagleford)	1197-1223
Limestone with crevices and water flowing at surface 3000 gals. per min.	1223-1280
Mud (Del Rio)	1287-1328
Limestone with crevices and water	1323-1440

102. San Antonio City Water Supply, Market Street. Surface elevation about 660 feet. Actual level top of Del Rio, 725.

Surface materials	0- 35
Blue clay	35- 220
Hard rock	220- 375
"Magnesian" rock	375- 500
Sulphur water at	505
Lignite (Eagleford)	600
Buda not given.	
"Mud" (Del Rio)	725- 775
Limestone rock	775- 887
Water mostly at	860- 885

103. San Antonio City Well, north city limits on San Antonio River. Benkendorfer, driller. This well starts in the Austin although as the record indicates, within about 100 feet of the base of this formation. The Eagleford is thin, apparently only about 15 feet thick. By reference to the map it will be seen that this well is located very close to a large fault.

Mud and soil	0- 12
Rock	12- 21
Yellow rock	21- 65
Blue rock	65- 73
Yellow rock	73- 82
Brown rock	82- 87
Blue rock	87- 96
Yellow rock	96- 101
Brown lignite (Eagleford)	101- 116
Yellow hard rock	116- 144
White hard rock	144- 149
Gray hard rock	149- 173
Blue mud (Del Rio)	173- 234
Yellow water rock, very hard; some flint to bottom of well	234- 702

Principal water supply at 650-670 feet; water rises just to top of pipe. Does not flow over.

104. San Antonio Portland Cement Company, on I. & G. N. Ry., 5

miles northeast of San Antonio. Log from memory; depth of formations approximate:

Yellow clay	0- 60
Blue hard rock	60- 250
White and yellow limestones	250- 400
Honey-combed hard limestones	400- 450
Lignite (Eagleford)	450- 462
Hard yellow limestone	462- 572
Black rock	572- 587
Sea mud (Del Rio)	587- 657
Hard limestones	657- 667

This record given to the writer by the driller from memory can be used only as an approximate statement of depths to the formations. Another record of a well at this locality, from notes contributed by Mr. Deussen, differs somewhat, placing the Del Rio probably nearer the surface. The uppermost 60 feet in this well is probably the Taylor formation. The next 390 feet is to be referred to the Austin formation. The materials recorded as lignite, hard yellow limestone, and as black rock presumably include the Eagleford and Buda formations, giving them a combined thickness of 122 feet. The Del Rio, "Sea mud," is recorded as having its usual thickness of 70 feet. The well is here recorded as entering the Georgetown at 657 feet, this formation having been drilled into only about 10 feet.

107. George Sauer, Bulverde Road, near Haags' store, 6½ miles from San Antonio. Alex Lorenz, driller.

Limestone (Austin)	0- 170
Shales (Eagleford)	170- 210
Limestone (Buda)	210- 260
Clay (Del Rio)	260- 330
Limestones (Georgetown)	330- 370

108. Henry Shumeier, 1 mile south of Wetmore, west side Bulverde Road. Lorenz, driller. Elevation 760; non-flowing artesian water.

Adobe and hard rock (Austin)	0- 250
Lignite (Eagleford)	250- 275
Hard rock (Buda)	275- 325
Mud (Del Rio)	325- 375
Limestone rock	375- 420

109. Shattuck well, on 19th Street, about 1 mile south of Elmendorf Lake, and near the west city limits of San Antonio. L. N. Knight, driller.

Chiefly yellow and blue clay	0- 335
Limestone	335- 703

Eagleford	703- 735
Buda	735- 798
Del Rio	798- 856
Limestones	856

111. Southern Ice Company, Durango and Frio streets, east of I. & G. N. Ry., and south of Commerce Street, San Antonio.

Soft pebbles	0- 5
Hard pebbles	5- 8
Yellow clay	8- 48
Brown clay	48- 160
Brown clay, light	160- 260
Magnesian rock	260- 385
Lime rock	385- 520
Sulphur water at	428
White limestone	557
Not recorded	557- 566
White clay	566
Not recorded	566- 585
"Coal" (Eagleford)	585-600?
"White lime (Buda)	600- 650
"Mud" (Del Rio)	650- 711
Limestone (Georgetown-Edwards)	711- 911

113. Southwest Land Corporation, about 300 yards south of Commerce Street and ¼ mile west of Lady of the Lake College, San Antonio. T. H. Little, driller. Sulphur water at 410 feet. Elevation, 708. Good water at 715 and 850 feet.

Gravel and yellow clay (Navarro-Taylor)	0- 60
Shale (Navarro-Taylor)	60- 390
Soft white lime (Austin)	390- 528
Lignite (or shale) (Eagleford)	528- 560
Hard white lime (Buda)	560- 620
Mud hole (Del Rio)	620- 672
Light brown lime (Georgetown-Edwards)	672- 700
White to gray lime (Georgetown-Edwards)	700-1000

118. Steves Irrigated Gardens, San Antonio. First water came to top at 1065-1070 feet. Drilled into water rock at 1185 feet when drilling had to be abandoned, on account of flow of water.

Surface materials, water	0- 28
Blue clay	59- 604
White clay or rock	604- 728
Gray rock	728- 780
Yellow rock	780- 805
Gray rock	805- 894

Sulphur water	850
Lignite (Eagleford)	894- 922
Gray rock (Buda)	922- 983
Mud hole (Del Rio)	983-1041
Gray rock	1041-1060
Water at	1065
Brown rock	1060-1100
Brown hard flint	1100-1140
Gray hard flint?	1140-1160
Yellow hard flint?	1160-1185

119. Steves well, 509 King William St., San Antonio. Surface elevation about 650 feet. First sulphur water at 449; big flow at 742 feet.

Surface	0- 2
Hard pan	8- 19
Gravel	19- 34
Yellow clay	34- 42
Blue clay	42- 250
Austin chalk	250- 442
White limestone	442- 472
Yellow limestone	472- 489
Gray limestone	489- 580
Lignite (Eagleford)	580- 613
Gray limestone	613- 682
Crystallized lime	682- 734
Total depth	758

120. Steves well, south of Chavanaux Road, west of S. A. & A. P. Ry. Benkendorfer, driller. Flowing warm sulphur water. The Del Rio clay in this well although not very definitely placed is reported to lie 1790 feet from the surface, or at the level 1130 feet below sea. This record places the formation nearly 400 feet lower than in the Alta Vista oil field. Scarcely more than a mile to the east-southeast.

123. Superior Oil Company, Linn farm, east of Palo Alto Road, 12 miles south of San Antonio. Fitzgerald, driller. Test well for oil. Oil showings as noted. Also warm flowing sulphur water from the Comanchean formations.

Black soil and clay	1- 14
Yellow clay	14- 18
Yellow clay	18- 50
Yellow and blue clay	50- 80
Blue and red shale	80- 125
Shale	125- 145

Greensand (set 178′ 8″ pipe)	145- 168
Tough shale	168- 187
Shale and slate	187- 263
Gas rock	263- 275
Soft lime rock	275- 279
Gas sand, hard	279- 282
Shale	282- 320
Lime rock	320- 328
Fine sand	328- 335
Shale with occasional boulders	335- 420
Soft shale and white slate	420- 500
Shale and soft slate	500- 750
Soft white lime	750- 753
Gypsum and shale	753- 758
Soft gray lime	758- 761
Shale	761- 783
Lime and shale	783- 796
Lime rock and pyrite of iron	796- 800
Gypsum and shale	800- 830
Lime rock	830- 834
Shale	834- 840
Lime, rock	840- 853
Shale	853- 855
Slate	855- 873
Shale	873- 904
Slate	904- 909
Shale	909- 922
Slate	922- 925
Rock, gray limes	925- 926
Blue mud	926- 950
Pyrites of iron	950- 953
Rock, lime	953- 980
Oil-bearing sand	980- 985
Set 989 feet of 6″ pipe	
Soft shale and mud	985-1020
White shale, strong gas	1020-1060
Oil-bearing shale	1060-1088
Rock, gray lime	1088-1125
Shale and slate	1125-1200
Lime, soft	1200-1235
Sand, showing little oil	1235-1241
Slate and shale	1241-1300
Soft shale, caving	1300-1420
Slate	1420-1430
Soft lime	1430-1439
Shale and sand, soft, caving	1439-1500

Slate and shale	1500-1520
Soft blue shale, caving	1520-1557
Set 4″ pipe	
Lime rock	1557-1600
Blue slate	1600-1635
Hard white lime	1635-1740
Honey-combed, soft lime, hot sulphur water	1740-1800
Hard and soft lime	1800-2600
Oil sand, small showing of oil	2600-2606
Hard blue lime	2606-2900
Little sand and fresh water	2900

In this well a greensand horizon is reported at 145 feet from the surface. The Del Rio clay appears from the log to lie at about 1500 feet from the surface, the interval between the green sand and the top of the Del Rio here being 1375 ft. while in the Kearney well nearby this interval appears to be 1326 feet. When reduced to actual elevations, the greensand horizon in the two wells is found to be about 20 feet higher in the Kearney than in this well. The well was drilled approximately 1500 feet into the Comanchean formations and hence probably terminates in the Travis Peak formation. Although not so stated in the log, one of the drillers on this well reports that near the bottom of the well was found little altered wood resembling cedar, similar to that found in the Ridder well.

124. Terrell Hot Wells, west of the Pleasanton Road, 5½ miles south of San Antonio. Record published in U. S. G. S., 18th Ann. Rpt., Pt. 2, p. 294. Flowing warm sulphur water, temperature reported to be 106° F.

From the record of this well it appears that the Del Rio clay was passed through here at from 1380 to 1425 feet or at the actual level of 750 feet below sea. From these data the top of the Comanchean formations would be expected at about 1320 feet from the surface. Accordingly the whole of the Upper Cretaceous and possibly some of the Tertiary is penetrated by this well. At the depth of 600 feet from the surface were fossils identified by Dr. Hill as **Gryphea vesicularis**, indicating the Navarro formation. Brown coal, or lignite, is reported in this well at 140; 240, and 280 feet from the surface. The lignite suggests that the Wilcox may be present, extending into this structurally low area possibly from the southwest.

125. J. H. Terrell, at west city limits, ½ mile north of south limits of San Antonio. Sulphur water from the Austin at 765 feet; good water at 1134 to 1140 feet.

Gravel and yellow clay	0- 60
Shale	60- 550
Soft white rock	550- 903
Lignite (or shale) (Eagleford	903- 938
Hard white lime (Buda)	938- 998

Mud hole (Del Rio)	998-1058
Brown and white lime	1058-1140

127. Louis Tezel, one mile north Culebra Road, 13 miles northwest of San Antonio. Goforth, driller. Actual level of Del Rio, 715 feet.

Rock, not hard (Austin)	0- 55
Lignite (Eagleford)	55- 90
Buda	90- 150
Del Rio	150- 210
Rock (Georgetown-Edwards)	210- 245

132 Townsite well, Somerset. This well was drilled to the depth of 2002 feet many years ago, and of this part of the well no log has been found. Showings of oil were reported at 800-1100 and 1400 feet. During the summer of 1919 the well was deepened to 2320 feet by Dr. F. L. Thompson. From 2002 to 2030 feet no record has been made altho the drilling is said to have been in rock (Buda?). Below 2030 the samples indicate 70 feet of light blue clay. Altho no fossils were found this clay in general appearance resembles the Del Rio formation. Below the clay from 2100 to 2320 the cuttings indicate limestones varying in texture and apparently representing the Georgetown-Edwards formations. The well terminated in strata containing a great deal of pyrite.

While the data on this well are not as complete as desired it appears probable that the Del Rio formation at this place lies from about 2030 to 2100 feet from the surface. The elevation at the depot at Somerset as shown by the profile of the Artesian Belt Railway is 650 feet above sea. The elevation at the well altho not accurately determined does not vary greatly from that at the depot. Accordingly the Del Rio is placed provisionally at this locality as lying about 1380 feet below sea level.

135. Union Meat Company, south Laredo street, between Ralph and Brazos. Sulphur water at 491 feet; good water at 1150 feet.

Gravel and yellow clay	0- 60
Blue shale	60- 340
White limestone	340- 656
Lignite (or shale) (Eagleford)	656- 686
Hard white limestone (Buda)	686- 751
Mud hole (Del Rio)	751- 820
Light brown limestone	820-1150
White and gray limestone	1150-1400
No water below	1250

137. Wm. Vogt, 1½ miles west of the Medina River and 1/2

mile north the Quintana Road. Flowing warm sulphur water from the Comanchean formations.

In this well the greensand was reached at 297 feet from the surface, or at the level 308 feet above sea. The Del Rio formation was reached at about 1485 feet and was found to be 52 feet thick. Water was obtained from the limestones at 1560 feet and successively thereafter to the bottom of the well, 1850 feet. This well was drilled into the limestones below the Del Rio 313 feet and hence terminates probably in the Edwards formation. The stratigraphic interval from the glauconitic greensand to the top of the Del Rio is here given as about 1188 feet, or 91 feet less than in the Ridder well. The record of the Ridder well is probably the more reliable.

138. Mrs. A. Voight, on the north side of Culebra Creek, 14 miles from San Antonio on the Culebra Road. This well is located near the axis of the large structure described as the Culebra anticline.

Surface materials and rather soft rock (Austin)	0- 35
Lignite (Eagleford)	35- 65
Buda	65- 120
Mud hole (Del Rio)	120- 180
Rock (Georgetown-Edwards)	180- 216
Actual level top of Del Rio	730

139. Waring well, on south side Bandera Road, about 7½ miles northwest of San Antonio. D. Benkendorfer, driller. Non-flowing artesian water probably from the Travis Peak formation.

Soil	0- 3
Gravel	3- 13
Adobe, lime and boulders	13- 70
Blue clay	70- 215
Yellow limestone	215- 230
Crevice	230- 232
White limestone	232- 265
Blue clay	265- 275
White limestone	275- 295
Blue slate	295- 325
Adobe limestone	325- 335
White limestone	335- 370
Lignite (Eagleford)	370- 400
White limestone (Buda)	400- 460
"Mud hole" (Del Rio)	460- 510
White limestone	510- 530
Crevice with water	530- 532
Yellow limestone	532- 550
Crevice with water	550- 555

White limestone	555- 600
White limestone	600- 615
Sand, brown limestone and water	615- 745
White limestone	745- 785
Brown limestone	785- 795
White limestone	795- 815
Brown limestone, water	815- 830
White limestone	830- 865
Brown limestone, water	865- 870
White limestone	870- 920
Brown limestone	920- 925
White limestone	925- 950
Crevice, brown limestone	950- 955
White limestone	955-1035
Brown limestone	1035-1080
Blue limestone	1080-1190
White limestone	1190-1230
Blue limestone	1230-1260
Blue slate	1260-1262
White limestone	1262-1455
Hard brown crystallized limestone	1455-1478
Blue limestone	1478-1505
Hard brown crystallized limestone	1505-1510
White limestone	1510-1530
Hard blue limestone	1530-1565
Blue limestone	1565-1580
Brown limestone	1580-1595
White limestone	1595-1635
Hard blue limestone	1635-1655
Brown limestone, white hard streaks	1655-1700
Hard blue limestone	1700-1715
Brown limestone	1715-1735
White limestone	1735-1795
Hard brown limestone	1795-1860
Soft gray rock	1860-1870
Hard blue sandy rock	1870-1915
No description	1915-1935
Mud	1935-1953
White limestone	1953-1985
Mud	1985-1987
White limestone	1987-1997
Mud at	2000
One foot of mud at	2008
Hard limestone, shells and mud to	2040
Soft white limestone	2040-2070
Very hard sandy limestone	2070-2100

White limestone	2100-2115
Mud	2115-2140
Limestone	2140-2190
Blue mud	2190-2483
Hard limestone, streaks of mud	2483-2600
White sand	2600-2645
White limestone	2645-2675
Dark limestone and sand	2675-2699
Trinity white sand, water	2699-2705
Very hard cap rock	2705-2711
Sand and hard streaks	2711-2784
Sondstone, very hard, filled with red mud	2784-2810
Crevice	2810-2813
Sandstone shale	2813-2853

This well is of interest as affording apparently the maximum thickness thus far recorded for the Comanchean formations in this county. The Buda limestone was entered at 400 feet from the surface, and while no cuttings were preserved, it would appear from the log that the Cretaceous extends to 2705 feet, if not to the full depth of the well. Assuming the base of the Cretaceous to lie at 2705 feet there is indicated a thickness of the Cretaceous of not less than 2300 feet. The age of the materials from 2705 feet to the bottom of the well, 2853, is in doubt. Dirt taken from the dump around the well when washed and examined failed to show the presence of schists such as were found below the Cretaceous farther to the north, altho this test can not be assumed to be conclusive as to the presence or absence of schists.

WELLS TERMINATING IN THE UPPER CRETACEOUS

Among wells terminating in the Upper Cretaceous the following are listed as indicative of conditions met with in drilling into these formations. The wells entering the Comanchean as already noted, are chiefly water wells, while those of the Upper Cretaceous are chiefly either oil-producing wells or wells drilled in testing for oil or gas.

145. Cohen & Roby, north of and near to the jog in the Dwyer cross road in the Gas Ridge oil and gas field. Depth, 1035 feet, Elevation about 750 feet. Showings of gas between 170 and 249 feet, large gas production 865-990; showings of oil at 480, 492, 550, 615, 780, 815, and 1000-1035.

Gravel	0- 10
Yellow clay	10- 90
Black shale	90- 100

Blue shale	100- 120
Light blue shale	120- 160
Dark blue shale	160- 170
Shelly rock, gas	170- 240
Blue shale	240- 400
Small shell rock, first oil	400- 444
Sand 6 inches	444- 450
Blue shale..	450- 460
Shell of rock, oil sand	460- 475
Oil sand	475- 498
Blue shale	498- 500
Shell of rock, oil sand	500- 550
Blue shale 6 inches	550- 570
Small shell rock, oil sand 6 inches	570- 615
Shell rock	615- 650
Blue shale	650- 700
Shell rock, more oil sand	700- 780
Blue shale	780- 800
Small shell rock, more showing of oil	800- 815
Shell rock and gas	815- 840
Blue shale	840- 850
Large shell rock, large gas	850- 865
Gas rock	865- 890
Gas rock	890- 990
Blue shale	990-1000
Oil sand	1000-1035

This well starts in the Navarro formation and probably terminates in the Austin formations. The large gas supply at about 850 feet is probably in the Taylor formation. The heavy oil from this well at the depth of 1035 feet, analysis of which has been given, is probably from the Austin formation.

146. Crosby well No. 4, in Bexar County, north of Somerset.

Soil	1- 16
Rock	16- 20
Black gumbo	20- 60
Rock	60- 62
Shale	62- 92
Water sand	92- 107
Gumbo	107- 132
Shale	132- 262
Rock	262- 265
Gumbo	265- 275
Water sand	275- 293
Gumbo	293- 343
Rock	343- 347
Gumbo	347- 382

Shale	382- 482
Gumbo	482- 552
Soft shale	552- 602
Gumbo	602- 682
Soft sandy shale	682- 742
Hard sandy shale, shell of rocks	742-1020
Very hard rock	1020-1022
Sand shale	1022-1048
Rock	1048-1051
Shale and gumbo	1051-1116
Shale	1116-1126
Gumbo	1126-1141
Shale	1141-1181
Gumbo	1181-1191
Shale	1191-1217
Rock	1217-1231
Shale and oil sand	1231-1251
Gumbo	1251-1254

As in the case of other wells in the Somerset field, in Bexar County, this well starts in the Wilcox formation. The formation in which it terminates and from which oil is obtained is not definitely determined but is assumed to be either the Navarro or the Taylor.

147. Ingram well in the Alta Vista Field, drilled 1905, Jacob Wolff, driller. Depth, 1120 feet; 6″ casing set at 960 feet.

Greensand stratum recognized at 260 feet.....30 ft. thick

This stratum according to Wolff made a barrel of oil per day, gravity 32 (some other tests reported the gravity 38).

Second stratum greensand at 700 or 740 feet, about..70 ft. thick

Contained a good deal of gas and some oil. Made 2½ to 3 barrels per day.

Austin chalk rock recognized at 1000 ft.

Heavy Alta Vista oil found at 1060 to 1080 ft. This heavy oil from a 5 or 6 foot crevice in the rock containing asphalt like material.

Although not a producing well, this well is of interest as the first well drilled within the Alta Vista field in which a pronounced showing of oil was obtained. The well was drilled for water. The first producing oil well in this field was drilled about ten years later.

148. Wells of the Kimbly and Brown lease on the Swearingen property, south of the Medina River.

The producing horizon is reported in the wells on this property at the following depths: Swearingen No. 1, located at north side of the property, producing sand at from 1210 to 1235 ft; Swearingen No. 2, producing sand at from 1216 to 1245 ft; Swearingen No. 3, producing sand at from 1248 to 1280 ft; Gale No. 1, produc-

ing sand at from 1360 to 1400 ft; Swearingen No. 4, producing sand at from 1425 to 1485 ft. The wells are listed in the order of their location from north to south or east of south. The dip of the formations is thus seen to amount to as much as 115 feet between wells No. 1 and No. 4. The distance between these wells is a little more than a mile.

These wells start in the Tertiary. The formation in which they terminate is undetermined but may be either the Navarro or Taylor.

The following log is of the Kimbly and Brown Swearingon No. 4. This is the southernmost and deepest of the five wells drilled in this field to the close of 1918. Log furnished by Mr. Brown.

Soil	0- 3
Red clay	3- 27
Yellow clay	27- 50
Sand	50- 80
Lignite	80- 81
Sand	81- 140
Streaks of lignite	140- 146
Sand	146- 200
Rock	200- 208
Sand	208- 317
Rock	317- 323
Brown gumbo	323- 386
Rock	386- 394
Shale, thin rocks	394- 490
Gumbo	496- 575
Rock	575- 581
Shale	581- 750
Rock	750- 752
Gumbo	752- 880
Black sand, gas	880- 900
Gumbo	900-1395
Soft rock shows some lime	1395-1425
Oil sand	1425-1458
Gumbo	1458-1462

149. Well of J. K. Lamb, drilled by Park Oil and Gas Co., west of Corpus Christi Road, about 2 miles south of the Medina River. Test well for oil.

Surface sand	0- 2
Red sandy clay	2- 20
Water sand and boulders	20- 112
Loose gumbo and boulders	112- 150
Gumbo	150- 160
Sand rock	160- 165
Gumbo	165- 172

Sand rock	172- 174
Sandy gumbo	174- 222
Sand rock	222- 227
Gumbo (Set 8″ pipe at 265 ft.)	227- 342
Hard sand rock	342- 362
Gumbo	362- 388
Sandy gumbo	388- 392
Sandy gumbo	392- 450
Sand rock	450- 453
Water sand	453- 460
Sand rock	460- 465
Sandy gumbo and boulders	465- 505
Shale and gumbo	505- 565
Hard rock and gumbo	565- 582
Sand rock	582- 587
Shale and boulders	587- 701
Sand rock	701- 704
Shale	704- 708
Hard rock	708- 711
Shale	711- 720
Sand and lime rock	720- 723
Shale	723- 747
Sand rock	747- 751
Shale	751- 790
Sand rock	790- 793
Shale	793- 800
Sand rock	800- 803
Shale	803- 811
Sand rock	811- 815
Hard shale	815- 850
Sand rock	850- 853
Shale	853- 860
Sand rock	860- 863
Shale and rock	863- 940
Gumbo	940- 980
Sand rock	980- 983
Shale and gumbo	983- 987
Sand rock	987-1000
Shale and boulders	1000-1030
Gumbo	1030-1046
Sand rock	1046-1048
Shale	1048-1095
Gumbo (Set 6″ pipe at 1118 ft)	1095-1110
Coarse shale	1110-1160
Fine shale	1160-1190
Shale (slight showing of oil)	1190-1309

Rock	1309-1313
Shale	1313-1375
Gumbo	1375-1385
Shale	1385-1450
Rock	1450-1453
Shale	1453-1510
Gumbo	1510-1535
Rock	1535-1538
Shale (Set 4″ pipe at 1555 ft)	1538-1600
White lime	1600-1620
Shale	1620-1638
Rock	1638-1641
Shale	1641-1661
Rock	1661-1662
Shale	1662-1740
Rock	1740-1742
Shale	1742-1900
Black shale	1900-1940
Sand and shale	1940-1980

This well starts in the Wilcox formation. The Austin formation would seem, so far as can be judged from the log, to have been entered at about 1600 feet from the surface. Allowing for the Taylor and Navarro formations their usual combined thickness of about 900 feet, there is indicated at least 700 feet of Tertiary at this locality. The Austin formation apparently is 300 feet thick, the Eagleford "black shales" having been entered at 1900 feet. Cuttings from this well were examined at the time the well was drilled, by Dr. J. A. Udden, who identified the Austin formation as extending from about 1600 to 1900 feet and the Eagleford below 1900 feet. If this well terminates in the Eagleford at 1280, as seems probable from both the log and the cuttings, there is here the maximum thickness, 80 feet, recorded for this formation in Bexar County. Assuming that the well terminates at or near the base of the Eagleford, the estimated level of the top of the Del Rio at this place is somewhat more than 2000 feet from the surface, or near 1500 below sea level.

150. Mars Discovery well, Alta Vista oil field. Elevation, 600 feet. Drilled in 1915, on Kelso tract, 8 miles south of San Antonio.

Surface	0-	2
Gravel	2-	4
Red clay	4-	16
Joint clay	16-	40
Rock lime	40-	46
Yellow sand	46-	54
Blue shale	54-	70

Sand rock, red	70- 72
Blue shale	72- 110
Sand rock, rough	110- 113
Blue gumbo	113- 133
Sand, showed oil	133- 160
Blue gumbo	160- 180
Lime shale, hard	180- 325
Rock, lime shell	325- 326
Blue gumbo	326- 340
Blue shale	340- 380
Rock, showed pyrites	380- 400
Hard blue shale	400- 436
Blue gumbo	436- 450
Hard blue shale	450- 470
Sand, hard and black	470- 482
Hard blue shale	482- 550
Blue gumbo	550- 590
Hard blue shale	590- 655
Blue gumbo	655- 691
Hard blue shale	691- 715
Blue gumbo	715- 763
Soft sand, showed oil	763- 780
Soft blue shale	780- 808
Sand, showed oil	808- 818
Blue gumbo	818- 840
Hard blue sand	840- 851
Blue shale	851- 875
Blue gumbo	875- 890
Lime rock	890- 891
Soft blue shale	891- 908
Soft sand rock	908- 911
Sand, showed oil	911- 915
Blue hard shale	915- 940
Blue lime rock	940- 941
Gray, hard sand	941- 946
Hard blue shale	946- 995
Blue gumbo	995-1010
Sand, showed oil	1010-1014
Soft blue shale	1014-1030
Hard, gray sand	1030-1033
Blue gumbo	1033-1050
Hard gray sand	1050-1058
Hard blue shale	1058-1070
Oil sand, hard	1070-1090

(Did not drill to bottom of oil sand)

151. Mathey No. 1 of the Bexar Petroleum Company, located on the J. H. Mathey property about one mile west of Losoya. Elevation 515 feet. Depth 2925.

Notes on this well supplied by Hamilton and Walker have been included in connection with a discussion of the thickness of the Midway and Wilcox formations, which appear to extend to the depth of between 1340 and 1402 feet. The driller believes that the Austin formation was reached at the depth of 1892 feet and continued to the bottom of the well, 2025. If the top of the Austin be placed at 1892 feet, and from the drillers log apparently it can not be placed at any higher level, the Del Rio formation is to be expected in this well at a depth approximating 2342 feet, or near the actual level of 1827 feet below sea. The seemingly great thickness of the Tertiary in this well and in the Sarah Smith well, log of which is given later, indicates that a part of the interval assigned to the Upper Cretaceous in the Ridder, Kearney, and Superior Oil Co. wells may possibly also be Tteriary.

LOG OF J. H. MATHEY WELL NO. 1

Bexar Petroleum Company, near Losoya, Bexar County, Texas. Elevation 515 feet. Commenced drilling Nov. 18th., 1919.

0- 68 feet, red clay and small gravel.
68- 74 feet, blue-gray sand rock.
74- 78 feet, black gumbo.
78- 80 feet, blue-gray sand rock.
80- 100 feet, red clay and small gravel.
100- 102 feet, blue-gray sand rock.
102- 130 feet, red clay and sand.
130- 135 feet, black gumbo.
135- 180 feet, red gumbo and hard sand (water).
180- 190 feet, black gumbo.
190- 201 feet, black shale.
201- 208 feet, black gumbo.
208- 222 feet, dry brown sandy shale.
222- 224 feet, brown sand rock.
224- 240 feet, black gumbo.
240- 260 feet, dry brown sandy shale.
260- 263 feet, shell.
263- 290 feet, dry brown sandy shale.
290- 293 feet, brown sand rock.
293- 330 feet, brown sandy shale (dry and hard).
330- 336 feet, black gumbo.
336- 350 feet, brown sandy shale (dry and hard).
350- 358 feet, black gumbo.
358- 359 feet, gray sand rock.

359- 365 feet, black sandy gumbo.
365- 367 feet, gray sand rock.
367- 385 feet, black shale with lignite.
385- 409 feet, black sandy gumbo.
409- 445 feet, gray sand rock (water) (used roller bit)
445- 465 feet, black gumbo.
465- 466 feet, gray sand rock.
466- 471 feet, black sandy gumbo.
471- 472 feet, gray sand rock.
472- 505 feet, black sandy gumbo and boulders.
505- 515 feet, black shale.
515- 519 feet, gray sand rock.
519- 557 feet, black sandy gumbo and small boulders.
557- 570 feet, black shale and lignite.
570- 574 feet, gray sand and lime rock.
574- 590 feet, black shale and lignite.
590- 640 feet, black gummy shale.
640- 645 feet, black gummy shale and boulders.
645- 730 feet, black hard gummy shale.
730- 740 feet, black soft shale.
740- 770 feet, black hard gummy shale. (Some fossils).
770- 815 feet, black hard gummy shale.
815- 819 feet, black soft coarse shale, with green marl.
819- 841 feet, black hard gummy shale.
841- 850 feet, black soft coarse shale.
850-1084 feet, black hard gummy shale. 921-928. Core No. 1.
1084-1085 feet, gray hard sand.
1085-1090 feet, black hard gummy shale.
1090-1097 feet, black hard gummy shale.
1097-1117 feet, black hard gummy shale.
1117-1124 feet, black hard sandy shale.
1124-1127 feet, black hard gummy shale.
1127-1129 feet, gray sand rock.
1129-1165 feet, black hard gummy shale.
1165-1170 feet, brown hard sandy shale.
1170-1200 feet, black hard gummy shale.
1200-1202 feet, gray sand rock.
1202-1214 feet, black hard gummy shale.
1214-1215 feet, gray sand rock with pyrites.
1215-1360 feet, black hard gummy shale (Core 1320-1322) No. 2.
1360-1372 feet, black hard sandy shale.
1372-1407 feet, black hard gummy shale (Core 1402-1406) No. 3.
1407-1417 feet, black soft shale.
1417-1472 feet, black hard gummy shale (Core 1457-1459) No. 4.
1472-1490 feet, gray shale with lime. (Lime only thin layers).
1490-1548 feet, gray hard gumbo.

1548-1556 feet, gray hard shale.
1556-1570 feet, gray hard gumbo.
1570-1582 feet, gray hard shale.
1582-1600 feet, gray hard gumbo.
1600-1622 feet, gray soft shale.
1622-1632 feet, gray hard gumbo.
1632-1670 feet, gray soft shale. (Gas and little oil showing).
1670-1710 feet, gray hard gumbo.
1710-1720 feet, black soft gummy shale.
1720-1740 feet, gray hard gumbo.
1740-1763 feet, black hard gummy shale. (Core 1760-1763) No. 5.
1763-1820 feet, black hard gummy shale.
1820-1825 feet, black soft gummy shale.
1825-1840 feet, black hard gummy shale.
1840-1845 feet, black soft shale.
1845-1861 feet, gray hard sandy gumbo.
1861-1862 feet, gray lime rock.
1862-1870 feet, gray hard sandy gumbo.
1870-1885 feet, gray soft shale.
1885-1892 feet, gray hard sandy shale. (Set 6-inch casing at 1892),
1892-1938 feet, blue-gray chalk. (Showing little gas and oil).
1938-2007 feet, blue-gray chalk.

152. National Oil Co., Alta Vista oil field: Depth, 1132; elevation, 585. Producing horizon, Austin formation, 1120; sulphur water encountered at 1132. Actual level, top of producing sand, 635 feet below sea level. Estimated position top of Del Rio clay, 835 feet below sea level.

153. Oliver well, 9½ miles southwest of San Antonio. Depth 1030 feet. Oil showing at 200 and at 600 feet. Strong gas flow at 800 feet. Gas flow reported to have been 350,000 cu. ft. per day at time well was drilled, subsequently probably reduced in flow. This well probably reached to the Austin formation; however, the showing of oil and the gas with little doubt is from the Taylor and Navarro formations.

154. Openheimer well No. 1. Alta Vista field, about 1400 feet northeast of Fuchs, No. 1. Smith, driller. Depth 1295 feet; elevation 620. About 500 feet east of the Pleasanton Road. Producing horizon at 1150 feet. Sulphur water at 1295 feet. Actual level producing sand, 530 feet below sea. Estimated place of the Del Rio 830 feet below sea.

155. Park Oil and Gas Co. Applewhite No. 1 well. North side of Rockport Cross-road, 1½ miles east of Applewhite Road, 16

miles south of San Antonio on south side of T. C. Applewhite property. Thompson, driller. Depth, 1952 feet. Elevation 500 feet, more or less. Test well for oil.

Clay	0- 50
Rock	50- 51
Sand	51- 60
Rock	60- 62
Sand and boulders	62- 80
Rock	80- 82
Sand	82- 90
Rock	90- 98
Sand and boulders	98- 120
Rock	120- 122
Sand and boulders	122- 150
Rock	150- 152
Hard sand	152- 200
Rock	200- 202
Sand and boulders	202- 240
Shale	240- 275
Packed sand	275- 280
Shale and boulders	280- 340
Packed sand and gravel	340- 370
Packed sand	370- 400
Rock	400- 405
Shale	405- 420
Rock	420- 421
Rock (water sand)	421- 542
Sand rock	542- 630
Shale	630- 675
Rock	675- 685
Gumbo	685- 706
Rock	706- 715
Gumbo	715- 740
Shale and boulders	740- 825
Gumbo	825- 885
Shale, boulders, oil and gas sand	885- 940
Gumbo	940- 972
Hard shale	972- 995
Gumbo	995-1011
Shale	1011-1020
Gumbo	1020-1030
Hard shale	1030-1036
Gumbo and boulders	1036-1048
Shale	1048-1050
Shale and boulders, showing oil	1050-1080
Gumbo	1080-1110
Gumbo	1110-1127

Rock 1127-1133
Gumbo 1133-1148
Rock (red sand and iron) 1148-1155
Shale and oil sand, showing oil 1155-1175
Gumbo 1175-1185
Rock 1185-1187
Hard shale 1187-1258
Gumbo 1258-1262
(Set 1261 ft. 6″ line pipe in cement)
Gumbo 1262-1268
Hard shale 1268-1290
Soft shale 1290-1380
Gumbo 1380-1390
Shale and boulders 1390-1425
Gumbo 1425-1435
Shale and boulders 1435-1472
Hard sand 1472-1491
Gumbo 1491-1512
Hard rock 1512-1514
Shale showing oil 1514-1524
Gumbo 1524-1530
Rock 1530-1532
Chalk rock 1532-1572
Gumbo 1572-1598
Shale and oil sand (showing oil and gas 1598-1645
Gumbo 1645-1655
Shale 1655-1688
Gumbo 1688-1710
Hard shale 1710-1715
Gumbo, white 1715-1720
Shale showing oil 1720-1730
Gumbo (Set 3″ lines) 1730-1732
Shale (Oil show) 1732-1796
Shale 1796-1809
Dark brown sand and shale (Oil show) 1809-1816
Shale 1816-1827
Sand 1827-1830
Gumbo 1830-1842
Soft shale 1842-1847
Gumbo 1847-1852
Soft shale 1852-1857
Gumbo 1857-1862
Shale and hard sand 1862-1867
Gumbo 1867-1874
Shale 1874-1877
Gumbo 1877-1886
Soft rock 1886-1889

Soft shale	1889-1896
Chalk rock	1896-1915
Chalk rock	1915-1934
Oil sand	1934-1952

The well starts probably in the Wilcox formation and to the depth of 1050 feet or more may be Tertiary, although one cannot be sure of this. The reference is chiefly because of the reported presence of boulders to that dpth. From 1050 to 1896 feet, so far as can be judged from the log, the Navarro and Taylor formations may very well be represented, their combined thickness being early 900 feet. The Austin formation appears to lie at about 1896 feet. If this is true the Del Rio may be expected at about 2350, or something like the actual level of 1850 feet below sea.

156. Perrinot well, about 2 miles southwest of Martinez, east of the Foster Cross-road on J. F. Schlather's property. Test well for oil.

Soil	0-	2
Yellow clay	2-	22
Shale	22-	63
Rock	63-	64
Shale and boulders	64-	87
Shale	87-	150
Gumbo	150-	236
Shale	236-	249
Gumbo	249-	269
Rock	269-	270
Shale	270-	297
Gumbo	297-	307
Shale and boulders	307-	359
Gumbo	359-	371
Shale	371-	391
Gumbo	391-	401
Shale	401-	438
Gumbo	438-	446
Shale	446-	451
Rock	451-	453
Shale	453-	478
Gumbo	478-	483
Rock	483-	492
Shale	492-	501
Gumbo	501-	522

Rock	522- 523
Shale, oil showing	523- 534
Gumbo	534- 547
Rock	547- 549
Gumbo	549- 559
Rock	559- 565
Blue clay	565- 570
Gumbo	570- 583
Rock	583- 585
Gumbo	585- 602
Sand and shale	602- 607
Gumbo	607- 661
Rock	661- 663
Shale, oil showing	663- 669
Gumbo	669- 684
Shale and boulders	684- 709
Shale and gumbo	709- 730
Gumbo, very tough	730- 761
Shale	761- 774
Gumbo	774- 779
Shale and boulders	779- 789
Soft rock	789- 806
Shale	806- 816
Rock	816- 827
Gumbo	827- 837
Rock	837- 848
Shale	848- 860
Black sand and shale, showing oil and gas	860- 868
Gumbo	868- 873
Black sand and shale	873- 900
Rock	900- 902
Not recorded	902- 953
Gumbo	953- 984
Shale	984- 986
Gumbo	986-1064
Chalk	1064-1080
Shale	1080-1107
Gumbo	1107-1118
Shale	1118-1129
Gumbo	1129-1134
Shale	1134-1150
Rock and shale	1150-1162
Shale	1162-1167
Gumbo	1167-1178
Shale	1178-1188
Gumbo	1188-1193
Shale	1193-1208

Rock	1208-1212
Shale, show gas and oil	1212-1239
Chalk rock	1239-1375

This well starts in the Tertiary, probably in the Midway formation, and extends into but not through the Austin formation. The dividing line between the Tertiary and Cretaceous can scarcely be determined from the log, although the Midway may provisionally be regarded as extending to 360 feet, as this is the last record of boulders suggestive of those of the Tertiary formations. From 360 to something more than 1200 feet is apparently referable to the Navarro and Taylor formations. Below about 1239 feet, the drilling record indicates the Austin formation in which the well terminates. Assuming that the top of the Austin formation lies at about 1250 feet, the Del Rio at this locality is to be expected at about 1700 feet below the surface or at about the actual level of 1000 feet below sea.

157. Porch well, east of the Pleasanton Road between Mitchell's Lake and the Medina River on Arroyo Hondo. Depth, 1505 feet; elevation about 530 feet. Test well for oil; showings of oil at about 1000 feet, and from about 1292 to 1493 feet. No water except small amounts between 60 and 70 feet, and a little salt water at the bottom of the hole. Record submitted to Bureau of Economic Geology by E. L. Porch.

Soil and clay	0- 30
Hard pan	30- 50
Soft sand rock	50- 60
Gravel, loose; water	60- 66
Very hard rock	66- 69
Sand fine, black	69- 72
Clay, 10″ casing set at 81′	72- 87
Lignite	87- 90
Sand rock	90- 135
Very hard sand rock, gray	135- 137
Sand rock	137- 164
High grade lignite or coal	164- 172
Sand rock	172- 182
Hard rock	182- 184
Shale	184- 193
Hard sand rock, blue	193- 203
Shale	203- 213
Gumbo	213- 286
Shale and boulder	286- 297
Rock, hard	297- 299
Gumbo, very stiff	299- 309
Rock, very hard	309- 312
Gumbo	312- 333

Sand rock, soft	333- 353
Hard blue rock	353- 355
Gumbo	355- 362
Hard rock	362- 364
Gumbo	364- 379
Boulder, flint	379- 381
Gumbo	381- 387
Rock, hard	387- 389
Gumbo, tough	389- 409
Rock	409- 410
Gumbo	410- 417
Rock	417- 420
Gumbo	420- 454
Hard rock	454- 456
Gumbo	456- 473
Rock	473- 474
Gumbo, very stiff	474- 492
Boulder	492- 494
Gumbo	494- 518
Gumbo and shell	518- 523
Very hard rock	523- 526
Gumbo	526- 544
Shale and boulder	544- 565
Gumbo with boulder	565- 595
Gumbo and shell (Cretaceous)	595- 609
Shale with boulders	609- 627
Rock	627- 629
Gumbo	629- 637
Shale	637- 647
Gumbo and boulder	647- 671
Shale and boulder	671- 689
Gumbo	689- 705
Rock	705- 706
Shale and shell	706- 719
Gumbo	719- 775
Shale and shell	775- 791
Gumbo	791- 865
Shale	865- 872
Rock	872- 874
Shale, blue	874- 881
Gumbo	881- 888
Shale	888- 892
Gumbo, light colored	892- 894
Shale, coarse, blue	894- 897
Rock, soft	897- 898
Shale and boulder	898- 904
Gumbo	904- 966

Shale, some soft	966- 985
Shale and sand	985-1003
Gumbo	1003-1056
Shell and rock	1056-1058
Gumbo	1058-1129
Shale and sand, compact	1129-1133
Shale	1133-1138
Shale, with large proportion of green sand	1138-1148
Shale and darker sand	1148-1157
Gumbo, dark sand, very fine	1157-1171
Boulder	1171-1172
Shale	1172-1175
Gumbo	1175-1180
Boulder	1180-1181
Gumbo	1181-1192
Boulder or rock	1192-1193
Gumbo	1193-1208
Very fine shale	1208-1213
Gumbo with pyrites	1213-1233
Gumbo, tough blue	1233-1292
Shale, gas and oil showing	1292-1296
Soft shale and sand, gas	1296-1329
Shale or gumbo and sand	1329-1394
Gumbo, blue, no sand	1394-1430
Shale and sand, gas and oil	1430-1464
Oil sand, little shale	1464-1483
Very dark shale, sand	1483-1493
Dark blue gumbo and sand, very hard	1493-1505

Supplementary data from owners of well: "From 1296 to 1394 the shale or gumbo was in alternate layers of about six inches, sand between; drilling was hard, while in the shale or gumbo and would go quickly through the sand. From each sand layer fine showings of gas and some oil were noticed. Five joints of Layne & Bowler screen were set to catch this, but was too coarse. A fine black sand came through and formed a bridge and would form as fast as was washed out. The oil sand from 1464 to 1483 would undoubtedly have made a well if same had been properly cased and washed. Live oil of light gravity and parafine base came out continually while going through with heavy gas pressure pieces of parafine as large as end of thumb came up with cuttings. In this well there was no evidence of Austin chalk which was struck in other wells 3 miles to the northwest at 1100 to 1200 feet; other sections show shallow oil ahd gas, none noticed in this well until about 1000 feet down; no water encountered except between 60 and 70 feet, although a little salt water showed up from the bottom of the hole."

158. Log of Oil Prospecting Well of W. C. Steubing, 2 miles southeast of Somerset, Bexar County, Texas. Sarah Smith No. 1.

(Prepared by L. W. Stephenson from samples furnished by the owner; fossils identified by C. W. Cooks).

		Thickness feet	Depth feet
1.	Reddish brown, slightly ferruginous, fine sand..	4	4
2.	Light gray, very fine argillaceous, micaceous sand blotched with yellow	16	20
3.	Fine gray sand like No. 2 but more completely blotched with sulphur yellow and some purplish tint	20	40
4.	Dark gray finely sandy, micaceous, carbonaceous clay with fragments of fine reddish to yellowish ferruginous sandstone	20	60
5.	Gray fine slightly calcareous sand with some mica and numerous reddish, yellowish and brownish grains; water bearing	20	80
6.	Gray sand like the preceding, but contains numerous small, white flaky grains that are probably rotten shell fragments, as they effervesce freely in acid; water bearing.....	20	100
7.	Fine gray clean sand with pinkish and yellowish grains, and some mica; water bearing....	20	120
8.	Dark gray fine micaceous sand with numerous fragments of gray shaly clay	20	140
9.	Fint gray calcareous sand with some mica and numerous dark grains; water bearing.....	20	160
10.	Gray sand like No. 9; water bearing.....	20	180
11.	Fine gray clean sand, with some mica and numerous dark grains; water bearing.....	20	200
12.	Gray sand like No. 11, but contains small fragments of gray shaly clay and small fragments of vein calcite; water bearing.....	20	220
13.	Fine clean sand like No. 11, with a few fragments of shaly clay; water bearing.....	35	255
14.	Ground-up gray hard slightly calcareous sandstone	4	259
15.	Fine gray clean sand with some mica and numerous dark grains	20	279
16.	Gray sand like No. 15	12	291
17.	Ground-up light gray medium grained sandstone	21	312
18.	Sandstone like No. 17	10	322
19.	Fine gray sand with some mica, numerous dark grains, numerous fragments of gray		

		Thickness feet	Depth feet
	shaly clay, and small particles of black lignite	22	344
20.	Light gray clean sand with numerous dark grains and small fragments of black lignite	31	375
21.	Dark gray argillaceous sand with some mica and some fragments of gray shaly clay	22	397
22.	Dark gray to blackish, finely sandy carbonaceous clay, containing some marcasite	16	413
23.	Dark gray carbonaceous clay mixed with fine gray sand	24	437
24.	Mottled mixture of fine white and light gray partly indurated sand, the cementing substance apparently being white and gray clay; some fragments of gray shaly clay	21	458
25.	Mixture of fragments of dark gray shaly clay, and white sandy clay (?)	20	478
26.	Mixture of dark gray calcareous sand, fragments of dark gray shaly clay, and black lignite	20	498
27.	Mixture like No. 26	21	519
28.	Mostly fragments of gray shaly clay, with some loose fine gray sand, and a few shell fragments	19	538
29.	Mixture of fine gray calcareous sand and fragments of gray shaly clay	19	557
30.	Mixture like No. 29; some shell fragments	21	578
31.	Mixture like No. 30	22	600
32.	Mixture like No. 30; some lignite and shell fragments	21	621
33.	Mixture like No. 30; recognized the fossil shell Toinostoma? sp—	17	638
34.	Mixture like No. 30; some shell fragments and some marcasite	21	659
35.	Mostly gray shaly clay with a few shell fragments; recognized the fossil shell **Ringicula** dalli Clark?	21	680
36.	Shaly clay like No. 35; recognized the fossil shells Cyclichna sp., Corbula sp., and Turritella sp.	20	700
37.	Dark gray clay (gumbo of the driller) with a few shell fragments; recognized the fossil shell Fuses sp. cf F **Meleri** Aldrich	21	721
38.	Gray shaly clay	19	740
39.	Gray shaly clay, with some shell fragments recognized Turritella sp.	21	761

		Thickness feet	Depth feet
40.	Gray shaly clay; recognized the fossil shells, **Olivella mediavia Harris, Natica** sp. **Turritella** sp.	21	782
41.	Gray shaly clay, larger fragments; recognized the fossil shell **Pleions rugata** (Hilprin)??	19	801
42.	Dark gray clay (from bit?)	21	822
43.	Gray finely shaly clay	21	843
44.	Gray shaly clay; recognized the fossil shells **Venericardia,** sp and **Natica** sp.	22	865
45.	Gray shaly clay; larger fragments	20	885
46.	Gray (finely shaly clay with a mixture of dark glauconitic sand; recognized the fossil shells **Venericardia** sp., and **Turritella** sp.	21	906
47.	Gray shaly clay and glauconitic sand, like No. 46	20	926
48.	Gray shaly clay and glauconitic sand like No. 46	21	947
49.	Gray finely shaly clay	21	968
50.	Gray finely shaly clay with some dark glauconitic grains and some shell fragments.	21	989
51.	Gray shaly clay, slight showing of oil and gas.	23	1012
52.	Gray shaly clay with some glauconite grains; recognized the fossil shell **Venericardia** planicosta Lamark. Some showing of oil and gas.	21	1033
53.	Shaly clay like No. 52, slight showing of oil and gas	22	1055
54.	Shaly clay like No. 52, gas and oil showing increase	4	1059

According to Dr. Cooke, the fossils enumerated in the log indicate the Midway Age of the containing beds.

Continuation of Log of Oil Prospecting Well of W. C. Steubing (Sarah Smith No. 1) 2 miles southeast of Somerset, Bexar County, Texas. (Prepared by L. W. Stephenson from samples furnished by the owner).

55.	Light gray to whitish, highly calcareous clay or argillaceous limestone ground to fine mud, with fragments of platy impure limestone.	16	1075
56.	Gray, calcareous somewhat shaly clay with some admixture of material like No. 55	20	1095
57.	Gray, calcareous, shaly clay	20	1115
58.	Gray, shaly clay like No. 57; observed 2 specimens of Foraminifera	21	1136
59.	Gray, shaly clay, like the preceding, with a few shell fragments	21	1157

		Thickness feet	Depth feet
60.	Gray shaly clay like the preceding, with a few shell fragments, recognized **Venericardia?** and a small smooth gastropod	20	1177
61.	Gray finely shaly, calcareous clay	20	1197
62.	Gray calcareous clay like No. 61	21	1218
62.	Gray calcareous clay like No. 61	21	1239
63.	Gray calcareous clay like No. 61	21	1239
64.	Gray calcareous clay like No. 61	20	1259
65.	Gray calcareous clay like No. 61	20	1279
66.	Gray calcareous clay like No. 61	20	1299
67.	Gray calcareous clay like No. 61	20	1319
68.	Gray calcareous clay like No. 61	20	1339
	Not represented by sample	11	1350
69.	Gray shaly calcareous clay	50	1400
70.	Gray shaly calcareous clay	20	1420
71.	Gray shaly calcareous clay	14	1434
72.	Gray shaly calcareous clay	6	1440
73.	Gray shaly calcareous clay with a little fine sand	4	1444
74.	Gray shaly clay like No. 73	11	1455
75.	Gray shaly clay like No. 73	5	1460
76.	Gray shaly clay like No. 73	20	1480
77.	Gray shaly clay like No. 73	4	1484
78.	Gray shaly clay like No. 73	5	1489
	Not represented by sample	5	1494
79.	Gray shaly clay like No. 73	5	1499
80.	Gray shaly clay like No. 73; contains a small gastropod	4	1503
81.	Gray shaly clay like No. 73	21	1524
82.	Gray shaly calcareous clay and very fine sand	20	1544
83.	Gray shaly calcareous clay with some fine sand; one or two shell fragments	21	1565
84.	Gray shaly clay and some sand; like No 83	21	1586
85.	Gray shaly calcareous clay and very fine sand	19	1605
86.	Gray shaly calcareous clay and very fine sand	21	1626
87.	Gray shaly calcareous clay and very fine sand	20	1646
88.	Gray shaly calcareous clay and very fine sand	21	1667

This set of samples (Nos. 55-88) is very much alike throughout. A fragment of a **Venericardia?** from sample No. 60 (depth 1157-1177 ft.) seems to indicate that the shaly clay at that depth belongs to the Midway group of the Eocene. Nothing was found below that depth to indicate that the well had passed from the Eocene into the underlying Cretaceous. If it is all Eocene the strata of this age are thicker at this place than we had supposed.

COPY OF ORIGINAL RECORDS OF SARAH SMITH 1 IN DRILLERS' NOTE BOOKS.

Well is located 2 miles in a southeast direction from Somerset, Bexar County, Texas, and is known as Sarah Smith Well No. 1. Owner, W. C. Steubing; Contractor, Robert Newton; Driller, Wm. Allen. Well begun 9-30-18; completed Jan. 1919. Rotary rig used. Diameter at mouth 10 inches. Six-inch casing extends to a depth of 1060 feet; cemented. Size of hole below 6-inch casing 5 7/8 inches; 4 1/2-inch liner extends from depth of 1046 feet to bottom of well. Recorded by W. C. Steubing, 806 West Woodlawn Ave., San Antonio, Texas.

Sample No.	Rock or Material	Color	Hard or Soft	From	To	Remarks
1	Sand	White	Soft	0	4	
2	Clay	Yellow	Soft	4	20	
3	Clay	Yellow	Soft	20	40	
4	Shale	Dark	Soft	40	60	
5	Sand	Light	Soft	60	80	Water sand.
6	Sand	Light	Soft	80	100	
7	Sand	Light	Soft	100	120	
8	Sand	Dark	Soft	120	140	12" of rock at 150 ft.
9	Sandy shale	Dark	Soft	140	160	
10	Sand	Light	Soft	160	180	
11	Sand	Light	Soft	180	200	Water sand.
12	Sand	Light	Soft	200	220	
13	Sand	Light	Soft	220	255	
14	Rock	Light	Hard	255	259	
15	Sand	Light	Soft	259	279	
16	Sand	Light	Soft	279	291	
17	Rock	Light	Hard	291	312	
18	Rock	Light	Hard	312	322	
19	Sand	Light	Soft	322	344	
20	Sand	Light	Soft	344	375	
21	Sand and shale	Dark	Soft	375	397	
22	Shale	Dark	Soft	397	413	
23	Shale	Dark	Soft	413	437	
24	Shale	Light	Soft	437	458	
25	Shale	Dark	Soft	458	478	
26	Shale	Dark	Soft	478	498	
27	Shale	Dark	Soft	498	519	
28	Shale	Dark	Soft	519	538	
29	Shale	Dark	Soft	538	557	

30	Shale	Dark	Soft	557	578	
31	Shale	Dark	Soft	578	600	
32	Shale	Dark	Soft	600	621	
33	Shale	Dark	Soft	621	638	Ribs of soft chalky rock from 6″ to 14″ thick.
34	Shale	Dark	Soft	638	659	
35	Shale	Dark	Soft	659	680	Note small shells and pieces of others.
36	Shale	Dark	Soft	680	700	
37	Gumbo	Dark	Hard	700	721	Rib of chalky limestone 12″ thick above gumbo.
38	Shale	Dark	Soft	721	740	
39	Shale	Dark	Soft	740	761	Note the shells.
40	Shale	Dark	Soft	761	782	
41	Shale	Dark	Soft	782	801	
42	Gumbo	Dark	Hard	801	822	
43	Shale	Dark	Soft	822	843	
44	Shale	Gray	Soft	843	865	Shale, some sand.
45	Shale	Gray	Soft	865	886	Shale, shells, and sand.
46	Shale	Bluish gray	Soft	886	906	Shale and black sand.
47	Shale	Bluish gray	Soft	906	926	Shale and some black sand.
48	Shale	Bluish gray	Soft	926	947	Shale and thin ribs of rock 1″ to 6″ every 6 to 10′.
49	Shale	Bluish gray	Soft	947	968	Shale and thin ribs of rock 1″ to 6″ every 6 to 10′.
50	Shale	Bluish gray	Soft	968	989	Shale, black sand. Slight showing of oil and gas.
51	Shale	Bluish gray	Soft	989	1012	Shale, 12″ rock at 1002′ some oil showing.
52	Shale	Bluish gray	Soft	1012	1033	2 ft. rock 1026, 2 ft. rock 1032.
53	Shale	Bluish gray	Soft	1033	1055	Slight oil showing. In 2 ft. of limestone. Rib 4″ thick. Extends in next sample.
54	Shale	Bluish gray	Soft	1055	1059	Gas and oil showing. Increase under 4″ of rock.
55	Shale	Dark gray	Soft	1059	1075	With 6″ rock at 1066. Showing oil underneath.
56	Shale	Dark gray	Soft to 1090, hard to 1095	1075	1095	2″ rock at 1080—small showing oil underneath.
57	Shale	Dark gray	Hard to 1103, softer 1103-1115	1095	1115	More or less oil saturation throughout entire 20′.
58	Shale	Dark gray	Very hard 1115-25, 2″ rock at 1134	1115	1136	Small amount shells, 6″ streak of soft shale at 1036, with oil and gas. More or less saturations throughout 20′.
59	Shale	Dark gray	Very hard 1125-45, softer 1145-50, harder 1050-57.	1136	1157	More or less gas and oil throughout entire length.
60	Shale	Dark gray	Very hard 1157-68, little softer 1168—77.	1157	1177	More or less oil showing throughout entire length.

Sample No.	Rock or Material	Color	Hard or Soft	From	To	Remarks
61	Shale	Dark gray	Very hard entire length	1177	1197	Steady drilling required 4 hours to finish 20'.
62	Shale	Dark gray	Very hard	1197	1217	6" rock at 112, 1" rock at 1214.
63	Shale	Dark gray	Hard, requiring 3½ hours for 20'	1217	1239	Good show oil at 1223. More or less oil entire length. 6" rock at 1230—spots oil underneath.
64	Shale	Dark gray	Hard first 4' with 3" rock at 1242, 17' being much softer requiring 1½ hours for 17 ft.	1239	1259	Spots of brown oil from 1249 to 1259.
65	Shale	Dark gray	Softer first 10 ft., harder second 10 ft. Thin shell of rock at 1270.	1259	1279	Quite a showing of gas at 1270 underneath rib of rock. Entire length shows increase in saturation of oil.
66	Shale and some sand	Dark gray	Medium hard	1279	1299	Oil showing in ditch increasing.
67	Shale and some sand	Dark gray	Medium hard	1299	1319	Oil showing increasing.
68	Shale and some sand	Dark gray	Medium hard	1319	1339	Rock 2" thick at 1334. No gas underneath. Took 1 hour and 30 minutes for 20'.
69	Shale and some sand	Dark gray	Medium hard	1339	1359	Some better showing of oil at 1350, balance of 20' about same as above.
70	Shale and some sand	Dark gray	Medium hard	1359	1380	Slight oil showing in entire length with streaks several inches thick of better showings.
71	Shale and some sand	Dark gray	Medium hard	1380	1400	Better showing of oil. Slight showing of gas at 1392.
72	Shale and some sand	Dark gray	Medium hard	1400	1420	1403—gas in good flow continuing for 2', then decreased in flow for 7 ft., where formation grew hard. Oil entire length.
73	Shale and some sand	Dark gray	Softer at last end	1420	1440	Good oil at 1434, continuing very good to 1444.
74	Shale and some sand	Dark gray	Hard from 1445 to 1457	1440	1460	Good oil from 1457 to 1462 when formation grew harder.
75	Shale and some sand	Dark gray	Hard and soft streaks	1460	1480	Good oil showing 1473½ to 1480.
76	Shale and some sand	Dark gray	Soft to 1484, hard and soft in streaks.	1480	1503	Good oil to 1488 and good saturation to 1499, then increased with gas for 2 ft.
77	Shale and sand	Dark gray	Soft; cuttings very fine and sandy in appearance.	1503	1514	Pulled stem at 1503. At starting again showed well for first 12 minutes of drilling when increased showing evident and continued for 10 minutes when showings dropped back to normal, continuing to 1514 with some gas.

78	Shale and sand	Dark gray	Soft; cuttings very fine and sandy in appearance.	1514	1524	See 11/24/18 work was resumed first half hour showing very good—indicating accumulation, balance of distance normal.
79	Shale and sand	Dark gray	Soft; cuttings coarser and less sandy in appearance.	1524	1544	Normal amount of showing. No extra oil or gas. 1514 to 1544 drilled in 2 hours.
80	Shale and sand	Dark gray	Softer first 5 ft.; cuttings coarse as above.	1544	1565	First 5 ft. in 25 minutes, second 5 ft. in 1½ hours, third 5 ft. in 35 minutes, fourth 5 ft. in 2 hours. More or less oil showing in entire length.
81	Shale and sand	Dark gray	Softer, requiring not more 2½ hours entire length.	1565	1586	After having been shut down since 11/24/18, water was very thick for pump Very good oil showing first 45 minutes of pumping. Then decreased normal showing.
82	Sandy shale	Dark gray	Hard	1586	1605	Entire 20′ drilled in 3½ hours. Decreased oil showing.
83	Sandy shale	Dark gray	Soft	1605	1726	Entire length drilled in 35 minutes; cuttings show more sand in panning. Oil showing increased throughout length and into next length for first 6 ft.
84	Sandy shale	Dark gray	Soft first 7′, hard 1633-38, soft 1638-43.	1626	1646	Wash water very thick, 1633 to 1638 very hard, requiring 1¼ hours. 1638-43 requiring 20 minutes, 1643-46 requiring 50 minutes. Increase of oil and gas after softer streak.
85	Sandy shale	Dark gray	Comparatively soft first 5′, harder second 5′.	1646	1668	First 5′ requiring 40 minutes, second 5′ hard for 1½′, then softer balance of way. Oil showing very slight at this point.

159. Walsch Oil Company, well No. 1 on south side of Leon Creek in Mission Oil Field, near the Applewhite Road crossing. This well starts probably in the Navarro formation, as indicated by the greensand horizon near the surface. They probably terminate in the Austin formation and illustrate the character of drilling in the Mission oil field.

Gravel	0- 18
Greensand and soapstone	18- 40
Clay, blue	40- 60
Clay and gumbo	60- 80
Shale and rock, soft; a little gas	80- 97
Shale, a little oil	97- 130
Rock	130- 132
Shale	132- 134
Rock	134- 135
Shale	135- 140
Rock and sand	140- 155
Shale	155- 167
Rock	167- 181
Mud and small boulders	181- 192
Shale	192- 250
Shale and mud	250- 350
Rock	350- 352
Gumbo	352- 360
Rock	360- 364
Gumbo and shale	364- 430
Rock	430- 432
Shale	432- 441
Rock, hard and soft	441- 445
Shale and mud	445- 523
Rock	523- 530
Shale	530- 637
Rock	637- 657
Shale	657- 661
Rock	661- 665
Shale	665- 670
Gypsum	670- 698
Rock	698- 702
Shale	702- 765
Rock	765- 786
Shale	786- 791
Rock	791- 801
Shale	801- 814
Iron pyrite	814- 815
Shale	815- 821
Boulders	821- 824

Shale	824- 835
Rock	835- 853
Shale	853- 861
Rock	861- 869
Rock	869- 876
Shale and pyrite	876- 893
Pyrites, hard	893- 902
Shale	902- 925
Rock	925- 937
Rock and shale	937- 957
Shale	957- 982
Rock, hard	982- 988
Rock and shale	988-1002
Brown rock	1002-1024
Shale and some iron pyrite	1024-1067

160. Wolfe and Elder, Alta Vista Oil Field, depth 1286, Elevation 600. Test well for oil.

Samples from this well from 965 feet to the bottom were submitted by E. L. Porch and described by Dr. J. A. Udden (Mns). According to Dr. Udden's interpretation of the samples the well entered the Buda limestone at 1270 feet and terminated in this formation at 1286 feet. From this record it would seem that the Del Rio formation is to be expected at this locality at between 1300 and 1400 feet, or at an actual elevation of between 700 and 800 feet below sea level.

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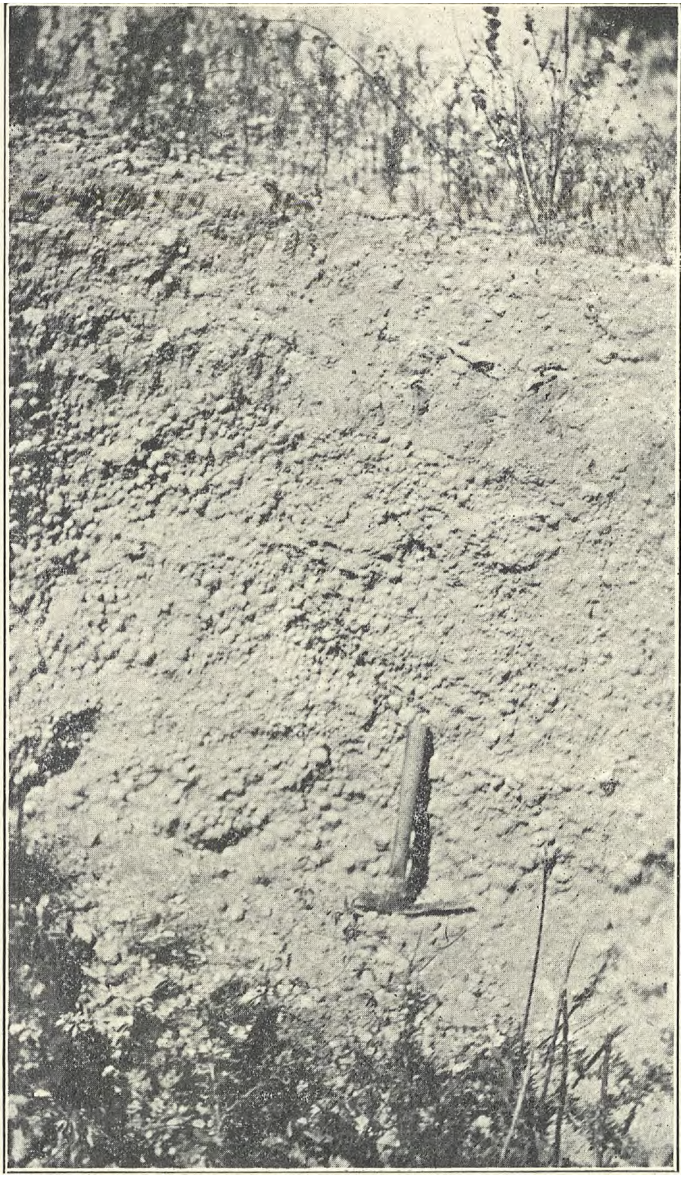

Pisolitic gravel in the Pleistocene as seen in pit excavated for road material near the Mission Loop Road south of San Antonio (See page 75).

UNIVERSITY OF TEXAS
BUREAU OF ECONOMIC GEOLOGY AND TECHNOLOGY
J. A. UDDEN, DIRECTOR

BULLETIN 1932.

GEOLOGICAL MAP OF BEXAR COUNTY, TEXAS

BY E. H. SELLARDS

Scale

0 1 2 3 4 5 6 7 Miles

LEGEND

Pleistocene
- Plt — Low Terrace
- Pmt — Middle Terrace
- Pht — High Terrace

Eocene
- Ec — Carrizo
- Ew — Wilcox
- Em — Midway

Upper Cretaceous
- Kn — Navarro
- Kt — Taylor
- Ka — Austin
- Kef — Eagleford

Comanchean—Cretaceous
- Kb — Buda
- Kdr — Del Rio
- Ke — Georgetown—Edwards
- Kgr — Glenrose

-100 — Contours on the Del Rio

Fault