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GEOLOGY AND GROUND-WATER RESOURCES OF DUVAL COUNTY, TEXAS

BY

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GEOLOGY AND GROUND-WATER RESOURCES OF DUVAL COUNTY, TEXAS

By Albert Nelson Sayre

ABSTRACT

Duval County is situated in southern Texas, 100 to 150 miles south of San Antonio and about midway between Corpus Christi, on the Gulf of Mexico, and Laredo, on the Rio Grande. The county lies on the Coastal Plain, which for the most part is low and relatively featureless. Between the Nueces River and the Rio Grande in this part of Texas the plain is interrupted by an erosion remnant, the Reynosa Plateau, which reaches a maximum altitude of nearly 1,000 feet above sea level and stands well above the areas to the east and west. The Reynosa Plateau includes most of Duval County and parts of Webb, Zapata, Starr, Jim Hogg, Jim Wells, McMullen, and Live Oak Counties. In Duval County the plateau is bounded on the west by the westward-facing Bordas escarpment, 75 to 150 feet high, which crosses the county with a southwesterly trend from about the middle of the north boundary to about the middle of the west boundary. On the east the plateau is bounded by a low seaward-facing escarpment, which passes through San Diego, trending a little west of south.

The streams that cross the area flow only during and immediately after periods of heavy rainfall, and their valleys are broad and rather shallow. Those on the Reynosa Plateau drain directly into the Gulf of Mexico; those west of the plateau drain into the Nueces River. The mean annual precipitation is about 20 inches.

The following formations crop out in the county from northwest to southeast, and all dip toward the southeast: Frio clay, Catahoula tuff, Oakville sandstone, Goliad sand, and Lissie formation. The Lagarto clay crops out in the bed of Lagarto Creek and its tributaries in northeastern Duval County and is also encountered in wells beneath the Goliad sand in the eastern part of the county. The Jackson formation is encountered in wells but does not crop out in this county. Its water is highly mineralized.

Caliche is nearly everywhere present on the Reynosa Plateau as a hard, impermeable layer either at the surface or from a few inches to a few feet beneath the surface. In certain rather small areas, however, it seems to be absent. Depressions called "sinks", either undrained or connected by stream channels, are rather common, and in these caliche seems to be lacking.

The Frio clay is composed dominantly of nonvolcanic clay. Its thickness, as estimated from wells down the dip and from the width of outcrop, is 300 to 400 feet in the outcrop area in extreme northwestern Duval County. It dips east or southeast at the rate of about 80 feet to the mile. Very little water is obtained from the Frio, and the water is highly mineralized.

The Catahoula tuff overlies the Frio clay unconformably. It dips southeast at the rate of about 80 feet to the mile and is about 1,100 to 1,300 feet thick. It is divided into three members. The lower member, the Fant tuff member, consists of tuff, tuffaceous clay and sand, and irregular beds of arkosic sandstone. In

general the lower part of this member yields little or no water to wells, but the upper part yields supplies of rather highly mineralized water sufficient for stock and domestic use. The middle member, the Soledad volcanic conglomerate member, consists of beds of conglomerate composed of boulders of volcanic origin, interbedded with tuffaceous clay and sandstone. The upper member, the Chusa tuff member, consists of tuff and tuffaceous clay with a few lenticular beds of conglomerate composed of volcanic material. Both the Soledad and the Chusa contain beds of sand or gravel that supply moderately to highly mineralized water sufficient for stock and domestic use and several wells yield sufficient water for use in drilling and for boilers. One flowing well at Crestonio yields sufficient water for irrigation of a small citrus orchard.

The Oakville sandstone overlies the Catahoula unconformably. It dips southeast at the rate of about 50 feet to the mile and is 400 to 500 feet thick. It consists of beds of fairly coarse gray to buff sandstone and clay. In the north-central part of the county it yields water to wells sufficient for stock and domestic use. The water is rather highly mineralized.

The Lagarto clay overlies the Oakville and is 0 to 1,000 feet thick. It consists dominantly of impervious clay, but it contains lentils of coarse sand and gravel, which yield supplies of water sufficient for stock and domestic purposes. The water is likely to be rather highly mineralized.

The Goliad sand overlies the Lagarto unconformably, overlapping the Lagarto and the Oakville completely and the upper part of the Catahoula. It is composed chiefly of beds of sand, gravel, and sandy clay, with some calcareous sand or sandstone and conglomerate. It dips southeast at the rate of about 25 feet to the mile and in the southeastern part of the county is between 350 and 600 feet thick. It is the chief water-bearing formation in the area and probably supplies the irrigation wells and the flowing wells in the counties east and southeast of Duval County.

The shallow wells in the Goliad sand in Duval County in general yield highly mineralized water, whereas the deeper wells yield water of comparatively low mineral content. It is believed that the greater mineralization of the shallow wells results from the wide distribution of caliche, which is practically impermeable and prevents much local recharge; consequently little fresh surface water can enter the beds supplying these wells. A few shallow wells yield good water; in these wells the water level rises rapidly after rainy periods, indicating considerable recharge. Such wells are near "sinks" or in other areas in which caliche is absent. The aggregate of the areas in which caliche is absent may be very large, even though the caliche is widespread. Some of the deeper wells yield water of high mineral content. It is believed that such wells are either located where local structure prevents ready circulation of ground water or that defective casing permits the contamination of the well by highly mineralized water from shallower beds.

The Lissie formation consists of reddish to chocolate-colored fairly coarse calcareous to clayey sand and crops out in the extreme southeastern part of Duval County. It is too thin in this county to yield appreciable quantities of water to wells.

In some stream valleys, such as those of Concepcion and Agua Poquita Creeks, near Concepcion, and San Diego Creek, near the Labbe ranch, sand and gravel of Pleistocene age occur. These deposits do not yield water to wells.

In the extreme southern part of the county near Sejita a thin mantle of windblown sand is present. Under natural conditions this sand is anchored by the vegetation.

Throughout most of the county there is little possibility of irrigation with well water, either because the quality of the water is unfavorable or because the water level is low and the lift necessary to raise the water to the surface would render the cost of irrigation prohibitive. In the extreme southeastern part of the county there is a large area in which the water level in the deeper wells stands 30 to 40 feet below the surface and the water is suitable for irrigation. It cannot be assumed, however, that the quantity of water is very great, and no large development should be made until the adequacy of the supply has been tested. This can be done by pumping at first from only a small number of wells and watching the effects of the pumping on the water level in selected observation wells over a considerable period of time. If the water level holds up reasonably well the development can proceed further.

INTRODUCTION

LOCATION AND GENERAL FEATURES OF THE AREA

Duval County is in southern Texas 100 to 150 miles south of San Antonio and about midway between Corpus Christi, on the Gulf of Mexico, and Laredo, on the Rio Grande. It lies between about 98°15′ and 98°45′ west longitude and 27°15′ and 28°5′ north latitude. It has an area of about 1,700 square miles, is nearly rectangular, and extends about 56 miles north and south and 33 miles east and west. (See fig. 1.) According to the census of 1930 Duval County has a population of 12,191. Its largest town is San Diego, which is also the county seat.

The area lies on the Coastal Plain, which for the most part is low and relatively featureless. The surface is gently rolling and in general rises from east to west to the crest of the westward-facing Bordas escarpment, which crosses the county in a southwesterly direction from about the middle of its north boundary to the middle of its west boundary. East of the escarpment the soil is generally sandy, but caliche appears at the surface in many places, and in the west-central part of the county there are many hills covered with coarse gravel. Much of the area is open grassy prairie with a scattered growth of mesquite and cactus. On the gravel hills there is a thick growth of low black chaparral. West of the Bordas escarpment the soil is rather clayey in most places and is covered by a dense brushy growth of chaparral, cactus, and mesquite. Cattle raising, farming, and oil production are the principal industries. Irrigation with well water has been attempted only in a few gardens, but some of the wells in the southeastern part of the county appear to be capable of yielding sufficient water for this purpose if properly safeguarded.

SCOPE AND PURPOSE OF THE INVESTIGATION

This paper presents the results of a study made by the United States Geological Survey in cooperation with the Texas State Board of Water Engineers for the purpose of determining the availability and quality of ground-water supplies in the county and the relation of the ground water to the artesian waters in Brooks, Kleberg, and Willacy Counties. The field work was carried on during the spring of 1931 and the summer of 1932. In February 1933 a mimeographed memorandum was released giving the essential results of the study.

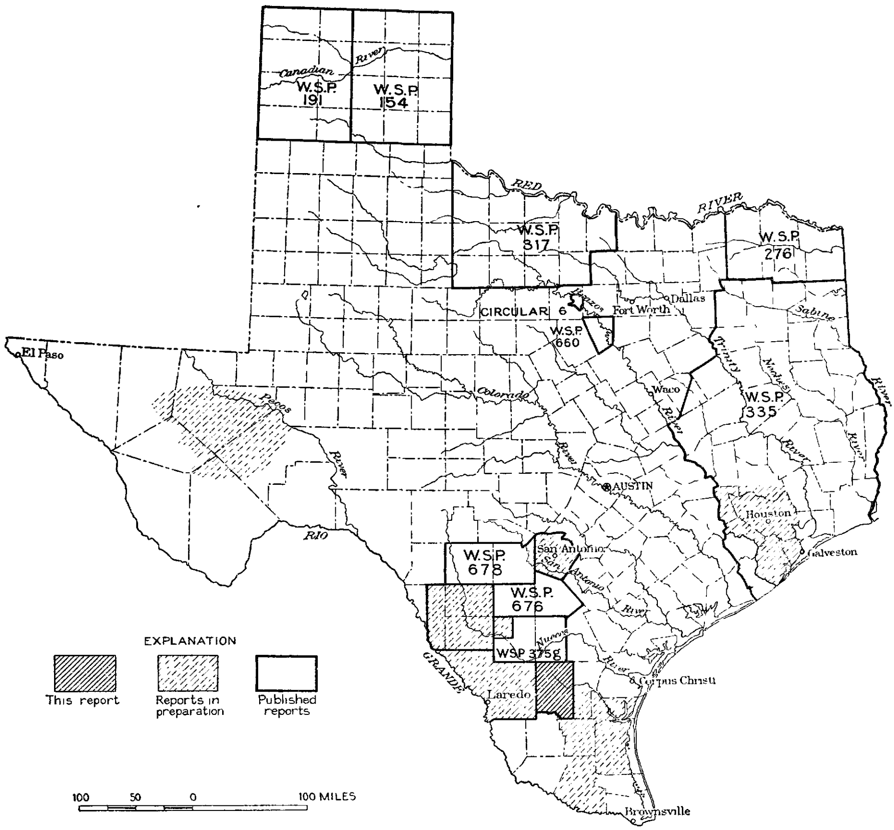

FIGURE 1.—Map of Texas showing location of Duval County (cross-hatched area), areas on which water-supply papers have been published (outlined with heavy black line and numbered), and areas on which ground-water reports are in preparation (broken lines).

Ground water, also called underground water, is one of the principal natural resources of Texas. In the long run it will prove to be the State's most valuable underground resource, because the supply is continuously replenished from rainfall and streams and will last indefinitely if withdrawals from the underground reservoirs are kept within safe limits. About 80 percent of the people of Texas are supplied with drinking water from wells or springs; nine-tenths of the towns and cities of the State obtain their public water supplies from wells or springs; water for stock in most parts of the State comes largely from wells; thousands of acres of land that would otherwise be of little value are now irrigated with water from wells, and much additional land will be similarly reclaimed.

Until recently little has been known as to the quantity of ground water available in the different parts of the State for municipal, irrigation, and other purposes, and some development has been made without adequate information on the vital question of available supply. Obviously, so important a factor in the economic structure of the State should be carefully studied to obtain full utilization of this resource without disastrous overdevelopment.

For a long time the State board of water engineers and the State department of health have realized the need of a thorough State-wide survey of the ground waters of Texas. Accordingly, when in 1929 appropriations were made by the Texas Legislature for this purpose, the cooperation of the United States Geological Survey was obtained and the investigation was actively undertaken. The present study was begun by the writer in February 1931 as a part of the original plan to cover the whole of the State by counties, in a State-wide survey to determine its ground-water resources. The work was carried on under the supervision of Walter N. White, hydraulic engineer in charge of ground-water investigations in Texas, and O. E. Meinzer, geologist in charge of the division of ground water of the United States Geological Survey.

In Duval County there is special need for knowledge of the ground-water supply, inasmuch as it is the chief source of water for both stock and domestic consumption. There are no permanent streams, and the only other available supply is storm water stored in tanks and in reservoirs formed by earth dams across the stream courses. In years of average rainfall satisfactory supplies for stock may be obtained from storm-water reservoirs, and in the sparsely populated parts of the county (such as Soledad ranch and the neighboring ranches), with proper care to prevent pollution, this water can be used for domestic consumption. In the central and eastern parts of the county, however, where the population is more dense, it is not safe to use surface water for drinking. It would probably not be practicable to build reservoirs of sufficient size to supply water for irrigation or industrial use, because the streams have broad, shallow valleys not well adapted for storing water and because the likelihood of a succession of dry years would necessitate hold-over storage. Therefore, it appears that any development in industry or irrigation that is made in the county must depend chiefly on water from wells.

In many years the rainfall is sufficient to permit the growing of cotton, corn, and, in the southeastern part of the county, watermelons, but it is not sufficient for such crops as citrus fruits, alfalfa, and garden truck. In a few gardens the rainfall has been supplemented by irrigation with water from wells, but thus far there has been no attempt to develop supplies for irrigation on a large scale.

During the present study the writer has attempted to determine the ground-water resources of the county, with special reference to the possibility of developing a supply of water from wells for irrigation and other uses. Records were obtained of over 300 wells, most of which had been dug or drilled in search for water but some of which were drilled in search of oil and gas. Samples of water were collected from 32 representative wells in the area and were analyzed in the laboratories of the Geological Survey. Small samples collected from many wells were analyzed in the field for chlorides, sulphates, and hardness, by S. F. Turner and J. C. Cumley. Numerous measurements were made of selected wells by J. C. Cumley and T. W. Bridges to determine fluctuations in the water level in response to rainfall. Outcrops of geologic formations were mapped by reconnaissance surveys. (See pl. 1.)

PREVIOUS INVESTIGATIONS

The geology of parts or all of Duval County has been described in a general way by Dumble,[1] Deussen,[2] and Bailey,[3] but no detailed work has been done, except locally by oil geologists. In 1909 to 1913 Deussen gathered a number of well records in the county and took a few samples of water for chemical analysis. In 1928, S. S. Nye, of the Geological Survey, visited the principal towns and villages in the county collecting well data and samples of water.

ACKNOWLEDGMENTS

The writer is greatly indebted to O. E. Meinzer and W. N. White for constructive criticism and suggestions at all stages of the investigation and for critical review of the manuscript for this report; to J. A. Norris, C. S. Clark, and A. H. Dunlap, of the Texas State Board of Water Engineers, for their helpful cooperation; to Julia Gardner, J. T. Lonsdale, and S. F. Turner for assistance in the field and in the office; and to Margaret D. Foster, who reviewed the section of the report dealing with quality of water and made many helpful suggestions concerning this phase of the work. Grateful acknowledgment is

[1] Dumble, E. T., Geology of southwestern Texas: Am. Inst. Min. Eng. Trans., vol. 33, pp. 912-987, 1902.

[2] Deussen, Alexander, Geology of the Coastal Plain of Texas west of Brazos River: U. S. Geol. Survey Prof. Paper 126, 1924.

[3] Bailey, T. L., The Gueydan, a new middle Tertiary formation from the southwestern Coastal Plain of Texas: Texas Univ. Bull. 2645, 1926.

made to the oil geologists of the San Antonio Geological Society, especially to D. R. Semmes, L. W. MacNaughton, and L. W. Clark, who furnished copies of maps showing geologic boundaries, which were helpful in planning the field work; to T. J. Galbraith and K. H. Crandall, who made important corrections of the Oakville-Goliad boundaries as a result of detailed field work in the area; and to G. B. Gierhart and Frith C. Owens, with whom the author spent several pleasant and profitable days in the field. Thanks are also due to A. W. Getzendaner, A. W. Weeks, T. W. Banks, W. A. Price, H. H. Cooper, and W. F. Calohan for helpful discussions and assistance with well logs and other information. The friendly and helpful cooperation uniformly given by the ranchers and farmers of the county made possible the gathering of the well data tabulated herein.

CLIMATE

The climate of Duval County is comparatively hot and dry. The United States Weather Bureau does not maintain a station within the county. Records at Alice, 10 miles east of San Diego, in Jim Wells County, and at Hebbronville, 6 miles south of Crestonio, in Jim Hogg County, indicate, in general, a decrease in rainfall from east to west.

Annual precipitation, in inches, in the region adjacent to Duval County, Tex.

	Alice	Hebbronville		Alice	Hebbronville
1911–20 (average)	24.62	19.17	1928	34.48	23.18
1921	19.15	14.43	1929	19.99	14.50
1922	24.21	15.71	1930	29.24	26.10
1923	37.47	22.10	1931	33.44	29.05
1924	17.04	18.83	1932	25.87	21.20
1925	21.49	22.39	1933	26.91	27.13
1926	24.07	18.68	1934	21.54	15.87
1927	19.46	22.85	1935	43.33	36.81

The rainfall is likely to be torrential, with intervening long periods of dryness. The growing season is long. At Alice during the period 1911–20 the average interval between the last killing frost in the spring and the first killing frost in the fall was 276 days. Snow very rarely occurs. During the summer the days are hot, but there is usually a breeze from the south or southeast, which increases in force in the late afternoon or early evening and continues during the night, so that the nights are usually comfortable. During most of the winter the weather is mild. Occasionally strong winds from the north cause the temperature to drop rapidly below the freezing point, but fortunately it remains below freezing for only a very short time, so that ordinarily little damage is done to crops.

GEOMORPHOLOGY

GENERAL FEATURES OF THE COASTAL PLAIN

Duval County lies on the Gulf Coastal Plain, which is, in general, low and featureless and rises gently from sea level toward the interior. The Coastal Plain is nearly flat for a distance of 50 miles or more from the Gulf of Mexico and is marked by a series of rather low seaward-facing escarpments. West of this belt the plain is gently rolling, becoming more dissected toward the west, and is marked by numerous westward-facing escarpments. The west and northwest boundary of the Coastal Plain is the seaward-facing Balcones escarpment, 150 miles or more from the coast. Deussen [4] has subdivided the Coastal Plain of southern Texas into several geographic units which "differ from one another in altitude, topography, character of soil, mineral resources, underground water supply, climate, vegetation, and culture."

The Coastal Plain of Texas has for a long time been rising with respect to the sea, as indicated by the deposits of marine sediments encountered on it and by the presence of the seaward-facing escarpments, far from the present shore line. Whether this change is due to an actual rise of the land or to a withdrawal of the sea is uncertain, but it appears that each of these events has occurred several times during the Tertiary and Quaternary periods. When the floor of the sea remains for a long time in the same relative position it is made smooth for a distance of many miles from shore as a result of the shifting of sand and silt by the currents, and a sharp escarpment is formed by wave action along the shore. When the sea retreats the smooth floor and wave-cut escarpment remain to mark its former position. Wind and water immediately begin to erode the surface and destroy its smoothness. The youngest surfaces are nearest the shore and are the least eroded; the oldest surfaces are farthest from the shore and are most eroded and dissected.

Near the coast the surface is exceedingly flat, except in such areas as the lowest terrace near Corpus Christi and the sand-dune area east of Falfurrias, where the wind has drifted sand a considerable distance from the shore and the surface is characterized by low sand hills. The slope of the surface is about 2 feet to the mile, and the stream channels are shallow. Farther inland between Alice and San Diego, the even surface slopes toward the Gulf at the rate of about 4 feet to the mile, but the valleys are deeper and in general the surface is less smooth.

[4] Deussen, Alexander, op. cit., pp. 3 et seq., 1924.

COASTAL TERRACES

Deussen,[5] partly on the basis of a profile along the Texas Mexican Railway drawn from altitudes furnished by the railway and partly on the basis of field observations, divided the coastal belt into three terraces—the Recent (0 to 20 feet), Beaumont (40 to 135 feet), and Alice (150 to 316 feet).

Cooke [6] has differentiated eight terraces on the Atlantic Coastal Plain between Maryland and Florida and has traced some of them as far west as northeastern Texas. These terraces are believed to have been formed when the sea stood at higher levels, probably during interglacial stages, when the water that had been locked up in glaciers was returned to the sea as a result of the more or less complete melting of the ice and, consequently, higher sea levels were common throughout the world. They are situated at altitudes of 12, 25, 42, 70, 100, 170, 215, and 270 feet above sea level.

A profile from Mustang Island to Aguilares, based on the Geological Survey's topographic maps of the Aransas Pass, Corpus Christi, and Robstown quadrangles and on levels run along the Texas Mexican Railway by the Geological Survey, the Coast and Geodetic Survey, and the railway company, is shown in figure 2. Cooke's terraces are not all clearly recognizable from the maps and profiles of this part of Texas. The 25-foot terrace shows clearly on Live Oak Ridge near Aransas Pass. The 42-foot terrace is not well defined, although there is a slight suggestion of it on the Nueces River south of Griffin Island, in the Robstown quadrangle. The 70-foot terrace is clearly shown on the ridge east of Oden. The 100-foot terrace is not evident but is probably present near Banquete. The 170-foot terrace is clearly marked east of Alice, where the escarpment forming its western

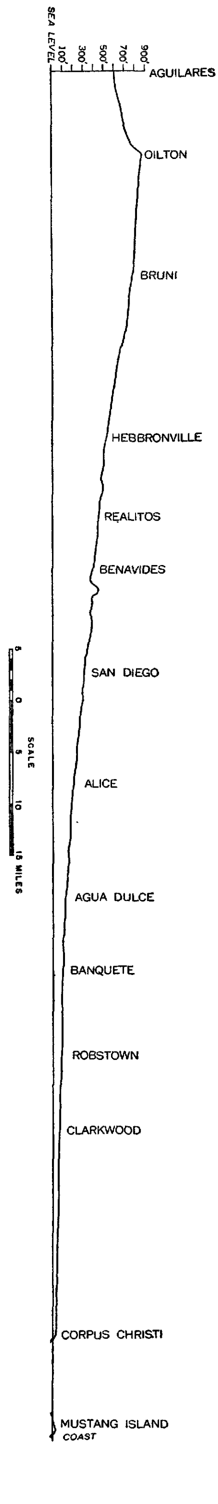

FIGURE 2.—Profile from Mustang Island to Aguilares.

[5] Deussen, Alexander, op. cit., p. 4.

[6] Cooke, C. W., Correlation of coastal terraces: Jour. Geology, vol. 38, no. 7, pp. 587–589, 1930; Seven coastal terraces in the Southeastern States: Washington Acad. Sci. Jour., vol. 21, no. 21, pp. 503–513, 1931; Tentative correlation of American glacial chronology with the marine time scale: Idem, vol. 22, no. 11, pp. 310–312, 1932; also oral communication.

boundary crosses the highway. The 215-foot terrace does not appear plainly along the railroad profile, but the escarpment marking the shore line of the 270-foot terrace is crossed about 3 miles east of San Diego. It seems likely that with accurate detailed topographic maps, all of Cooke's terraces might be identified.

REYNOSA PLATEAU

Between the Nueces River and the Rio Grande in this part of Texas is an erosion remnant which Dumble[7] and, later, Price[8] called the "Reynosa Plateau." Deussen[9] called it the "Reynosa Plain." This plateau is bounded on the east by a low seaward-facing escarpment, which passes southward near San Diego and crosses the Duval-Brooks county line 2 or 3 miles west of the southeast corner of Duval County, and on the west by the westward-facing Bordas escarpment.[10] Its altitude is 304 feet at San Diego and rises gradually to a maximum of nearly 1,000 feet near its western margin. The extent of the plateau is represented approximately on plate 1 by the outcrop area of the Goliad and Oakville sandstones. The surface is rolling and dissected by numerous dry stream courses, most of which head at or near the Bordas escarpment. Price[11] calls the plateau a typical karst plateau and refers to the alternating knolls and basins. Some of the basins are enclosed, but many are connected by surface outlets. Price sees no evidence of the development of underground channels. Barton[12] in a recent paper shows several such depressions near the Palangana salt dome.

Deussen[13] subdivided the Reynosa Plateau into the Torrecillas Plain, west of Hebbronville, and the Realitos terrace, between Hebbronville and San Diego. Deussen's profile along the Texas Mexican Railway[14] followed the railway, which runs southeastward from Aguilares to Hebbronville and northeastward from Hebbronville to San Diego. The slope of the surface is, in general, southeastward, so that the railway follows the slope from Aguilares to Hebbronville but is nearly at right angles to it from Hebbronville to San Diego, and the width of the Realitos terrace is very much lengthened in the profile and the terrace appears much more nearly level than it is. The writer's profile (fig. 2) was prepared by drawing a straight line from Aguilares to San Diego and projecting to it, by lines parallel to the contours, the altitudes at points along the railway. This line,

[7] Dumble, E. T., The Cenozoic deposits of Texas: Jour. Geology, vol. 2, p. 562, 1894.

[8] Price, W. A., Reynosa problem of south Texas and origin of caliche: Am. Assoc. Petroleum Geologists Bull., vol. 17, p. 497, May 1933.

[9] Deussen, Alexander, op. cit., pp. 5, 8.

[10] Dumble, E. T., Geology of southwestern Texas: Am. Inst. Min. Eng. Trans., vol. 33, pp. 918–919, 1902.

[11] Price, W. A., op. cit., pp. 498–499.

[12] Barton, D. C., Surface fracture system of Texas: Am. Assoc. Petroleum Geologists Bull., vol. 17, no. 10, p. 1197, 1933.

[13] Deussen, Alexander, op. cit., p. 5.

[14] Idem, pl. 1.

also, fails to follow the ideal course normal to the slope of the surface, but it has the advantage of having known altitudes at both ends and of being projected to a straight line, and it gives a more nearly accurate picture of the topography than Deussen's profile. On the redrawn profile the Realitos terrace is not nearly so pronounced a feature as on Deussen's profile, and the profile of the Torrecillas Plain projected eastward meets the profile of the Realitos terrace near San Diego, suggesting that the Realitos terrace may be a somewhat eroded part of the Torrecillas Plain.

CUESTA NEAR BENAVIDES

Barton [15] describes a cuesta near Benavides formed by a phase of the Goliad sand.

BORDAS ESCARPMENT

The westward-facing Bordas escarpment crosses Duval County in a northeasterly direction from about the middle of the west boundary to about the middle of the north boundary. It is 100 to 150 feet high in southeastern Webb County but becomes lower toward the north, and near the north boundary of Duval County is about 75 feet high. It is broken in many places by deep reentrants due to stream erosion. The escarpment is formed by resistant sandstone overlying the softer Catahoula tuff. From its south end about as far north as Freer the escarpment is capped by beds of the Goliad; north of Freer, by the Oakville sandstone.

GUEYDAN PLAIN, GUEYDAN HILLS BELT, AND FRIO PLAIN

West of the Bordas escarpment is the Frio Plain of Deussen,[16] which Bailey [17] subdivided into the Gueydan Plain, the Gueydan Hills belt, and the Frio Plain.

The Gueydan Plain coincides with the outcrop area of the upper (Chusa) member of the Catahoula tuff. It is rolling to nearly flat and is bounded on both sides by rolling country. At the north it is 5 or 6 miles wide, but it terminates southward at the foot of the Goliad escarpment near Las Parillas Hills. Its surface is marked in several places by hills capped by outliers of the Goliad, such as Atravesada Hill, and of the Oakville, such as Loma Alta, in McMullen County, and in several places by chalcedony knobs. The soil of the Gueydan Plain is light-gray to buff clayey loam, which supports a rather dense growth of mesquite and chaparral.

The Gueydan Hills belt is formed by the outcrops of the middle and lower members of the Catahoula. Its surface is distinctly rolling and

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[15] Barton, D. C., The salt domes of south Texas: Am. Assoc. Petroleum Geologists Bull., vol. 9, no. 3, p. 540, 1925.

[16] Deussen, Alexander, op. cit., p. 9.

[17] Bailey, T. L., op. cit., pp. 22 et seq.

in the eastern part is characterized by a series of nearly flat topped hills, such as the Soledad Hills, which have been well described by Bailey. The soil of the Gueydan Hills belt is in general light to dark clayey and sandy loam, which in most places supports a very dense growth of mesquite and chaparral, particularly in the valleys. In the western part of the belt this growth is almost impenetrable. In many places on the outcrop of the Soledad conglomerate the soil is thin and gravelly, and the vegetation consists of low, widely spaced bushes and sparse grasses.

The Frio Plain coincides with the outcrop of the Frio clay. It occupies the extreme northwest corner of Duval County, where it forms a low, almost featureless grassy plain 4 or 5 miles wide, which, is in strong contrast to the brushy Gueydan Hills belt. The soil is black or brown clayey loam, and pieces of silicified wood are common on its surface.

DRAINAGE

No large streams cross Duval County. All the stream channels are dry during most of the year and carry running water only immediately after heavy rains. West of the Bordas escarpment the drainage goes northward to the Nueces River; the area east of the escarpment is drained directly toward the Gulf of Mexico.

The Nueces River, which in its upper course flows southeast, turns abruptly in southeastern La Salle County and flows northeast to its junction with the Atascosa River, thence again southeast to the Gulf. Deussen [18] suggested that the Nueces and Frio Rivers were deflected northeastward into the Atascosa River by the Torrecillas uplift in comparatively recent time. Bailey, [19] commenting on Deussen's suggestion, notes that the valley of Prieto Creek, in northeastern Webb County (see pl. 2), may have been a part of the former valley of the Nueces; that the Bordas (Reynosa) escarpment makes a pronounced eastward bend 2 miles north of Moglia, in east-central Webb County; that there is a large reentrant in the scarp in western Duval County suggestive of a wind gap; that the altitude of the Nueces River in southeastern La Salle County at the bend where the river turns northeastward is 320 feet, whereas the altitude of the Rio Grande at Laredo is 420 feet, and thus the river farther east has the advantage; that the Bordas and Oakville escarpments are higher in their southwestern parts than farther northeast and constitute barriers difficult for streams to cut across; and that most of the large streams of Texas empty into shallow bays, but Baffins Bay receives no large stream. Bailey believes, therefore, that although the evidence is not conclusive, it points toward the supposition that the Nueces and Frio

18 Deussen, Alexander, op. cit. (Prof. Paper 126), p. 126.

19 Bailey, T. L., The Gueydan, a new middle Tertiary formation from the southwestern Coastal Plain of Texas: Texas Univ. Bull. 2645, p. 32, 1926.

Rivers were captured by the headward erosion of subsequent tributaries of the Atascosa flowing over the weak strata of the Frio Plain.

The writer concurs in the essential features of Bailey's interpretation of the cause of the change in the course of the Nueces River. It is believed that the superior resistance of the sandstone and caliche deposits on the Reynosa Plateau would retard the cutting of the old Nueces River channel sufficiently to give the Atascosa a distinct advantage over the Nueces and probably over the Frio. The evidence for the Torrecillas uplift seems inconclusive (see pp. 16–18); but if it had occurred the 200 feet of uplift which Deussen postulated would have been insufficient to cause the deflection of the stream across the divide into the valley of the Atascosa River.

About 2 miles southwest of the Sternes & Akin ranch are two small unnamed stream channels, which extend directly northeast for about 2 miles and join the northwestward drainage of the valley south of the Soledad ranch. These channels have the appearance of having once drained into a southeastward-flowing stream. Bailey suggests that the valley of Parilla Creek may represent the former channel of the Nueces, but the valley of Las Animas Creek appears to be wider and is in direct line with the wide valley south of the Soledad ranch, whereas the valley of Parilla Creek is separated from this wide valley by a discontinuous ridge. It is therefore believed that the Las Animas Valley was once occupied by the Nueces River.

ECONOMIC DEVELOPMENTS

The greater part of the population of Duval County is supported by agriculture or cattle raising. Cotton and corn are the principal crops, but watermelons are raised in the southeastern part of the county. East of the Bordas escarpment (see pl. 1) the soil is mostly red sandy loam, which is fertile when sufficient water is available; but in many parts of the area tillage is hindered by the presence of hard caliche near the surface. West of the escarpment the soil is in general more clayey but in the stream valleys is well adapted to the growth of crops. Except in the northwestern and western parts of the county, which are divided into large ranches, the population is rather evenly distributed throughout the area, and cultivated fields are found along all the main roads, but they are almost nowhere continuous for more than a mile or so, and nearly every cultivated field is surrounded on all sides by cattle land.

There are five reported oil and gas fields [20] in Duval County (see pl. 1), all of which produce from the Jackson formation. The Cole-Bruni field was discovered in 1924 and produced gas from a depth of 1,700 feet; later it produced oil from a depth of 2,300 feet, and in 1930 a

[20] Oil and gas development in southwest Texas: Southwest Texas Oil Scouts Assoc. Bull. 1, pp. 32 et seq., 1930.

new sand yielding both oil and gas was encountered at 2,800 to 3,000 feet. The Driscoll field was discovered in 1927 while drilling for water and produces oil from depths of 2,400 to 2,900 feet. The Government Wells oil field was discovered in 1928 and produces oil from a depth of 2,240 feet; drilling is still actively in progress, and the field now has a north extension and a south extension. The Sarnosa field, which lies just south of the south extension, was discovered in 1931 and is being actively developed. The S. R. C. Vacuum field was discovered in 1930 and produces principally oil. The total production of oil in the county to the beginning of 1930 was 3,170,325 barrels. In addition to the production from these five fields a small amount of oil is produced from the two salt domes of the county—Palangana and Piedras Pintas.

Sulphur is being produced at the present time from the Palangana salt dome.

Several pipe lines cross the county, carrying oil or gas from the oil fields of Webb, Duval, and Zapata Counties northeastward to the refineries and to the larger cities that use gas. The Texas Mexican Railway connects Laredo and Corpus Christi, crossing Duval County. There are several graded roads in this county and one hard-surfaced highway that connects Laredo and Corpus Christi, passing through Hebbronville (in Jim Hogg County) and San Diego.

GENERAL GEOLOGY

The formations exposed in Duval County are all of sedimentary origin and range in age from Oligocene (?) to Recent. They consist of sandstone, clay, shale, and conglomerate, with beds of volcanic ash, conglomerate composed of volcanic boulders and pebbles, and sand cemented rather thoroughly by chalcedony. Deposits of calcium carbonate known as "caliche" crop out at the surface or lie below a shallow soil over much of the county; these occur either in solid ledges or cementing the grains of sand, pebbles, and boulders into a more or less well consolidated rock. Most of the rocks appear to have been deposited in shallow lagoons along the seashore, but some are of subaerial origin, and in the southeastern part of the county wind-blown sand covers the surface. The rocks dip eastward at rates ranging from 80 feet to the mile for the oldest to less than 20 feet to the mile for the youngest. Therefore, in crossing the county from west to east the traveler crosses the beveled edges of successively younger formations, and beds that crop out in the western part of the county are far below the surface in the eastern part. Thus the base of the Oakville sandstone crops out on the Bordas escarpment but is 1,600 feet below the surface in the Thompson No. 1 Parr oil test well, 7 miles south of Benavides.

The accompanying table of geologic formations gives a brief description of each of the formations and indicates its position relative to the other formations of the area.

Geologic formations in Duval County, Tex.

System	Series	Formation	Thickness (feet)	Character	Water-bearing properties
Quaternary.	Recent.	Caliche: Wind-blown sand.	0–25	Soil and sand.	
	Pleistocene.	Caliche: Lissie formation.	0–15±	Mottled red to chocolate-brown calcareous to clayey sand; some chert gravel near base.	Yields water east of Duval County but very little or none within the county.
		Unconformity.			
Tertiary.	Pliocene.	Goliad sand.	0–600±	Gray calcareous sandy clay, sandstone, and conglomerate; red calcareous sandy clay; gray calcareous sand and in western Duval County massive gravel. Surface characterized by presence of caliche.	Sand and gravel beds yield large quantities of water. particularly in southeastern Duval County.
		Unconformity.			
	Miocene (?).	Lagarto clay (restricted).	0–1,000	Reddish-brown clay and sandy clay with abundant gypsum and some lentils of coarse sand and gravel.	Yields water to a few wells in Duval County.
	Miocene.	Oakville sandstone.	0–500±	Massive grayish-brown cross-bedded sandstone containing clay balls, gravel, and sandy or ashy clay.	Yields rather highly mineralized water to many wells in Duval and adjacent counties.
		Unconformity.			
	Miocene (?).	Catahoula tuff.	0–1,300±	Pink tuffaceous clay, coarse volcanic conglomerate, sandstone, clay, and tuffs.	Upper members yield small quantities of more or less highly mineralized water.
		Unconformity.			
	Oligocene (?).	Frio clay.	300–400±	Buff and green noncalcareous gypsiferous clay and fine sandy clay and silt.	Yields highly mineralized water to a few wells in Duval County.
	Eocene.	Jackson formation.	1,000–1,600	Brown to buff sandy shale and sand; beds of volcanic ash. Does not crop out in Duval County.	Yields highly mineralized water.

STRUCTURE

The geologic structure of Duval County is, in general, simple. The Goliad sand dips east or southeast at a rate of 20 to 25 feet to the mile; it overlaps the Lagarto clay, the Oakville sandstone, and, in the west-central part of the county, the upper part of the Catahoula tuff. The Oakville, Catahoula, and Frio dip east or southeast 50 to 80 feet to the mile, but in places this simple structure is disturbed by faulting or folding. (See pl. 3.)

DOMING AND FOLDING

Two salt domes occur in the county—the Piedras Pintas dome, at Noleda, 2 miles northeast of Benavides, and the Palangana dome, 9 miles north of Benavides. Barton [21] has described these domes in detail and shows that there has been uplift in the Piedras Pintas dome of the order of 1,000 feet or more, and in the Palangana dome of the order of 2,000 feet. Apparently the Goliad sand is continuous across the tops of these domes, although it may have been involved in the doming. The deeper formations have been more intensely deformed.

North of San Diego in the Shaeffer gas field the formations appear to be higher than would be normally expected if the structure were simply monoclinal,[22] and a similar structural high is reported in the Cole-Bruni gas and oil field,[23] in southwestern Duval County and southeastern Webb County.

Deussen [24] considers his Torrecillas Plain an uplifted area, with a maximum upward movement in southeastern Webb County of 200 feet, forming a broad, gentle arch which he calls the "Torrecillas arch." His reasons are as follows: (*a*) The divide between the Nueces and the Rio Grande has an altitude of 720 feet 18 miles north of Laredo and 872 feet at Torrecillas (Oilton) 40 miles to the east (he considers that the gravel at both places is †Reynosa [25] [Goliad]); (*b*) the northward deflection of the Nueces and Frio Rivers appears to be due to the formation of the arch; (*c*) the change from a northeast to a northwest strike in the formations south of Webb County shows that they have been affected by uplift; (*d*) the widening of the outcrop areas of the Pleistocene formations in this area indicates shoaling of the sea floor accompanying the uplift; (*e*) the chalcedony knobs probably represent infiltrations of silica-bearing solutions along the line of folding; (*f*) a large tongue of †Reynosa [Goliad]

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[21] Barton, D. C., The Palangana salt dome, Duval County, Tex.: Econ. Geology, vol. 6, pp. 497–510, 1920; The salt domes of south Texas: Am. Assoc. Petroleum Geologists Bull., vol. 9, no. 3, pp. 536–589, 1925; Geology of salt-dome oil fields, pp. 718–771, Am. Assoc. Petroleum Geologists, 1926.

[22] Owen, F. C., oral communication. Cooper, H. H., oral communication.

[23] Oil and gas development in southwest Texas: Southwest Texas Oil Scouts Association Bull. 1, p. 68, 1930.

[24] Deussen, Alexander, op. cit., pp. 125–126.

[25] A dagger (†) preceding a geologic name indicates that the name has been abandoned or rejected for use in classification in publications of the U. S. Geological Survey.

has been removed by erosion along the Nueces River Valley, exposing the older formations; (*g*) the Beaumont terrace is 20 feet below the Alice terrace at Mikeska and 50 feet below it at Sandia; (*h*) the presence of oil and gas in this region seems to indicate that folds and faults mark the boundaries of the uplift.

The writer feels that Deussen's arguments for the existence of the Torrecillas uplift are not conclusive, as the conditions cited may have been due to other causes.

The Uvalde gravel which caps the divide between the Nueces and the Rio Grande north of Laredo, slopes gradually toward the Bordas escarpment and does not arch upward to the gravel along the escarpment. These gravel deposits are therefore of different ages, as there appears to be no evidence that the Bordas escarpment is a fault scarp. As Uvalde gravel does not occur on the Torrecillas Plain, it is concluded that this plain already existed at a higher level during the deposition of the gravel.

The Goliad sand in Duval County is well cemented by caliche and, near its contact with the Catahoula, by silica; it is therefore more resistant to erosion here than farther north. As the formations that crop out west of the Bordas escarpment are easily eroded, and the Goliad and Oakville are more easily eroded in Live Oak County, to the northeast, than in Duval County, it seems reasonable to suppose that the deflection of the Nueces and Frio Rivers was due to piracy by tributaries of the more favorably situated Atascosa River.

The change in strike of the formations south of Webb County is chiefly due to a large eastward-trending anticline south of the Rio Grande.

The widening of the outcrop area of the Pleistocene and the erosion of the tongue of Goliad so that the Lagarto and Oakville are exposed may have been the result of erosion in the Nueces River Valley and lack of erosion, due to lack of precipitation, on the Torrecillas Plain.

The chalcedony knobs are probably connected with the fissures along which silica-bearing waters have come to the surface, but they do not necessarily imply movement in connection with arching of the sedimentary rocks.

The oil fields along the Bordas escarpment may possibly have resulted from accumulation of oil and gas on a large anticline, but since Deussen published his paper many new fields have been brought into production north of the supposed center of the arch, from which it appears that these pools are formed by the accumulation of oil and gas on local structural features. The cause of the accumulation of oil in many of the pools is obscure, but in some it is undoubtedly due to gentle folding or faulting or both, and in others it is probably due to the pinching out of the oil sands up the dip, as suggested by Cooper.[26]

[26] Cooper, H. H., paper presented before the San Antonio Geological Society, 1933.

The relations of the terraces along the Nueces River appear to the writer to afford the only conclusive evidence of differential uplift in this area, but the Nueces is some 80 miles north of the place that Deussen designated as the center of the Torrecillas arch, and therefore these terraces constitute no proof of the existence of such an arch.

On the other hand, the normal dip of the Goliad sand is about 20 to 25 feet to the mile. A line drawn from the outcrop of the base of the Goliad on the Nueces River to the outcrop on the Rio Grande will approximate the strike of the Goliad. The distance, measured normal to the strike, between this line and Oilton multiplied by an assumed average dip of 20 feet should give the height of the base of the Goliad at Oilton above the base of the Goliad at any point on the line, provided the dip is constant. This calculation, admitted to be a very rough one, indicates that the base of the Goliad at Oilton should be 1,000 to 1,200 feet higher than on the Nueces River. As the base of the Goliad on the Nueces is about 100 feet above sea level, and at Oilton 800 to 900 feet, it is seen that a large arch such as Deussen postulated is not necessary to explain the presence of the Goliad on the Torrecillas Plain or, indeed, the high altitude of the Torrecillas Plain itself.

FAULTING

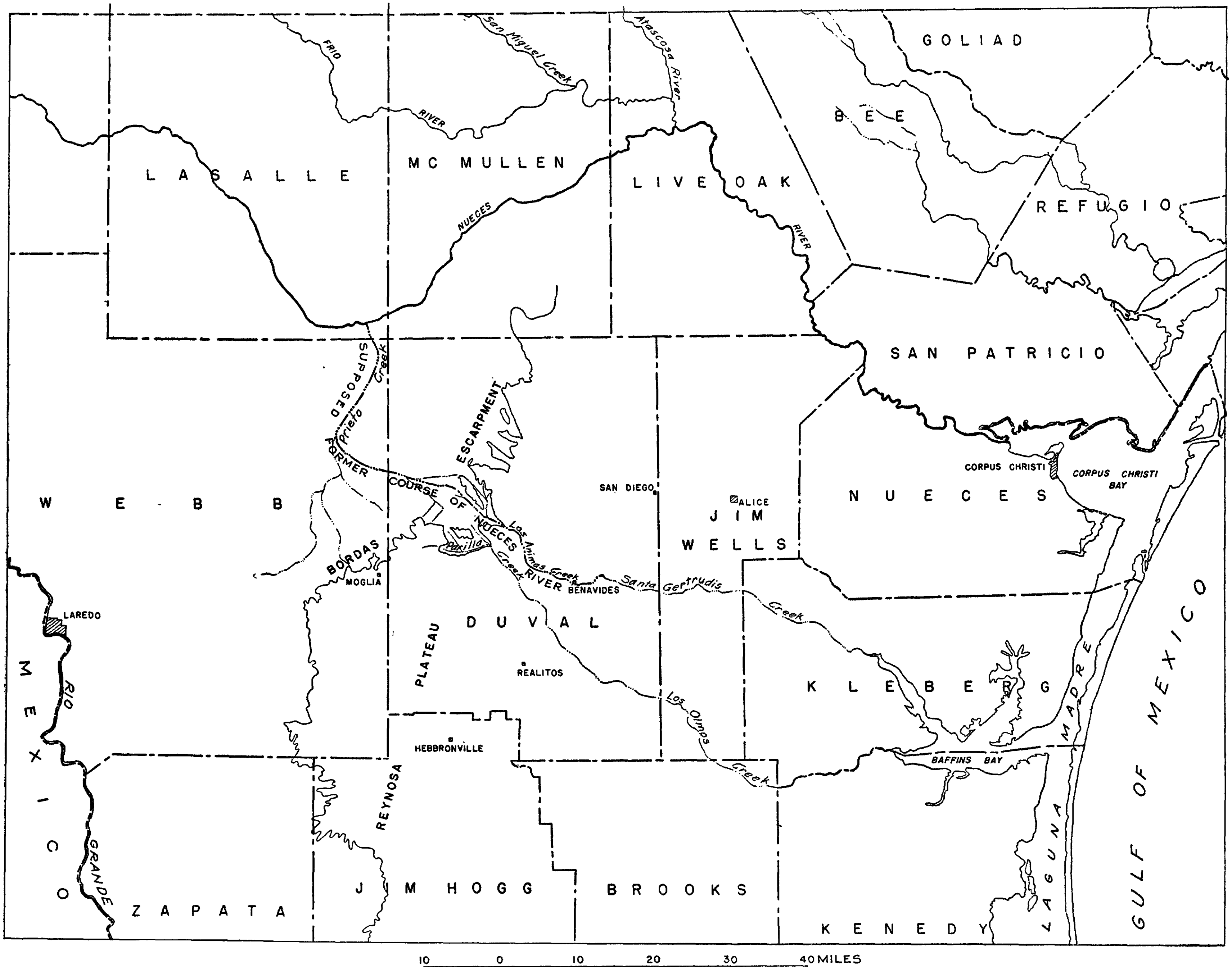
There are several faults in the area. Galbraith and Crandall[27] report faults of large magnitude in the vicinity of the Government Wells field.

The northwest-southeast escarpment formed by the Soledad conglomerate south of the Soledad ranch strongly suggests a fault scarp, although it may be merely an erosional escarpment. No similar conglomerate is found on the south side of the valley or on the valley floor, and no other surface indication of such a fault was observed. The dip of the conglomerate carries it below the valley about a mile east of the Soledad Hills. As the valley floor is covered by soil the conglomerate might not appear at the surface even if present, and the conglomerate member may grade into a sandy phase to the south. Consequently the presence or absence of a fault here would have to be determined by detailed work along the Bordas escarpment.

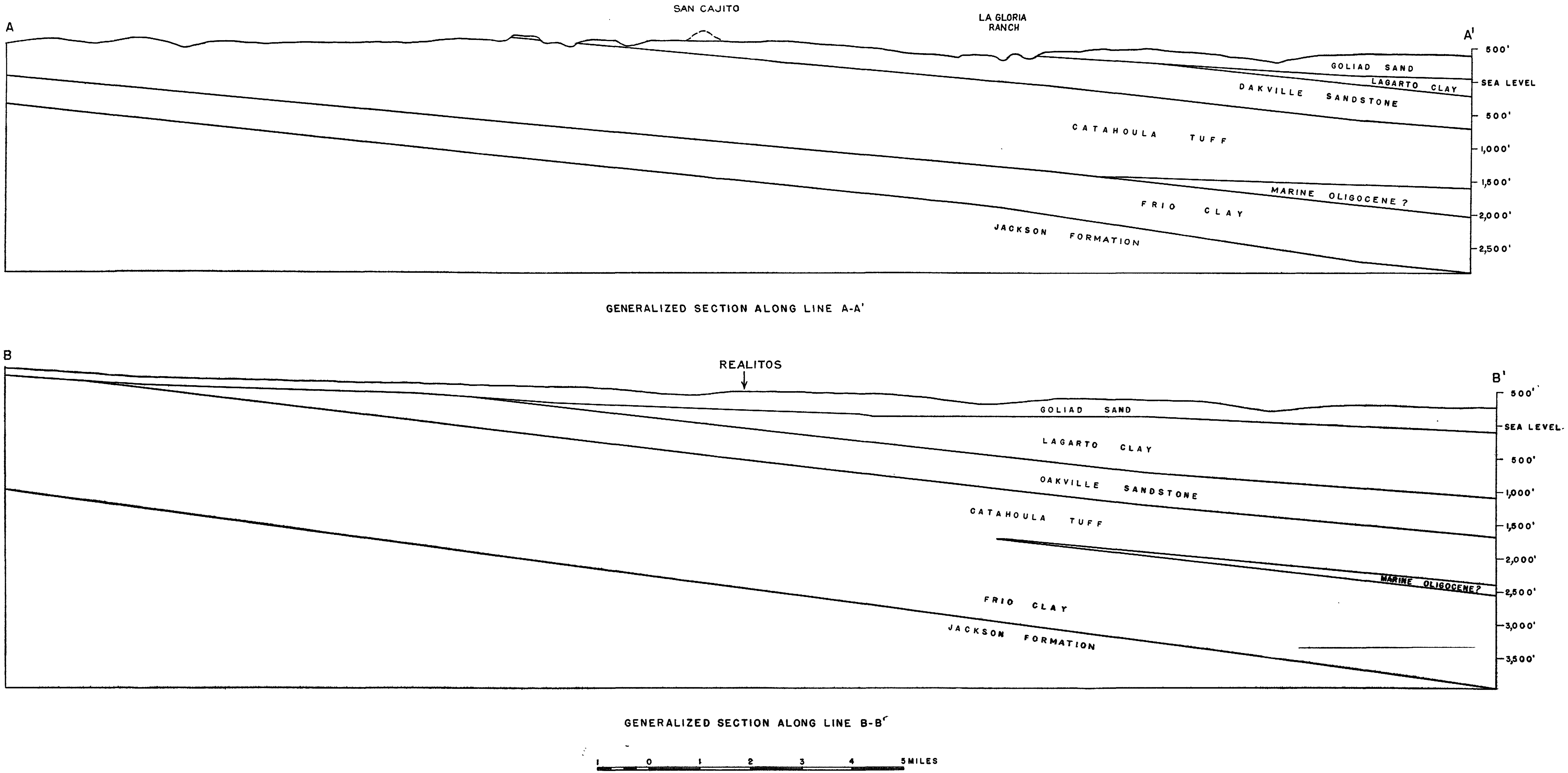
Bailey[28] has described a northeastward-trending fault through Los Picachos Hills, in north-central Duval County. These hills are a series of chalcedony knobs extending N. 42° E. On the east side of the southernmost hill a series of beds of Chusa tuff dip strongly to the southeast, suggesting either faulting or intrusion of the chalcedony to bend the tuff beds upward. The chalcedony plugs in the vicinity of Las Parillas Hills, in west-central Duval County, may mark the

[27] Galbraith, T. J., Jr., and Crandall, K. H., oral communication.

[28] Bailey, T. L., The Gueydan, a new middle Tertiary formation from the southwestern Coastal Plain of Texas: Texas Univ. Bull. 2645, pp. 148-153, 1926.

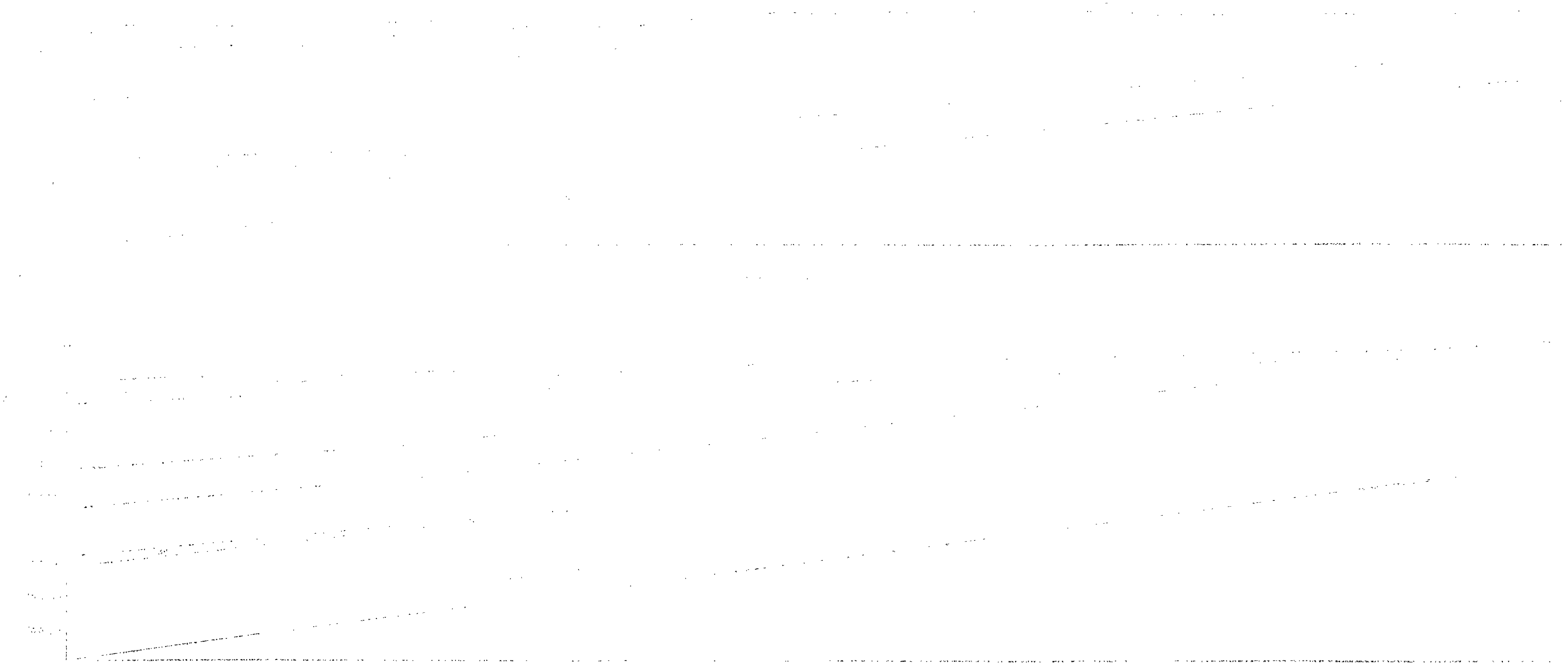


SKETCH MAP OF PART OF SOUTHWESTERN TEXAS SHOWING PRESENT COURSE OF THE NUECES RIVER AND ITS RELATION TO OTHER STREAMS.



GENERALIZED GEOLOGIC SECTIONS OF DUVAL COUNTY.

Lines A–A' and B–B' shown on plate 1.



trace of two faults that have allowed a block of Goliad sand to be dropped. These hills consist of two groups of silicified knobs. The western group has a trend of about N. 50° E. and comprises six or seven small chalcedony knobs in a distance of three-quarters of a mile, of which the southern three are highest and most pronounced. About 1 mile southeast of these are two more silicified knobs, of which the larger is on the north. These have a trend of about N. 45°–50° E. On the east side of the northernmost hill is Goliad sand, and in the area between the two groups of hills is Goliad sand which appears to have been dropped by faulting.

About 1½ miles south of these hills is another series of hills trending N. 65° E. These, also, are composed of chalcedony, with some opal. The largest is in the center and is between 75 and 100 feet high. Their alinement suggests localization of ascending silica-bearing ground water along a fault, but the geologic relations are obscure.

In sec. 182, on the west side of the Sutherland ranch, a fault trending about N. 70° E. terminates the outcrop of the Goliad sand in this section.

Cedro Hill, 4 miles south of the Soledad ranch house, is composed of white massive upper Catahoula tuff. (See fig. 3.) On the east side is a ridge of impure halloysite perhaps 25 feet high, 15 feet wide, and 50 feet long, which strikes N. 10° E. On the east side of this ridge is a small patch of conglomerate composed largely of angular boulders cemented by chalcedony and opal and lying only a little above the surrounding land surface. West of the halloysite ridge is a small arroyo cut into the tuff, and beginning a little west of the ridge and trending N. 70° W. is a dike of opal that passes into chalcedony on the west. About 50 yards north of Cedro Hill is a vein of fibrous calcite, which from its structure was probably originally aragonite. This vein has a maximum width of 10 feet and can be traced N. 70° E. for a distance of 630 feet. A short distance northeast of the last point at which this vein is seen is another vein or the continuation of the same one, which extends in the same general direction for a distance of 150 feet. This localization of veins of calcite and siliceous materials suggests three faults. If a line along the calcite vein is extended northeast it cuts across the two knobs Sarnosa Chiquita and Sarnosa Grande, which are considered by some geologists to be due to faulting.

In general, the consensus of opinion among oil geologists appears to be that the throw of most of the faults increases with depth; some faults that are believed to have a great throw at a depth of 2,000 feet or more are relatively insignificant at the surface. To locate such faults would require more detailed work than could be done in the present investigation.

GENERAL PRINCIPLES OF THE OCCURRENCE OF GROUND WATER

POROSITY OF ROCKS

Water occurs in the cavities and pore spaces, large and small, that exist in the soils and rocks beneath the surface of the earth. The total volume of these cavities and pore spaces as compared with the total volume of a rock or soil is a measure of its porosity and is usually expressed as a percentage. The porosity of a sedimentary rock is controlled by (*a*) the shape and arrangement of its constituent particles, (*b*) the degree of assortment of these particles, (*c*) the compacting and cementation to which the rock has been subjected since its deposition, (*d*) its solubility, which permits the formation of solution channels by percolating waters, and (*e*) the amount of fracturing of the rock, resulting in joints and other openings.[29]

Well-sorted deposits of uncemented gravel, sand, and silt have a high porosity regardless of the size of the individual grains, but in poorly sorted material the smaller particles fill the interstices between the larger particles, and the pore space is thus reduced. In some well-sorted deposits of sand or gravel the pore spaces may gradually be filled with cementing material and the pore space reduced in this manner; thus very well cemented rocks, such as quartzite and dense limestones, may have a very low porosity. A deposit composed of irregular-shaped fragments may have a very high porosity if the fragments are so arranged that their irregular edges meet and bridge over cavities, as in many recently deposited beds of silt and clay, but such a deposit may have its porosity greatly reduced if it is subjected to high pressure. Relatively soluble rocks, such as limestone, although they were originally dense and of very low porosity, may have channels developed in them through solution. Hard, brittle rocks, such as limestone, hard sandstone, and most igneous and metamorphic rocks, may be fractured as a result of earth movements or other causes in such a way as to acquire rather large openings. Although solution channels and fractures may not give a rock high porosity, such openings are likely to have an important bearing on its water-yielding possibilities. Slichter [30] and Meinzer [31] have discussed in considerable detail the various factors controlling porosity, and to those who wish to study the subject further their writings and the references given therein are recommended.

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[29] Meinzer, O. E., Occurrence of ground water in the United States: U. S. Geol. Survey Water-Supply Paper 489, p. 3, 1923.

[30] Slichter, C. H., Theoretical investigation of the motion of gound waters: U. S. Geol. Survey 19th Ann. Rept., pt. 2, pp. 305–328, 1899.

[31] Meinzer, O. E., op. cit., pp. 4 et seq.

PERMEABILITY OF ROCKS

The capacity of a material to yield water is determined by its permeability, or capacity for transmitting water under pressure. It is quantitatively defined as the rate at which the material will transmit water through a given cross section under a given difference in pressure per unit of distance. The two principal forces that affect permeability are gravity and molecular attraction. Thus water tends to be moved through porous rocks by the force of gravity but is retarded in its movement by molecular attraction—that is, by the cohesion or viscosity of the water itself and by its adhesion to the walls of the cavities and pores. The force of molecular attraction may be greater than the force exerted by gravity, as in many deposits of silt and clay, because of the small size of the interstices between the particles; such rocks are said to be impermeable. Sand and gravel, on the other hand, having larger interstices, will transmit water freely unless their interstices are choked with fine, impermeable material. Fine-grained or poorly assorted materials may be saturated with water but may give it up so slowly that they are of little value for water supply, whereas well-sorted sand and gravel, even with a relatively small amount of water, may yield larger quantities because of their greater permeability.

ZONE OF SATURATION AND ZONE OF AERATION

Below a certain level, which varies with climate, kind of rock, and topography, the permeable rocks are saturated with water under hydrostatic pressure. These rocks are said to be in the zone of saturation, and the upper surface of this zone is called the water table. The water in the zone of saturation is called ground water. Wells dug or drilled into the zone of saturation will become filled with ground water up to the level of the water table.

Above the water table is the zone of aeration, so called because its interstices are largely filled with atmospheric gases, but this zone also contains much water. Much of the water in the upper part of the zone is withdrawn by the transpiration of plants and evaporation from the soil, but some of it moves downward and becomes part of the body of ground water in the zone of saturation.

In most places there is only one zone of aeration and one zone of saturation. In some places, however, where an impermeable layer of hardpan, clay, or other impervious rock serves to prevent water from passing downward, an upper zone of saturation may be formed over such an impervious layer, above the main zone of saturation with an intervening zone of aeration. The water in such an upper zone is called perched water.

ARTESIAN CONDITIONS

Artesian conditions are likely to exist where a water-bearing bed is overlain by an impermeable or relatively impermeable bed that dips from its outcrop in the same direction as the slope of the land surface but at a greater angle. Normally water from rain and snow will enter at the outcrop and will percolate downward into the water-bearing bed and gradually fill it. The water will be held in the water-bearing bed or retarded in its escape by the overlying confining bed. Thus a water table will be formed in the outcrop area, but down the dip the water will be under sufficient hydrostatic pressure to rise in wells in much the same way that water in a city water system will rise to the faucets in a house. As water moves through the water-bearing bed there is some loss of head due to friction, so that the static level in the artesian wells is likely to be lower than the water table in the outcrop area.

Practically all the water that is within economical reach of the drill in Duval County occurs in beds of sand, gravel, and sandy shale, which are interbedded with clay, shale, and volcanic ash and with tuffaceous sand, clay, and conglomerate formed from volcanic fragments. In general the beds that carry water vary considerably in thickness over wide areas, and some of them apparently pinch out completely. On the other hand, the less permeable materials such as clay and shale usually predominate and are much thicker than the water-bearing beds. They rarely thin to such an extent as to pinch out entirely, and as they are very nearly impermeable, they serve as barriers to the passage of water from one bed of sand or gravel to another.

As the beds in Duval County dip eastward and the slope of the surface is eastward, but at a less angle, the conditions are ideal for the development of an artesian system. A part of the water that falls on the surface as rain runs off in drainage channels, a part evaporates, and a part sinks into the ground. Of the water that sinks into the ground a part is returned to the surface by capillarity and transpiration from plants, and the other part continues downward until it reaches the zone of saturation and becomes a part of the main mass of ground water. Much more water enters the ground in areas where the soil and underlying rocks are sandy or gravelly than in areas where the soil and underlying rocks are clayey or where thick beds of caliche are near the surface. For the same reasons it may be expected that an area underlain by permeable sand and gravel will have a less well-developed surface drainage than an area underlain by impermeable beds, because a larger proportion of the rainfall sinks into the ground and consequently there is less direct run-off to carve stream channels. The Torrecillas Plain west of Hebbronville appears to present an excellent example of this condition.

As the outcrop of each water-bearing bed in this area is higher than any other part of that bed, the water rises above the top of the bed where it is encountered in wells. The height to which it will rise is determined by the height of the water table in the outcrop area minus the loss of head resulting from friction as the water percolates through the bed. If the difference between the altitude of the water table in the outcrop area and the altitude at the surface where the well is drilled is sufficient the well may be a flowing well. Only two flowing wells (nos. 225 and 269) are known in Duval County, although practically everywhere in the county the water in the deeper beds rises materially when the beds are penetrated by the drill.

CHEMICAL CHARACTER OF GROUND WATER

As the water that enters the ground percolates downward through the soil and underlying rocks it dissolves some of the more soluble constituents and carries them in solution. The most common and abundant of these constituents are calcium (Ca), magnesium (Mg), sodium (Na), and potassium (K), which are called basic radicals; and chlorine (Cl), bicarbonate (HCO_3), sulphate (SO_4), and nitrate (NO_3), which are called acid radicals. In the analyses of the United States Geological Survey the abundance of these constituents is expressed in the number of parts of the constituents in 1,000,000 parts of water. Where one basic and one acid radical predominate the water is characterized by the name of the salt composed of these radicals—for example, calcium sulphate, sodium bicarbonate (black alkali).

The chemical character of water largely determines its usefulness. In water intended for industrial use hardness is the most common objectionable characteristic. Hardness is caused almost entirely by calcium and magnesium. Water with a hardness of 190 parts per million or more is not satisfactory for use in laundries,[32] without treatment to reduce the hardness, because it necessitates the use of excessive amounts of soap, nor is it satisfactory for use in steam boilers, because it causes the formation of boiler scale. Water having a high content of silica or iron, or both, also tends to form scale in boilers.[33]

In water used for irrigation the most common of the objectionable constituents are sodium bicarbonate (black alkali) and sodium chloride (common salt); boron and sulphate also are harmful under certain conditions. The safe limits of concentration of these constituents depends upon the character of the water, the amount of water used, rainfall, and drainage. Scofield [34] in a recent paper has suggested

[32] Hudson, H. W., Quality of water and soap consumption: Am. Water Works Assoc. Jour., vol. 25, pp. 645–654, 1933.

[33] Partridge, E. P., Formation and properties of boiler scales: Michigan Univ. Eng. Research Bull. 15, 1930.

[34] Scofield, C. S., Quality of irrigation waters: California Dept. Public Works, Div. Water Resources, Bull. 40, 1933.

limits of safety for certain constituents of irrigation waters. Waters in which the concentration is below the lower limit specified are not likely to be harmful when used in ordinary irrigation. Waters in which the concentration is above the upper limit specified are likely to have harmful effects either on the plants or on the soil. Concentrations between the upper and lower limits may or may not cause injury to crops and soil, their effect depending on the composition of the water, the characteristics of the land, and the way in which the water is used. The following table shows the limits suggested by Scofield:

Suggested limits of concentration of mineral constituents in waters to be used for irrigation

[Parts per million, except as indicated]

	Safe	Unsafe
Total dissolved solids	700	2,000
Sodium (Na) percent	50	60
Sulphate (SO_4)	192	480
Chloride (Cl)	142	355
Boron (B)	0.5	1.0

The percent of sodium is obtained by multiplying the quantity of sodium by 100 and dividing by the sum of the milligram equivalents of calcium, magnesium, and sodium, thus:

$$\frac{Na \times 100}{Ca + Mg + Na} = \text{percent of sodium}$$

Most large city water supplies contain less than 250 parts per million of total dissolved solids. The upper limit of concentration of dissolved mineral matter in water for drinking adopted by the United States Public Health Service [35] is 1,000 parts per million. However, in some areas the residents have accustomed themselves to water containing 2,500 parts per million and even more. Stock can use water with higher mineral content, but more than 10,000 parts per million is not acceptable for any use.[36]

Analyses of samples of water from wells in Duval County made by the usual methods [37] indicate that the ground waters of the county differ greatly in chemical character and mineral content. In the waters of low mineral content calcium bicarbonate predominates as a rule, although in a few of these waters sodium bicarbonate predominates. In the waters of higher mineral content there is usually about as much calcium bicarbonate as in the waters of low mineral content,

[35] Drinking-water standards—standards adopted by the Treasury Department June 20, 1925, for drinking and culinary water supplied by common carriers in interstate commerce: Public Health Reports, Reprint 1029, April 10, 1925.

[36] Hall, G. M., and Howard, C. S., Ground water in Yellowstone and Treasure Counties, Mont.: U. S. Geol. Survey Water-Supply Paper 599, p. 16, 1929.

[37] Collins, W. D., Notes on practical water analyses: U. S. Geol. Survey Water-Supply Paper 596, pp. 235-261.

but there are greater amounts of sodium chloride or calcium chloride or both, and in the more concentrated waters these are the predominating constituents. If the analyses are arranged in the order of increasing total solids they show chloride increasing in almost the same order. The bicarbonate content is as a rule very uniform. Sulphate ranges from 8 to 405 parts per million but is not usually the determining acidic constituent.

The results of these analyses are shown in the following table and are discussed in greater detail under the various formations from which the water was drawn.

Analyses of water from wells in Duval County, Tex.

[Parts per million. Well numbers correspond to those used on pl. 1 and in table of well records, pp. 94–113. Samples from wells 51, 150, and 269 analyzed by W. T. Read, of the University of Texas; other analyses by Margaret D. Foster, of the U. S. Geological Survey]

Well no.	Owner	Date of collection	Total dissolved solids	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulphate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Total hardness as $CaCO_3$
	Catahoula tuff													
9	J. T. Johnson	June 12, 1931	[a]2,412			[b]104		[a]821		181	204	1,212	26	306
97	Duval County Ranch Lands Co.	June 9, 1931	[a]2,578			[b]100		[a]779		263	336	1,082	112	488
104	do	do	[a]7,477			[b]60		[a]2,983		480	[b]1	4,419	3.8	144
118	United Gas Co.	June 10, 1931	[a]799			[b]8		319		420	114	179	11	30
129	John Sutherland	do	[a]2,448			[b]110		[a]768		537	291	971	28	465
130	do	June 12, 1931	[a]1,552			[b]6		[a]601		[c]216	245	642	.60	32
269	Melvine Irrigation & Cattle Co.	do	[a]1,089			[b]12		[a]410		324	184	338	15	54
[d]269	do	Mar. 22, 1913	1,174		0.3	13	3.0	[a]400		278	190	345		[a]45
	Oakville sandstone													
27	G. B. Baker	June 11, 1931	[a]1,489			[b]120		[a]305		429	96	273	400	495
74	Jesús Ruíz	do	[a]1,000			[b]40		[a]342		446	107	280	22	147
[d]150	Texas Mexican Ry.	Mar. 22, 1913	1,146		0.0	84	40	[a]251		260	86	436		[a]374
	Goliad sand													
31	Marcial Rodriguez	Mar. 22, 1913	[a]3,230		0.38	515	214	[a]336		260	405	1,564	68	[a]2,165
37	Pedro García	do	[a]443			[b]52		[a]90		313	[b]8	43	73	188
38	Vicente Moya	do	[a]565			[b]48		[a]157		344	[b]56	107	20	166
43	Amado Garza Martínez	Apr. 4, 1933	[a]573			32	20	[a]162		334	67	115	12	[a]162
[d]51	A. L. Muil	Mar. 4, 1913	[a]3,200		2.0			[a]1,000			181	1,672		680
52	Bruno Ríos	Feb. 28, 1928	1,247	25	.54	92	48	278	8.5	274	75	515	7.5	[a]427
72	F. Valerio	June 12, 1931	[a]505			[b]48		[a]140		320	[b]32	114	8.3	159
140	Duval Texas Sulphur Co.	Apr. 7, 1933	[a]545			38	13	[a]154		268	62	135	11	[a]148
155	F. Vaellos	Feb. 29, 1928	640	32	.21	34	14	173	5.8	272	38	178	24	[a]142
168	A. Parr	Mar. 22, 1933	[a]499		3.4	41	13	[a]137		260	33	145	2.3	[a]156
183	Lazaro Vela	June 13, 1931	[a]1,605		1.6	[b]80		[a]328		314	177	676	9.6	690
189	Pedro López	do	[a]1,590		.79	[b]130		[a]366		256	137	724	19	592
196	Anastacio Sáenz	do	[a]1,746		11	[b]88		[a]360		338	112	807	12	758
204	Hilario Sáenz	do	[a]771			[b]80		[a]200		278	103	229	20	240
209	W. S. Evans	do	[a]247			[b]56		[a]27		223	[b]12	8.7	22	166
220	E. García	Apr. 7, 1933	[a]637			42	19	[a]177		294	84	168	2.3	[a]183

229	Karl Mann	June 12, 1931	[a]826			[b]46		[a]200		324	[b]70	266	23	297
241	J. S. Barnes	do	[a]1,174		3.8	[b]130		[a]188		292	134	444	23	615
281	George A. Nieft	June 13, 1931	[a]1,582			[b]120		[a]316		269	154	691	26	690
301	Hilario García	do	[a]1,215			[b]120		[a]358		243	[b]54	560	29	291
320	J. D. Moore	do	[a]758			[b]72		[a]194		284	89	227	24	244
321	Hilario Garza	do	[a]2,904			[b]130		[a]800		359	312	1,333	25	780

[a] Calculated from determined calcium and magnesium.
[b] By turbidity.
[c] Includes equivalent of 98 parts per million of carbonate (CO_3).
[d] Sample collected by David Donoghue under the supervision of Alexander Deussen.

63964—3——37

GEOLOGIC FORMATIONS AND THEIR WATER-BEARING PROPERTIES

TERTIARY SYSTEM

EOCENE SERIES

JACKSON FORMATION

Name.—The history of the changes in the nomenclature of the sedimentary rocks of Jackson age is well outlined by Plummer,[38] who states that the deposits have not been subdivided into formation units in Texas. He considers that the beds between the Yegua and the Catahoula or Frio properly belong to the Jackson group, and for the part of the Jackson group that occurs in Texas he retains the term "Fayette formation."

Miss Ellisor [39] has shown that the Jackson in Texas northeast of Duval County may be subdivided on the basis of lithology and microfaunas into three formations—the Cadell, McElroy, and Whitsett—each of which contains two or more members. From Duval County south, however, the section changes and the fauna above the Cadell becomes scant, so that it is not possible to place the contact between the McElroy and the Whitsett.

In this report the Jackson deposits have not been subdivided and are treated as one formation.

Character.—The following description of the Jackson formation is taken from Lonsdale's report on Webb County,[40] west of Duval County:

> The Jackson formation consists of grayish-green and buff clay, gray and buff sandy clay, buff and light-grayish sandstone, and light-gray and white volcanic ash or partly hydrated ash. Limestone concretions are not uncommon, and opalized and silicified wood is abundant.
>
> The sandstone is medium-grained, generally micaceous, and usually contains a whitish bentonitic or ashy clay matrix. * * * Beds more than a few feet thick are not observed in the exposures, and the total amount of sandstone is a small part of the whole formation. Many of the sandstone beds are fossiliferous.
>
> Much of the clay is bentonitic and grades into ashy sandstone. Greenish and buff colors are common on fresh exposures, but weathered surfaces or soils are often purplish. Oyster beds are found here and there in the clay. * * *
>
> The thickness of the Jackson is estimated at 1,500 feet. The dip is about 80 feet to the mile.

Distribution.—The Jackson crops out in a rather wide belt extending across southwestern McMullen County, eastern Webb County, and thence both north and south. Thin-bedded sandstones belonging to the uppermost Jackson are found on the Yeager ranch, in northeastern

[38] Plummer, F. B., The geology of Texas, vol. 1, Stratigraphy: Texas Univ. Bull. 3232, pp. 677–699, 1932.

[39] Ellisor, A. C., Jackson group of formations in Texas: Am. Assoc. Petroleum Geologists Bull., vol. 17, no. 11, pp. 1293–1350, 1933.

[40] Lonsdale, J. T., and Day, J. R., Geology and ground-water resources of Webb County, Tex.: U. S. Geol. Survey Water-Supply Paper 778 (in press).

Webb County, and sandstones bearing large *Ostrea georgiana* are found in the extreme southwestern part of McMullen County, near the northwest corner of Duval County. The Jackson deposits do not crop out in Duval County, but because of their eastward dip they are encountered in numerous wells in this county.

Occurrence of ground water.—The Jackson sands contain water throughout much of the outcrop area of the formation in Webb and McMullen Counties, but the water is so highly mineralized as to be unfit for domestic use. One well in Duval County possibly draws its water from the Jackson; this is well 4 at the S. R. C. pool, on the Soledad ranch. It is situated on the outcrop of the Catahoula tuff, near the base of that formation, and is over 600 feet deep. The water-bearing sand encountered near the bottom of the well is probably of Jackson age, although it is possible that the water comes from a sand in the Frio clay. This water is so highly mineralized that it has to be treated to make it fit for drinking. Well 104 also draws from the Jackson formation.

OLIGOCENE (?) SERIES

FRIO CLAY

Name.—There has been much confusion regarding the definition and correlation of the Frio clay and the Catahoula tuff. The available information has been summarized by Trowbridge [41] and also by Plummer.[42] The term "Frio" was used originally to include all the strata overlying the Jackson formation and underlying the Oakville sandstone. Bailey [43] divided the original Frio into a lower, dominantly nonvolcanic clay formation for which he retained the name "Frio" and an upper volcanic formation to which he applied the term "Gueydan." This division is now generally accepted, but the Gueydan has been correlated with the Catahoula tuff of eastern Texas, and the term "Gueydan" has been dropped in favor of the term "Catahoula."

Character and distribution.—The Frio clay consists of massive or obscurely bedded clays of pastel tints of pink, green, gray, or yellow. In the upper part of the section the clay is remarkably pure, but the lower beds commonly carry a small amount of fine angular quartz mingled with the clay, and in Starr County thin beds of sandstone are reported.[44] Gypsum is of common occurrence, and calcareous nodules are numerous, but no cone-in-cone structure like that of the Jackson formation was seen. The clay offers little resistance to

[41] Trowbridge, A. C., Tertiary and Quaternary geology of the lower Rio Grande region of Texas: U. S. Geol. Survey Bull. 837, pp. 156–159, 1932.

[42] Plummer, F. B., The geology of Texas, vol. 1, Stratigraphy: Texas Univ. Bull. 3232, pp. 700–705, 1932.

[43] Bailey, T. L., The Gueydan, a new middle Tertiary formation from the southwestern Coastal Plain of Texas: Texas Univ. Bull. 2645, pp. 42–52, 1926.

[44] Owens, F. C., and Gierhart, G. C., oral communication.

erosion, and consequently outcrops are not common except where the formation is protected by overlying harder formations. The Frio is distinguished from the Jackson by its clayey character and the general absence of fossils and from the overlying Catahoula by the nonvolcanic character of the clay.

Because of its slight resistance to erosion the Frio ordinarily forms broad gentle valleys. The drainage is commonly poor and wherever water is present the streams meander and form swamps. The change from Catahoula outcrop to Frio outcrop is plainly indicated along the San Diego-Cotulla road by the change in topography and vegetation—the brushy rolling country that characterizes the Catahoula gives way to flat, open, grassy country with scattered clumps of mesquite and clepano and rare pitaya and prickly pear.

The thickness of the Frio in its outcrop area in Duval County is probably about 300 to 400 feet. For the most part it has not been differentiated in wells, but Cooper assigns to it a thickness of nearly 900 feet in the De Lange-Frates oil test, about 1 mile northeast of the La Gloria ranch. It has a dip of about 80 feet to the mile.

No good exposures of the Frio were found in Duval County, but its presence can be inferred at many places from the notable absence of exposures and the distinctive vegetation. The belt of outcrop extends through the northwest corner of the county, where it is about 4½ miles wide, nearly its maximum width of outcrop.

Age.—For many years the Frio clay was regarded as of Eocene age, but Plummer [45] says:

> The correlation of subsurface data seems to indicate that the outcropping Frio grades down dip above strata that carry a microscopic fauna related to marine lower Oligocene faunas of the Gulf coast region. The Frio formation has therefore been removed from the Jackson group in recent publications and is classified with Oligocene formations.

Very few fossil animals have been found in the Frio, and the only ones reported are from Starr County. Fossil wood, mostly palms, is commonly found in the Frio in its outcrop area. The line of contact between the Jackson and the Frio is drawn somewhat arbitrarily on the basis of differences in topography, vegetation, and color of the soil. The contact between the Catahoula and Frio, on the other hand, is recognizable at a number of places and according to Bailey [46] appears to be conformable. However, the Frio varies considerably in width of outcrop, and in Atascosa County [47] it is apparently overlapped by the Catahoula. As the Catahoula is probably of Miocene age, it has been suggested that this overlap represents the Oligocene-Miocene break and that therefore the Frio is Oligocene. According

[45] Plummer, F. B., op. cit., p. 678.

[46] Bailey, T. L., op. cit., p. 50.

[47] Gardner, Julia, and Lonsdale, J. T., oral communication.

to Plummer,[48] detailed subsurface correlations in oil wells by geologists of the Humble Oil & Refining Co. and the United Gas Co. indicate that the Frio formation lies beneath strata assigned to the middle Oligocene and above strata assigned to the Vicksburg. Miss Ellisor [49] states that in several wells north of Duval County beds of Vicksburg age are encountered beneath clays having typical Frio lithology.

In this paper the Frio is considered to be probably Oligocene.

Occurrence of ground water.—One well in Duval County is believed to draw its water from the Frio. This is well 1, on the Soledad ranch, near the Frio-Catahoula contact and near the west line of the county. This well is 300 feet deep, and the water is salty. The S. R. C. Co.'s water well (no. 4) may draw its water from the Frio but more probably draws its water from the Jackson. Well 2, which is 600 feet deep, failed to encounter water in either the Frio or the Jackson.

MIOCENE (?) SERIES

CATAHOULA TUFF

NAME AND CORRELATION

The Catahoula formation in southern Texas was first described as the "Gueydan tuffs" by Bailey,[50] who made the first detailed field and laboratory study of the area and in the short space of one field season covered a very large area with a thoroughness and an eye for detail that are truly remarkable. His report stands as a monument to his industry and ability.

Bailey's †Gueydan had previously been considered by various authors to be Fayette or Frio. Penrose [51] included it in his Fayette "series" in 1890. Dumble [52] in his first description of the Frio clay, in 1894, gave a section in the upper Catahoula as the type section. In 1903 [53] he mapped the Catahoula as a part of the Frio in Live Oak County, and in 1924 [54] he again included it in his Frio formation and thought it was of Jackson age. Deussen,[55] in 1916, mapped the Frio in McMullen County in such a way as to include the Catahoula and Frio and part of the Fayette, and in 1924 [56] he included the Catahoula

[48] Plummer, F. B., op. cit., p. 707.

[49] Ellisor, A. C., op. cit., pp. 1325–1350.

[50] Bailey, T. L., op. cit., pp. 62–164.

[51] Penrose, R. A. F., Jr., A preliminary report on the geology of the Gulf Tertiary of Texas from Red River to the Rio Grande: Texas Geol. Survey 1st Ann. Rept., p. 47, 1890.

[52] Dumble, E. T., The Cenozoic deposits of Texas: Jour. Geology, vol. 2, pp. 549–567, 1894.

[53] Dumble, E. T., The geology of southwestern Texas: Am. Inst. Min. Eng. Trans., vol. 33, pp. 913–987, 1903.

[54] Dumble, E. T., A revision of the Texas Tertiary section: Am. Assoc. Petroleum Geologists Bull., vol. 8, pp. 424–444, 1924.

[55] Deussen, Alexander, Ground water in Lasalle and McMullen Counties, Tex.: U. S. Geol. Survey Water-Supply Paper 375, pp. 141–177, 1916.

[56] Deussen, Alexander, Geology of the Coastal Plain of Texas west of Brazos River: U. S. Geol. Survey Prof. Paper 126, pp. 91 et seq., 1924.

of southwestern Texas in the Frio, excluding the upper part of the Fayette. Although he recognized the Catahoula farther north, he mapped it as pinching out in Gonzales County and stated that its time equivalent in southwestern Texas might be the upper part of the Frio clay.

Trowbridge [57] writes:

> The field relations suggest that the latter [Catahoula] is of the same age as the Catahoula formation of central Texas, Louisiana, and Mississippi. This correlation is further suggested by the results of the work of Baker and Lonsdale, who have found that all the larger deposits of fuller's earth in Texas are in either the Catahoula tuff or the typical Catahoula.

Bailey [58] states that the "clays of the upper †Gueydan (Chusa) when traced northeastward are found to overlie, apparently conformably, the typical Catahoula sandstone of Gonzales and Lavaca Counties." The †Gueydan is now considered the equivalent of the Catahoula tuff of northeastern Texas, and the older term has replaced "Gueydan" in the literature.

Bailey considered the †Gueydan to be upper Oligocene but thought it quite possible, in the absence of fossil evidence, that a part or the whole of the Chusa member of his Gueydan might be of lower Miocene age. The United States Geological Survey considers the Catahoula to be probably lower Miocene, but the evidence is inconclusive, and the stratigraphic relation of the Catahoula sand to the underlying Vicksburg in Mississippi indicates that the Catahoula may be either Miocene or Oligocene. Weeks [59] states that he visited a locality on the banks of a small creek on the Derrick farm, 3½ miles west of Burton, in Washington County, in company with the man who found at that place a jawbone of a middle or upper Miocene rhinoceros. Deussen, in reporting the find, considered the beds to be Oakville, but Weeks states that they occur about the middle of the Catahoula outcrop area. At a locality near Rio Grande City beds that Bailey considered Oakville but that Weeks assigned to the Catahoula contained *Protohippus sejunctus*, of upper Miocene or lower Pliocene age as determined by J. L. Wortman, of Brownsville. These fossils in conjunction with well data are considered by Weeks to indicate the Miocene age of the Catahoula. The present usage of the United States Geological Survey, pending conclusive evidence to the contrary, is to place the Catahoula in the lower Miocene, with a query.

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57 Trowbridge, A. C., Tertiary and Quaternary geology of the lower Rio Grande region, Texas: U. S. Geol. Survey Bull. 837, p. 159, 1932.

58 Bailey, T. L., op. cit., p. 147.

59 Weeks, A. W., Lissie, Reynosa, and Upland Terrace deposits of Coastal Plain of Texas between Brazos River and Rio Grande: Am. Assoc. Petroleum Geologists Bull., vol. 17, no. 5, pp. 456–457, May 1933.

CHARACTER AND DISTRIBUTION

Bailey [60] divided the Catahoula into three members—the Fant tuff (characterized by mud flows); the Soledad volcanic conglomerate (volcanic conglomerate, sandstone, and tuff); and the Chusa tuff (tuff and tuffaceous clay). He described the formation in detail and mapped the approximate contacts of the three members as far south as west-central Duval County, where all of the Chusa and the upper part of the Soledad are overlapped by later formations. The lower part of the Soledad and the Fant extend southward through Webb, Zapata, and northern Starr Counties. Along the Rio Grande Bailey mapped the Frio as overlain directly by the Oakville.

Each of the members of the Catahoula gives rise to a distinctive topography: the outcrop area of the Fant member is rolling; the conglomerate of the Soledad member forms rather high, steep hills; and the outcrop area of the Chusa is a broad valleylike area with scattered hills.

Fant tuff member.—The Fant tuff member was named for the town of Fant City, in northern Live Oak County. It is composed dominantly of light greenish-gray and creamy-white to pinkish trachyandesitic tuffs. Some of the tuff beds show vertical polygonal jointing, evidently the result of shrinkage due to drying. Bailey considers these to be sun cracks. Some of the tuff exhibits a ropy structure characteristic of mud flows, and in general it has a rather lumpy or nodular appearance suggesting movement after deposition. In no place was stratification within the beds noted. Bailey [61] lists and describes the following other types of rocks occurring in the Fant:

> Light-gray to white or grayish-pink, very dense textured, chertlike, silicified tuff or porcelanite; friable white to light-gray or yellowish-green medium-grained tuff, which on first glance resembles sandstone; soft creamy-gray to grayish-green argillaceous, bentonitic tuff; thick beds of purplish-pink and grayish-green mottled noncalcareous to marly unlaminated bentonitic clay; creamy-gray to light pinkish-brown fine- to medium-grained argillaceous, arkosic, and generally tuffaceous sandstone of fluviatile origin; coarse to fine conglomerate composed largely of bluish-gray rounded to subrounded pumice pebbles or lapilli.

The Fant member is not so well exposed in Duval County as in the counties to the northeast, though there are a few exposures worthy of recording.

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[60] Bailey, T. L., op. cit., pp. 65 et seq.

[61] Bailey, T. L., op. cit., pp. 66–73.

Section of Fant tuff member near Esteban ranch house, 5 miles west of Soledad ranch house

	Feet
Greenish-gray arkosic, argillaceous, slightly calcareous, gypsiferous sandstone containing numerous clay balls, which weather out and give the surface a pockmarked appearance; composed of grains of quartz, chert, and feldspar cemented with opal and calcareous clay; some portions are very firmly cemented and ring under blows of the hammer	2
Grayish to white chalky, calcareous tuff; covered	2+
Greenish mottled clay with abundant veinlets of earthy calcite and numerous plates and clusters of gypsum as much as 8 inches across; exposed in the arroyo west of the ranch house	15+
	19+

About 1 mile west of the ranch house in the arroyo a friable grayish-green argillaceous, arkosic, gypsiferous sandstone is exposed.

About 2½ miles west of the Soledad ranch, near the tank or reservoir at the old Cinencia ranch, which is now in ruins, a pinkish-white lumpy calcareous ashy tuff is exposed in the small arroyo. The tuff shows no signs of stratification and is composed of white clay or ash, angular grains of quartz, feldspar, and glass, and scattered flakes of black to golden-brown mica.

Section of Fant tuff member in small arroyo on south side of road between Soledad ranch and Baji pasture, 7 miles northwest of Soledad ranch

	Ft.	in.
Buff soft, friable, finely granular volcanic ash, regularly bedded in ½-inch beds	12	
White to light-gray soft, granular, friable volcanic ash, unstratified, containing lentils of greenish volcanic ash ½-inch thick and 3 to 4 inches long; grades downward into greenish fine-grained ash	4	
Resistant light-gray calcareous arkosic sandstone with much ash and considerable quantities of gypsum		4
Light greenish-gray fairly coarse sandy, ashy tuff, roughly stratified	6	
Same as bed next above except that it is better stratified and more firmly cemented; partly covered	2+	
	24	4

Lying loose upon the surface are numerous rounded boulders of brown to dark-gray trachyandesite from half an inch to 4 or 5 inches in diameter.

Section of Fant tuff member on hill half a mile east of Casa Blanca on San Diego-Cotulla road, 7 miles northwest of Freer

	Feet
Grayish-green arkosic, calcareous sandstone, hard (rings under blows of the hammer) and firmly cemented; grades downward into an agglomerate of bentonitic clay balls and coarse volcanic fragments	2–5
Greenish bentonitic clay containing abundant gypsum	15
	17–20

In general the outcrop area of the Fant member is characterized by rolling topography. The rather numerous lenses of eastward-dipping firmly cemented tuff or tuffaceous sandstone overlying beds of more or less tuffaceous clay form many small cuestalike hills 30 or 40 feet high with steep slopes to the west, gentle slopes to the east, and still more gentle slopes to the north and south. The east slope is presumably a dip slope. The north and south slopes are due to the lensing out of the resistant bed. The valleys are flat-bottomed and covered with extremely heavy brush consisting of black chaparral, mesquite, retama, prickly pear, and a branching variety of cactus known as tasajillo.

Soledad volcanic conglomerate member.—The Soledad volcanic conglomerate member was named for the Soledad Hills, in western Duval County, because of the excellent exposures there. In Duval County the Soledad member is made up of brownish-gray fine to very coarse boulder conglomerate consisting of pebbles and boulders, many of them water-worn, of andesite, trachyte, and trachyandesite, dense to vesicular and cemented by milky-white to blue chalcedony or opal, grading into coarse sandstone; vivid green friable volcanic sandstone; and massive and cross-bedded brownish-gray to brownish-pink coarse- to fine-grained calcareous, tuffaceous sandstone, friable to well cemented.

Bailey [62] gives the following section:

Section in bluffs on both sides of Cotulla road 2 miles north of Government Wells

	Feet
Gueydan (Soledad member):	
4. Coarse-grained grayish-brown sandstone or grit and conglomerate with vertical and lateral gradations from sandstone to conglomerate. These rocks are fairly hard and thin- to massive-bedded. The pebbles consist mainly of buff, gray, or light-brown chert, but many pebbles of brown, red, and purplish trachyandesite (?) and pink argillaceous tuff and clay are also present. The pebbles are generally rounded and range in size from coarse sand to boulders 1 foot in diameter. The largest boulders consist of vesicular volcanic rocks	20

[62] Bailey, T. L., op. cit., pp. 86-87.

Section in bluffs on both sides of Cotulla road 2 miles north of Government Wells—
Continued

	Feet
Gueydan (Soledad member)—Continued.	
3. Brownish-pink dense-textured sandy, much jointed silicified tuff or tuffaceous clay containing numerous irregular lenses, streaks, and pockets of coarse sandstone or fine conglomerate. This grades into no. 4	1
2. A yellowish-green very friable arkosic, pebbly grit or coarse conglomeratic sandstone. Many of the sand grains and pebbles in this sandstone consist of volcanic rocks, apparently andesite and trachyandesite. The cement is a mixture of greenish argillaceous material and calcite. The base of this bed has a 5° inclination to the south	12
Disconformity.	
Fant member (?):	
1. Profusely jointed, more or less silicified, dense-textured white tuff grading upward into a soapy cream-colored bentonite, which breaks into spheroidal joint fragments and irregular to tetrahedral pieces. Some glass grains containing bubbles can be seen in the upper portion with the naked eye	15
Total thickness	48

Dip uncertain, beds approximately horizontal.

Section at south end of Soledad Hills

	Feet
Gueydan (Soledad member):	
2. Well-indurated to friable brownish-gray massive-bedded conglomerate consisting almost entirely of pebbles, cobbles, and boulders of porphyritic volcanic rocks of several types (most trachyandesite) and some of tuffaceous clay. The cement is white chalcedony, opal, and silicified tuffaceous (?) clay. Some lenses and angular, boulderlike masses of pink silicified tuffaceous clay up to 2 feet in thickness are present in places	50
Disconformity (?):	
1. Soft, powdery, finely pisolitic pink altered tuff or bentonitic clay containing streaks and lenses of conglomerate like no. 2. Base not exposed; thickness exposed	25
Total thickness	75

Approximate strike N. 24° E.; dip ½°–1° SE.

Banks[63] states that there are at least two beds of the conglomerate phase of the Soledad on the Soledad ranch. South of the escarpment at this ranch the Soledad changes character greatly. It is not exposed in the valley, but on the east side of Cedro Hill, 4 miles south of the ranch house, a conglomerate of unknown thickness crops out

[63] Banks, T. W., personal communication, May 1931.

at the base of the hill. This conglomerate is composed of subangular grains of chalcedony, chert, andesite, and trachyte, cemented by chalcedony, and it may represent the Soledad. Along the Bordas escarpment in western Duval County, Bailey apparently mistook the gravel beds that belong in the Goliad formation for part of the Soledad member. He recognized that these beds consist mainly of chert pebbles and boulders, whereas the Soledad consists largely of pebbles and boulders of igneous rock, but he believed that this difference was due to variation along the strike of the member. The writer did not observe the Soledad conglomerate anywhere along the Bordas escarpment.

Throughout most of the area of its outcrop the conglomerate of the Soledad member forms rather high, steep-sided hills. The escarpment near the Soledad ranch house is about 60 feet high, and some of the Soledad Hills are probably higher. To the south the formation is lost in the broad valley of Cedro Creek and, so far as the writer has been able to determine, its place is taken by sandstone or it is faulted out of sight. North of the Soledad Hills the topography shows less relief, although there are several prominent westward-facing escarpments formed by resistant beds. In the Soledad outcrop area the hills are likely to be more or less free of brush, although in places patches of black chaparral and frijolito or "mountain laurel" occur. The soil is favorable to the growth of bluebonnets, which flower here in great profusion in the spring. The valleys usually are densely covered with brush and cactus much like the growth on the outcrop area of the Fant member.

Chusa tuff member.—The Chusa tuff member was named for La Chusa Mesa, in southeastern McMullen County, where good exposures of the tuffaceous clay are found on the slopes beneath the capping of Oakville sandstone. This member is composed of white to pink argillaceous tuff and tuffaceous clay, usually unstratified but containing numerous pebbles and boulders and in some places beds of conglomerate, as along the hill north of Novillo Hill. The following sections were observed:

Section on hill 2.5 miles S. 75° E. of Freer town site

	Feet
Goliad sand:	
Top of hill is a gentle slope covered by flat fragments of caliche containing very small amounts of fine-grained quartz sand and supporting very sparse vegetation	5
Brownish-pink to pink calcareous, moderately cemented sandstone; sand grains rounded to angular, ranging in diameter from 1 to 0.1 millimeter; mostly clear quartz but includes a moderate amount of amber quartz and brown to honey-colored chert and a little feldspar	8

Section on hill 2.5 miles S. 75° E. of Freer town site—Continued

	Feet
Goliad sand—Continued.	
Grades into bed above; light-gray to pinkish-gray calcareous mud balls and some large andesitic pebbles (as much as 3 inches in diameter) near the base	4
White hard, lumpy calcareous sandy clay with dendritic manganese and small veinlets of calcite; contact with bed next above irregular	3
Chusa tuff member of Catahoula tuff: Pinkish-brown calcareous, tuffaceous clay	5
	25

Section on Novillo Hill, 3 miles northeast of Freer town site

	Feet
Oakville sandstone:	
Light-gray hard, dense, calcareous, fine-grained to conglomeratic sandstone; sand mostly small grains of clear quartz	1
Light pinkish-gray calcareous conglomerate composed of pebbles of chert, igneous rock, clayey sand and tuff, and clear quartz firmly cemented by chalcedony and calcite; pebbles range from 1 to 30 millimeters in diameter	2–5
Chusa tuff member of Catahoula tuff:	
Pinkish-buff tuffaceous conglomerate containing pebbles and boulders of tuff as much as 4 inches in diameter	4
Pinkish-brown to gray argillaceous tuff	14
Pinkish-brown faintly stratified lumpy argillaceous tuff. Contains siliceous "rootlets", many of which are vertical; they range in size from tiny hairlike forms up to those nearly an inch in diameter and are due to deposition of chalcedony by ascending meteoric waters; they display no regularity of location but usually consist of a hard core of chalcedony surrounded by less completely silicified tuff. (See pl. 4, *A*.) This bed is sufficiently resistant to form a terrace on the westward-facing bluff of Novillo Hill	40
	61–64

On the hill north of Novillo Hill the lowest tuffaceous bed is capped by coarse conglomerate 4 to 10 feet thick. This conglomerate is only moderately well cemented by calcite and chalcedony, and about 95 percent of the boulders are of igneous rocks similar to those found in the Soledad member. The largest are 18 inches in diameter, and many are 4 to 6 inches in diameter. Toward the north this conglomerate grades into a coarse sandstone, but still farther north the sandstone gives way again to coarse conglomerate, which eventually pinches out completely. The conglomerate appears to represent a local renewal of the conditions that gave rise to the Soledad. Drillers' logs that indicate the character of the Catahoula formation as it is encountered in wells are given on pages 82–93.

The Chusa outcrop area is, for the most part, low and featureless, forming a broad valleylike depression between the Bordas escarpment and the Soledad Hills belt. The beds of conglomerate form prominent hills, such as the hills north of Novillo Hill, and where the formation is sufficiently silicified to be resistant to erosion this also results in prominent hills, such as the terrace on Novillo Hill.

The soil formed by the weathering of the Chusa is favorable to a dense growth of brush.

THICKNESS AND DIP

The irregular character of the Catahoula tuff in Duval County and the fact that most of the exposures are shallow render difficult an actual measurement of its thickness. On the San Diego-Cotulla road the entire thickness of the formation is crossed, and numerous exposures are seen. The Catahoula dips east at a rate estimated to be about 80 feet to the mile. The average width of its outcrop area in Duval County is about 13 miles, and its thickness is therefore estimated at 1,100 feet.

Bailey[64] estimated the thickness of the Catahoula in Duval County at 850 feet and stated that the samples from the Peters well show a thickness between 870 and 970 feet. He believed that this well penetrated the full thickness of the formation. It is now known that the formation is overlapped here for a distance of several miles, and that the upper part of the formation is missing in this well. Bailey's estimate of the thickness is therefore too low. Cooper[65] states that in the De Lange-Frates well, about 1 mile northeast of La Gloria ranch, the Catahoula is 1,100 feet thick. Several wells in the vicinity of Freer in which nearly the whole thickness of the Catahoula is penetrated encountered the top of the Jackson at about 1,700 to 1,800 feet. In these wells the Frio was not differentiated. But if it is assumed that the Frio is 400 to 500 feet thick—that is, not materially thicker than in its outcrop area—the Catahoula is not less than 1,300 feet thick.

ORIGIN

The evidence bearing on the origin of the Catahoula tuff is well discussed by Bailey,[66] who concludes that the pyroclastic materials in the Catahoula probably came from one or more volcanoes in western Duval County or southwestern McMullen County. The neck of the ancient volcano has not been found, but it may have been covered by later deposits.

The following lines of evidence indicate a source close at hand:

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[64] Bailey, T. L., op. cit., pp. 62–65.
[65] Cooper, H. H., oral communication.
[66] Bailey, T. L., op. cit., pp. 155–164.

The greatest thickness of the Catahoula is found in Duval and McMullen Counties.

The larger individual grains in the tuffs and tuffaceous clays are angular to subangular, indicating that although reworked by running water they have not been carried a great distance; some of the finer material, however, may have been carried great distances in the air.

Mud flows are widespread in the lower part of the Catahoula, and mud flows do not move a great distance from the parent volcano unless the slopes are steep. The dip of the Jackson and the Frio indicates that they were not deposited on steeply inclined surfaces, and the Catahoula was apparently deposited on a gently sloping surface of the same kind.

Many boulders of andesitic character are found in Duval and McMullen Counties. The largest boulder noted by the writer was about 3 feet across and occurred in the Chusa tuff member about 3 miles northeast of Freer; most of them, however, are less than 2 feet in diameter. Many of these boulders are subangular, and their number, size, weight, and shape preclude a source more than a few miles distant.

Boulders and pebbles of other than volcanic material are rare. This fact is very difficult to explain if a distant source is assumed, as under normal processes streams transporting boulders from a distant source would also pick up and transport boulders of many other types of rock.

The presence of 20 feet of apparently intrusive serpentine 230 feet below the surface in the Hawley well, in Live Oak County, is cited by Bailey as another indication that a volcano once existed in the vicinity of the Catahoula outcrop. If this serpentine mass was connected with the magma that produced the Catahoula pyroclastic materials it represents an ultrabasic differentiation product from this magma.

OCCURRENCE OF GROUND WATER

Water is encountered in the Catahoula tuff by comparatively shallow wells throughout most of its outcrop area. Most of these wells yield sufficient water for domestic and stock use and for drilling, but no large supplies are encountered. Most of the water is rather highly mineralized but is acceptable for stock and domestic use. A few wells yield water that is unfit for use until it is treated to lessen the mineral content.

Because of the general irregularity of the water-bearing sands, it is not possible to predict in advance of drilling the depth at which water will be encountered in a well, but most wells obtain water within 200 to 600 feet of the surface. The wells on which information was obtained during the field work are indicated by numbers on plate 1, and their depth is given. The data obtained concerning them are given in the tables on pages 94–113.

The lower part of the Fant member of the Catahoula apparently does not yield water to wells. Several dry or unsuccessful wells in the outcrop area of this member are reported by drillers. Well 2 is more than 600 feet deep and encountered no water. Such wells as have been successful on the outcrop of this member appear to obtain their water from beds of sand in the Frio clay or the upper part of the Jackson.

The upper part of the Fant member, the Soledad member, and the Chusa member can usually be counted upon to yield water to wells, although occasionally an unsuccessful well is reported. A well drilled to a depth of 413 feet in sec. 73 on the Welder Wood ranch, north of Freer, was unsuccessful, but successful wells have been drilled on all sides of it.

Well 6, known as the Government well, was used many years ago to supply water at the station on the route to Laredo. It is a dug well 5 to 6 feet square, with stone curbing 50 feet deep. A few years ago the owner drilled a small well in the bottom to a depth reported to be about 100 feet in order to obtain a more permanent supply. Wells 7 and 8 were drilled to supply water for oil-well drilling operations. Well 7 encountered three water-bearing beds—one at 70 to 110 feet, one at 135 to 195 feet, and one at 270 to 280 feet; the lowest water-bearing bed furnishes most of the water, which rises within 40 to 50 feet of the surface. This well yields about 700 barrels of water a day, or about 20 gallons a minute. Well 9 encountered a "sand" at 104 feet that furnishes sufficient water to irrigate a small garden and supply domestic needs. Well 98, known as the big well, was drilled as an oil test. This well encounters sand from 92 to 150 feet and is said by Ab. Rutledge to have been tested at 700 barrels a day. A smaller well was drilled within a few feet to supply water for stock. Well 102 was drilled to supply water for oil-well drilling. It is said to yield 550 barrels of water in 12 hours, or about 30 gallons a minute, and is 208 feet deep. Well 91 is 160 feet deep and contained water when it was drilled, but it went dry the first time it was pumped and has yielded no water since. Two wells worthy of notice because they are unusually deep for dug wells are well 127, which is 200 feet deep, and well 123, which is 223 feet deep.

From a study of the data it appears that the average depth of wells in the Catahoula is about 200 feet.

QUALITY OF WATER

Most of the water from the Catahoula tuff is rather high in dissolved mineral matter. Of seven samples analyzed from widely spaced wells in the formation six contained 799 to 2,578 parts per million of total dissolved mineral matter, and the seventh contained 7,477 parts per million. (See table, p. 26, wells 9, 97, 104, 118, 129, 130, and 269.)

Although the waters that were analyzed contain sodium salts in quantities generally considered harmful to soil and crops when used for irrigation, water from two of the wells is being used on a small scale. Well 9, northeast of Freer, supplies water to irrigate a small garden tract. Mr. Johnson, the owner, reports that more than two applications of this water to a crop cause the plants to wilt. At Crestonio a small orchard of citrus trees not yet in bearing has been irrigated successfully with rather light applications of water from well 269, which is 1,600 feet deep and apparently derives its water from the Catahoula. A sample from this well showed total dissolved solids of 1,089 parts per million. This use of the water is probably possible only because extreme care is exercised in its application, and the land is well drained. Under ordinary conditions the Catahoula water would be harmful to crops. It is satisfactory for stock, and it may be used for drinking, apparently with no ill effects, by people who have become accustomed to it.

MIOCENE SERIES

OAKVILLE SANDSTONE

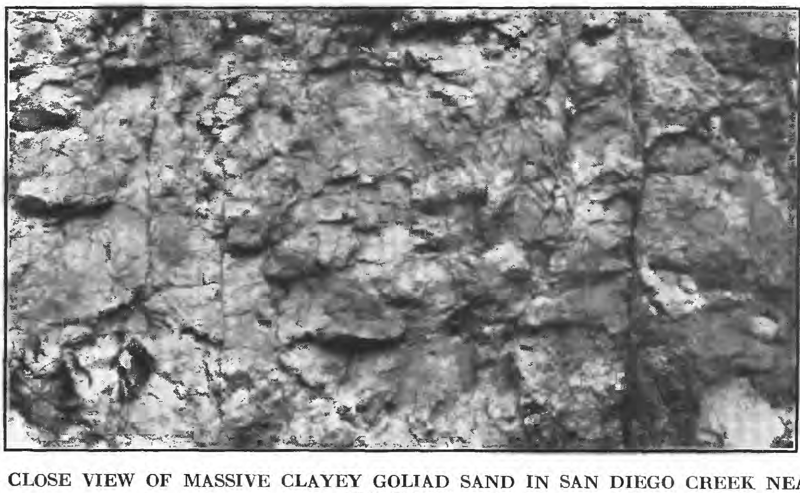
Name and distribution.—The type locality of the Oakville sandstone is along the Nueces River in the vicinity of Oakville, Live Oak County, where the section includes beds from the top of the Catahoula to the base of the Lagarto clay. The formation was first described by Dumble[67] as the sandstone, grit, and silt interbedded with clay between the Frio clay (the Catahoula tuff of this report) and the overlying Pliocene formation. Thus, as originally described the term was applied to both the Oakville and the Lagarto as now restricted in Live Oak County. Until recently the term was used essentially with this significance in southern Texas by various writers, as described by Plummer,[68] although many geologists working in the area considered the yellow to gray, green, and red clays at the top of Dumble's Oakville to belong to the Lagarto formation. The United States Geological Survey in the preliminary map of Texas[69] restricted the Oakville in accordance with the present usage of the Texas geologists. Plummer states that the Oakville formation as now defined includes all the strata of Miocene age above the Catahoula formation and below the Lagarto clay (restricted).

[67] Dumble, E. T., The Cenozoic deposits of Texas: Jour. Geology, vol. 2, pp. 556–559, 1894.

[68] Plummer, F. B., The geology of Texas, vol. 1, Stratigraphy: Texas Univ. Bull. 3232, pp. 729–730, 1932.

[69] Darton, N. H., Stephenson, L. W., and Gardner, Julia, Geologic map of Texas, preliminary edition, U. S. Geol. Survey, 1932.

A. IRREGULAR MASSES OF SILICIFIED CHUSA TUFF.



B. CLOSE VIEW OF MASSIVE CLAYEY GOLIAD SAND IN SAN DIEGO CREEK NEAR SAN DIEGO.

The comparatively resistant sandstone of the lower part of the Oakville overlies the Catahoula, which is much less resistant, on the prominent westward-facing Bordas escarpment in Duval County as far south as the vicinity of the town of Freer, where it is overlapped by the Goliad. (See pl. 1.) East of the escarpment the outcrop area of the Oakville is rather featureless, open sandy country supporting a scattered vegetation of mesquite trees and grass.

The area of outcrop of the Oakville in Duval County is irregular. At the north boundary of the county it is about 1½ miles wide, but it increases to about 7 miles on San Diego Creek. Southeast of Freer it is completely overlapped on the hills but has an outcrop width of several miles in the valleys. It disappears beneath the Goliad on the south side of the Hubbard ranch but according to some geologists reappears on Parilla Creek on the Sutherland ranch, which is the southernmost point at which the formation has been encountered in Duval County. From the topography it appears that if the exposure seen on the bluff near the Sutherland ranch house is correctly assigned to the Oakville the formation should appear in Las Animas Creek, to the north; no exposures of the Oakville were seen in this creek valley, however. Additional field work is necessary to determine whether the outcrop on Parilla Creek is Oakville or an indurated part of the Goliad.

Character.—In Duval County the exposures of Oakville observed consisted of fine- to coarse-grained dirty-gray to buff sandstone containing considerable clay in the form of little clay balls. North of Duval County considerable amounts of clay are noted in the outcrop area of the formation. Beds of dirty-buff clayey sand and sandy clay are reported to occur in the area north of Duval County and are logged in numerous oil test wells in Duval County (see pp. 82–93), but no clay outcrops were noted in this county in the Oakville outcrop area.

In sec. 224, in the roadway about 10 miles northeast of Freer and half to three-quarters of a mile west of the Tilden-San Diego highway there is a shallow section of thin-bedded, firmly cemented dirty-buff medium-grained Oakville sandstone, consisting mostly of grains of clear quartz but with numerous grains of black chert and igneous rocks. It contains numerous tubular molds of silt or clay (possibly worm holes) and many pellets of ashy clay. Underlying the Oakville is a brownish-pink lumpy tuff or tuffaceous clay belonging to the Chusa.

In sec. 215, about 6 miles northeast of Freer, dirty-brown fairly coarse Oakville sandstone, in part poorly and in part firmly cemented, overlies the buff to pink compact tuffaceous Chusa clay. The sandstone is composed of well-rounded grains of clear quartz, brown chert, and black igneous rock. Its total thickness is about 10 feet.

In places it is cemented by opaline material (chalcedony) into a rock resembling quartzite. The silicification has taken place along joint cracks, and the sand on both sides of the joint is firmly cemented, though the inside of the block is nearly uncemented. The sand in the vicinity of the intersection of joint cracks is very firmly cemented, and in places tubular bodies of sandstone result from the erosion of the surrounding unsilicified sand. In some beds the silicification seems nearly complete. Such a bed may have a thickness of 2 or 3 feet. This silicification is believed to be the result of the evaporation of silica-bearing meteoric waters ascending by reason of capillary attraction and depositing silica where the evaporation takes place.

Near well 77, in sec. 73, about 5 miles east of Freer, the Oakville crops out as an indurated dirty-buff sandstone.

Thickness and dip.—It was not possible to measure a complete section of the Oakville in Duval County. From the dip of about 50 feet to the mile and the width of outcrop the thickness is estimated to be in the neighborhood of 500 feet. In the De Lange-Frates well, about 1 mile northeast of La Gloria ranch, Cooper [70] assigned to the formation a thickness of more than 400 feet, definitely recognizable beds of the Oakville being encountered at a depth of 240 to 620 feet and its top being probably considerably higher than 240 feet. In the R. A. Thompson well No. 1 A. Parr, about 8 miles south of Benavides, Price [71] assigned the beds between 1,080 and 1,590 feet to the Oakville, and in the Southern Crude Oil Co.'s well No. 1 Dunn (well 257), northwest of Crestonio, Owens [72] assigned the beds between 545 and 954 feet to the Oakville.

Occurrence of ground water.—In Duval County 15 wells were visited that probably draw their water from the Oakville sandstone. With one exception these are ranch wells and yield small quantities of rather highly mineralized water. The Texas Mexican Railway well at Benavides yields about 600 to 900 gallons of water a day, partly from the Oakville, and has a total depth of 582 feet. About three-quarters of a mile northeast of San Cajito, in the southeast corner of sec. 592, is an abandoned well dug into the Oakville. The deep well at Crestonio (no. 269) encountered two sands in the Oakville which yielded small quantities of water. (See log, p. 93.) The water from the first of these rose within 120 feet of the surface and that from the second rose within 75 feet of the surface. These strata, however, were cased off, and the water supply for this well apparently comes entirely from the Catahoula tuff. Cooper [73] reports that two wells were drilled near the De Lange-Frates oil test well, about 1 mile northeast of La Gloria ranch, to a depth of

[70] Cooper, H. H., oral communication.
[71] Price, W. A., letter of Dec. 10, 1932.
[72] Owens, F. C., oral communication.
[73] Cooper, H. H., oral communication.

about 200 feet. These wells draw water from the Oakville formation and yield 200 to 300 barrels a day of water comparatively high in mineral content.

On the whole it does not appear that the Oakville sandstone is likely to furnish a large amount of water. Its outcrop area is comparatively narrow, and the formation is completely overlapped south of Freer. The sandstone contains a considerable amount of silt, which reduces its permeability. The wells drilled as oil tests indicate that in most places clay and shale are the predominant materials in the formation.

Quality of water.—Although only three samples of water from the Oakville were collected for analysis, these three were high in dissolved mineral matter, containing between 1,000 and 1,489 parts per million. (See table, p. 26, wells 27, 74, and 150.) In all of them sodium salts predominated—in one sodium bicarbonate and sodium chloride, in another sodium chloride, and in the third sodium chloride and sodium nitrate. The total hardness ranged from 147 to 495 parts per million.

MIOCENE (?) SERIES

LAGARTO CLAY (RESTRICTED)

Name.—The Lagarto formation was named by Dumble [74] for beds on Lagarto Creek in Live Oak County, which he considered Pliocene. Dumble [75] described the formation and gave sections on Lagarto Creek near Lagarto, at the mouth of Lagarto Creek at Chandlers Bluff, and on Penitas Creek. The section at Lagarto is as follows:

Brown calcareous sandrock.
Adobe.
Adobe conglomerate.
Clay, with pebbles.
Brown sandstone.
Calcareous conglomerate in calcareous clay, passing downward into mottled greenish-gray and reddish-brown clay in which strings of limestone from the overlying calcareous beds run down 6 to 8 feet. Much of this material contains quantities of semicrystalline limestone, with manganese dendrites. The manganese occurs in the clays as well and appears to be characteristic of the beds both here and elsewhere.

The lowest clay bed extends for a considerable distance both up and down the creek, and a similar clay bed overlies the Lapara sand along Ramirena Creek, on the road between Dinero and Lagarto. Dumble considers it possible that these sand and clay beds are the upper part of the Lapara sand, which he described and named for beds cropping out on Lapara Creek. He described similar beds on Hog Hollow. There is reason to believe that he included in the Lapara some beds that preferably belong in the Lagarto and others

[74] Dumble, E. T., The Cenozoic deposits of Texas: Jour. Geology, vol. 2, p. 560, 1894.

[75] Dumble, E. T., Geology of southwestern Texas: Am. Inst. Min. Eng. Trans., vol. 32, pp. 972–976, 1902.

that belong in the Goliad. The Pliocene fossils collected came from beds in the Goliad.

Deussen [76] states that the Lapara sand crops out only in the Nueces River and that if present elsewhere it is overlapped by the Lagarto clay. His map shows a continuous outcrop of Lagarto clay overlying the Oakville as far south as southern Karnes County and a lenticular outcrop of Lagarto overlying the Lapara sand along the Nueces River. He says:

> The Lagarto clay was named * * * from Lagarto Creek, in Live Oak County, where it is typically exposed. In the Nueces Valley the Lagarto clay lies unconformably (?) above the Lapara sand. North of San Antonio River it lies unconformably above the Oakville sandstone.

It has since been demonstrated that the clay formation which Deussen mapped as Lagarto northeast of Karnes County can be traced across Bee and Live Oak Counties to Duval County and that it lies unconformably below the Lapara sand on the Nueces River and is underlain conformably by the Oakville sandstone. This clay has been considered a part of the Lagarto clay of Dumble by so many workers in the field that the name has come into general usage to designate it. For this reason, Plummer [77] recently emended the term to apply to the clay section 500 to 1,000 feet thick between the top of the Oakville sandstone and the base of the Lapara sand member of the Goliad formation. Although the Lagarto as thus defined does not extend as far down the Lagarto Creek Valley as the village of Lagarto, the headwaters of the creek follow the outcrop of the formation for 6 or 8 miles.

Character.—The Lagarto clay is typically a somewhat calcareous or marly yellow, gray, to green joint clay containing in places numerous small calcareous and ferruginous nodules. It is, in general, massive, laminated, and tough, has a soapy feel, and breaks with a conchoidal fracture. In some places it contains thin seams of silty sand and lentils of sand and gravel. The sand is medium-grained to coarse, cross-bedded, brown, gray, reddish gray, and in some places mottled, more or less calcareous, and commonly friable. Fossil bones and wood fragments are reported from the formation but are extremely rare and not sufficiently well preserved to permit positive identification In Duval County the Lagarto ranges in thickness from a knife edge in the north-central part of the county to about 1,000 feet in the southeastern part.

Distribution.—The Lagarto clay lies conformably on the Oakville sandstone and is overlapped unconformably by the Goliad sand. It crops out in the extreme northeastern part of Duval County in t

[76] Deussen, Alexander, Geology of the Coastal Plain of Texas west of Brazos River: U. S. Geol. Survey Prof. Paper 126, p. 100, 1924.

[77] Plummer, F. B., The geology of Texas, vol. 1, Stratigraphy: Texas Univ. Bull. 3232, pp. 740–741, 1932.

bottoms of Palo Creek and Lagarto Creek. Elsewhere in the county it is completely overlapped by the Goliad sand but is encountered in wells in the eastern part of the county immediately below the Goliad. (See log of well 34, p. 85.)

Occurrence of ground water.—So far as known there are only a few wells in Duval County that draw water from the Lagarto clay. The water from these wells is reported to be satisfactory although rather highly mineralized. Wells 30 and 35 probably encounter water in the Lagarto, and the railroad well at Benavides (no. 150) may penetrate the Goliad and obtain part of its water from the Lagarto but more probably water-bearing beds in the Oakville underlie the Goliad at Benavides, and the well obtains part of its water from them.

PLIOCENE SERIES

GOLIAD SAND

Name and correlation.—The Goliad sand as defined in this paper includes most of the beds to which Dumble, Deussen, and Trowbridge applied the term "Reynosa" and most of the beds to which Dumble applied the terms "Lagarto" and "Lapara." In 1890 Penrose [78] described a terrace deposit of caliche containing pebbles, of probable Pleistocene age, at the town of Reynosa, Tamaulipas, Mexico, and named it the "Reynosa limestone." In 1894 Dumble [79] extended the term "Reynosa" to include the series of rocks cropping out on the Reynosa Plateau and all of the caliche deposits of the Gulf coast. He says in this connection:

> The variable series of beds intended to be included in this division has usually at the base a conglomerate of pebbles of various sizes embedded in a lime matrix, often indurated, sometimes tufaceous, sandy, or even clayey. Above this is often but not always a series of interbedded clays, limy clays, limy sands, and sandstones with some pebbles. This closely resembles the Lagarto clays. The whole is capped by the Reynosa limestone. This is a tufaceous limerock, but often so mixed with clay or sand as to lose that character. There are few exposures which show the entire series of beds. In places along the middle Rio Grande, the basal bed of conglomerate is all that is present, while on the divides the basal uppermost beds are usually found, but without the intermediate Lagarto.

In 1902 he considered the formation to be of Pliocene age and stated that his Lagarto formation was possibly identical with his Reynosa.[80] Many later writers have used the term with more or less similar intent. Deussen [81] considered the caliche an integral

[78] Penrose, R. A. F., Jr., A preliminary report on the geology of the Gulf Tertiary of Texas from the Red River to the Rio Grande: Texas Geol. Survey 1st Ann. Rept., p. 63, 1890.

[79] Dumble, E. T., The Cenozoic deposits of Texas: Jour. Geology, vol. 2, pp. 560–563, 1894.

[80] Dumble, E. T., Geology of southwestern Texas: Am. Inst. Min. Eng. Trans., vol. 53, pp. 976–977, 1902.

[81] Deussen, Alexander, Geology of the Coastal Plain of Texas west of Brazos River: U. S. Geol. Survey Prof. Paper 126, p. 102, 1924.

part of the section of sand, clay, and gravel cropping out on the Reynosa Plateau and extending down the dip as a definite bed or series of beds, but he questioned the correlation of these deposits with the "limestone" at Reynosa, Mexico. In 1926 Bailey [82] apparently followed Deussen in the use of the term "†Reynosa" but erroneously included in the formation beds containing Pleistocene fossils at La Cruz Hill, near Rio Grande City, and placed the formation in the Pleistocene. Trowbridge [83] in 1922 and again in 1932 placed the †Reynosa in the Pliocene (?), following Dumble's usage of the term, and extended it to include the high-level gravel deposits west of the Bordas escarpment, dropping the term "Uvalde," which had previously been used for these deposits. He reaffirmed Dumble's correlation of the deposits on the Reynosa Plateau with the caliche deposit at Reynosa, Mexico. In 1932 he pointed out that Bailey had erred in correlating the Pleistocene gravel beds on La Cruz Hill, near Rio Grande City, with the †Reynosa and stated that they should be correlated with the Lissie formation.

As the †Reynosa of Penrose is a Pleistocene terrace deposit and the caliche contained in it is Pleistocene or younger, it cannot be correlated with the Pliocene deposits of the Reynosa Plateau. Dumble's correlation was undoubtedly based largely on the similarity of the caliche at Reynosa, Mexico, to that on the Reynosa Plateau and on the erroneous belief that the caliche represented a limestone deposit lying on top of the Pliocene deposits of the Reynosa Plateau and, in places, interbedded with them. In recent years many geologists have studied the southern Texas area in the search for structural features that may indicate the presence of oil or gas below the surface. Some of these geologists have followed Dumble and applied the term "Reynosa" to the Pliocene beds between the Lissie and the Lagarto; others have maintained that the term "Reynosa" should be restricted to the caliche and that a new name should be applied to the Pliocene beds of Texas; and still others have thought that the term "Reynosa" should be confined to the original usage of Penrose. As a result of this confusion it has been considered advisable to restrict the term "Reynosa" to its original usage and to introduce a new name for the beds between the top of the Lagarto and the base of the Lissie. According to the rules of geologic nomenclature, these beds should be named "Lagarto", as the type locality of the Lagarto of Dumble lies within the outcrop area of the formation, but this term has been so widely used for the thick clay section described on pages 45–47 of this report that its restriction to the beds outcropping

[82] Bailey, T. L., The Gueydan, a new middle Tertiary formation from the southwestern Coastal Plain of Texas: Texas Univ. Bull. 2645, pp. 59–61, 1926.

[83] Trowbridge, A. C., A geologic reconnaissance in the Gulf Coastal Plain of Texas near the Rio Grande: U. S. Geol. Survey Prof. Paper 131, pp. 98–100, 1922; Tertiary and Quaternary geology of the lower Rio Grande region, Texas: U. S. Geol. Survey Bull. 837, pp. 187–188, 1932.

at the type locality would introduce much additional confusion that could be avoided by the use of a new term.

Weeks[84] attempted to solve this difficulty by using the term "Lower Lagarto" for the thick section of clay now called "Lagarto" and the term "Upper Lagarto" for the beds herein called Goliad. However, it seems likely that the Lagarto is Miocene, whereas the Goliad contains Pliocene fossils, and consequently following his suggestion would entail the application of the term "Lagarto" to beds of two different epochs.

The term "Goliad", from the town of that name, was introduced by Howeth and Martyn,[85] who found, as a result of field work in several of the counties of the Coastal Plain, that the beds along the San Antonio River between the top of the Lagarto and the base of the Lissie formed a unit that could be mapped over a large area. On the San Antonio River they divided the Goliad into three subdivisions, as follows:

Upper sandstone bed. Grayish white, medium- to fine-grained, cross-bedded in some places and massive in others; weathers to form rough-surfaced bluish-black ledges.

Middle marl member. A greenish-gray, pink, or reddish calcareous clay containing white calcareous nodules.

Lower sandstone bed. Grayish white, medium- to coarse-grained, in places grading into calcareous cross-bedded conglomerate lentils that change laterally into massive and poorly bedded layers. The cobbles that make up the conglomerate are coarse and hard and consist mostly of chert and quartz pebbles. The sand contains numerous grains of red and brown jasper and also in many places balls of green clay derived from the Lagarto.

Howeth and Martyn placed the base of the Goliad at Lagarto, at the top of the clay section on Lagarto Creek and considered the underlying Lapara sand a part of the Lagarto. Weeks placed the base of his Upper Lagarto at the base of the Lapara sand, and Richardson,[86] who made detailed geologic investigations in the area and mapped the base of the Goliad for a considerable distance, states that the Lapara sand is the lower member of the Goliad and has at its base a major unconformity. He traced it from the Guadalupe River to the Nueces River. At Mount Lucas, on the Nueces River, the Lapara underlies a massive pinkish-brown to reddish clay containing calcareous nodules, which is similar to the clay bed on Lagarto Creek and which Richardson correlates with it. This clay probably should be correlated also with the middle member of Howeth and Martyn's section on the San Antonio River.

[84] Weeks, A. W., Lissie, Reynosa, and Upland Terrace deposits of Coastal Plain of Texas between Brazos River and Rio Grande: Am. Assoc. Petroleum Geologists Bull., vol. 17, no. 5, pp. 457–460, May 1933.

[85] Howeth, I. K., and Martyn, P. F., Goliad sandstone formation of southwest Texas, paper presented at annual meeting of San Antonio Geological Society at Corpus Christi, Tex., February 1932.

[86] Richardson, H. T., paper presented at Laredo meeting of San Antonio Geological Society, October 1932.

As a result of the recent field work in the area, the term "Goliad" has been adopted by the San Antonio and Houston geological societies, by the Texas Bureau of Economic Geology,[87] and by the United States Geological Survey for the stratigraphic unit of Pliocene age between the top of the Lagarto (restricted) and the base of the Lissie formation. The term "Reynosa" is restricted to the caliche terrace deposit at the type locality in Mexico, although Weeks [88] applies the term to all the caliche deposits of southern Texas.

Fossils.—Weeks [89] reports that H. T. Richardson collected vertebrate fossils from the Lapara on Medio Creek 6½ miles northeast of Beeville. These were sent to C. W. Gilmore, of the United States National Museum, who identified them as a jawbone and a tooth of *Teleoceros fossiger*, of Pliocene age. Richardson also collected fragmentary vertebrate fossils from a tributary of Medio Creek about 2 miles southeast of Normanna, Bee County, which were sent to C. L. Camp, of the Museum of Paleontology, University of California, who reported the following species, of lower to early middle Pliocene age.

Hipparion cf. H. venustum.
Pliohippus cf. P. interpolatus.
Aphalops sp.
Camel, gen. and sp. undet.

Character and distribution.—North of Duval County the Goliad consists essentially of a lower sandy to conglomeratic calcareous zone, generally gray, about 40 feet thick; a middle brownish-green to red sandy clay of uncertain thickness containing many fairly large calcareous nodules; and an upper gray calcareous sand or sandstone and conglomerate interbedded with layers of clay and weathering to a sandy soil. The surface of the Goliad is generally characterized by the presence of caliche. The sandstone beds are calcareous, with more or less clay, rather massive, and light gray to buff. (See pl. 4, *B*.) In Duval County the exposures are for the most part insufficient to differentiate the formation into three divisions, but through the center of the Goliad outcrop area there appears to be a more or less clayey phase, which is believed to correspond to the middle clay of the section north of Duval County. In general the Goliad is rather well cemented by calcium carbonate, stands up well in sharp escarpments, and forms several boxlike hills in Duval County. A rather prominent escarpment is seen on the west side of the Tilden-San Diego road near the northern boundary of the county. The Goliad caps the hills and forms the escarpment south of Freer and along Parilla Creek in the west-central part of the county. San Cajito Hill and a similar hill about 4 miles north of Bess and near the northern boundary of the county along the San Diego-George West

[87] Plummer, F. B., The geology of Texas, vol. 1, Stratigraphy: Texas Univ. Bull. 3232, pp. 750–752, 1932.
[88] Weeks, A. W., op. cit., p. 467.
[89] Idem, pp. 459, 460.

road are examples of boxlike hills held up by the resistant beds of the Goliad. Numerous outliers of the formation form flat-topped mesas, such as Atravesada Hill and Dos Hermanitas Hills.

The soil of the Goliad outcrop area is in most places red and sandy, but in the central part of the area it is sandy clay, and in the extreme western part of the county the hills are capped by coarse gravel.

The gravel hills are covered by a dense growth of guajillo, catclaw, and black chaparral, with smaller amounts of cactus. Throughout the rest of the county the soil supports a dense to open growth of rather brushy mesquite and various kinds of grasses. Nearly everywhere on the Goliad outcrop caliche is present either at the surface or under a comparatively thin mantle of soil. This caliche is usually hard white calcium carbonate, containing impurities of sand and clay and having an undulating surface. Especially common in the outcrop area covered by caliche is a low shrub with a gray velvety leaf and in spring beautiful purple flowers, which the Mexicans call "cenizo."

In southern Live Oak and McMullen Counties the Goliad overlaps the Lagarto clay (restricted) and the upper part of the Oakville sandstone. In west-central Duval County it overlaps the lower part of the Oakville and the upper part of the Catahoula tuff. Its average dip along the western part of its outcrop area is about 25 feet to the mile, and as the surface slope is about 15 feet to the mile the increase in thickness of the Goliad toward the east is very gradual. In the northeastern part of Duval County its maximum thickness is 100 to 150 feet, and in the southeastern part it is at least 400 feet and may be as much as 600 feet. Only one well (no. 314) has been drilled through the Goliad in this area, and as samples were not obtained the exact thickness of the formation is not known.

Because of the very gradual rate at which the thickness of the Goliad increases eastward the larger streams of the area have cut deep reentrants into the western margin of the formation, and many outliers are seen south of Freer. In the northern part of the county the width of the outcrop is more than 13 miles, and in the southern part the Goliad is at the surface over the whole area except for a narrow strip of Lissie sand at the southeast corner.

Several sections of the Goliad have been measured in Duval County.

Section in Palo Creek at bridge on San Diego-George West road 17 miles north of San Diego

	Ft.	*in.*
Goliad sand:		
Light-gray cross-bedded sand and gravel; sand fine to coarse, composed principally of grains of quartz, with subordinate amounts of black chert and pebbles of white sandy caliche as much as 1½ inches in diameter	10	
Coarse, friable buff to gray sandstone containing large buff to green clay balls, maximum diameter ½ inch; sand grains mostly well rounded, consisting of clear quartz and black and brown chert	1	3

Section in Palo Creek at bridge on San Diego-George West road 17 miles north of San Diego—Continued

	Ft.	in.
Goliad sand—Continued.		
Same as bed next above but finer-grained and cross-bedded	1	
Buff to green clay; varies greatly in thickness		6
Cross-bedded grayish-brown sandstone containing numerous grains of black chert, biotite mica, and feldspar, also numerous rounded caliche fragments and some clay balls; most of the sand grains are clear quartz	1	6
Grayish coarse-grained sandstone similar to that next above	3	
Covered	5	
Lagarto clay (restricted): Dark grayish-red joint clay	12	
	24	3

The beds included in the section above are shown in plate 5. These beds are believed to be lowermost Goliad except the clay at the bottom, which has been traced down the creek for over a mile and is believed to be the uppermost part of the Lagarto clay.

Another section of the Goliad is seen on the boxlike hill on the east side of the San Diego-George West road south of the south fence of the Clegg ranch. The hill is capped by a hard, massive, rather fine grained sandstone in which the grains appear to be set in a white matrix of calcium carbonate and clay. The grains are predominantly clear quartz, but there are also grains of honey-colored to black chert. This sandstone is 2 to 3 feet thick; below it is 10 to 15 feet of reddish-brown sandy clay; and below that is exposed 4 or 5 feet of another bed of sandstone similar to the first but rather well bedded.

A specimen of Goliad sandstone taken from well 37 at a depth of 90 feet is light-buff, rather hard, massive silty sandstone consisting of clear quartz grains and minor amounts of black to amber chert cemented by calcium carbonate, which composed 19.3 percent of the sample. Mechanical analysis of the sand showed the following constituents:

	Percent
Sand:	
Larger than 1 millimeter	0. 3
1 to 0.50 millimeter	. 6
0.50 to 0.25 millimeter	5. 5
0.25 to 0.125 millimeter	32. 7
0.125 to 0.062 millimeter	17. 0
Silt: 0.062 to 0.005 millimeter	36. 1
Clay: Less than 0.005 millimeter	6. 3
	96. 25

A section in the westward-facing escarpment on the west side of the Tilden-San Diego road in sec. 117, near the northern boundary of the county, is as follows:

Section of Goliad sand in sec. 117

	Feet
White sandy caliche grading downward into white clayey, calcareous fine-grained sandstone with manganese stains along the joints	3–4
Red clay containing scattered sand grains and seams of gray clay; breaks with conchoidal fracture; manganese stains common	5
Red clayey calcareous sandstone, covered	10
	18+

San Cajito Hill is a small boxlike hill in the northern part of sec. 358. The following section was observed on it:

Section of Goliad sand on San Cajito Hill

	Feet
White caliche grading downward into fine-grained white calcareous, clayey sandstone made up principally of clear quartz grains with minor amounts of black chert; becomes coarser and light pink toward the base; dendritic manganese stains are common throughout	11
Gray to reddish-gray clayey, calcareous sandstone or sandy clay	10±
Covered.	21±

On Agua Poquita Creek at the steel bridge on the Benavides-Concepcion road several feet of caliche-cemented gravel (probably Pleistocene) overlies typical white calcareous, clayey Goliad sandstone.

On the low bluff a quarter of a mile southeast of the Sutherland ranch house a massive cross-bedded conglomerate about 10 feet thick (see pl. 6, *B*), composed of pebbles of chert and chalcedony firmly cemented by chalcedony, overlies white to pink tuffaceous clay of Catahoula age. F. C. Owens considers the conglomerate capping the bluff to be Oakville sandstone. A few feet above the conglomerate is coarse gravel of unquestioned Goliad age.

On Las Parillas Hills, in sec. 37, a chalcedony knob in the Goliad rises about 5 feet above the top of the rise of the hill. A section at this place shows the very irregular Goliad-Catahoula contact.

Section on Las Parillas Hills

	Feet
Goliad sand:	
Chalcedony, largely replacing a sandy clay	5
Clean indurated sandstone; becomes more argillaceous toward the base; at the base contains large fragments of chert and chalcedony and rounded pellets of tuff	35
Catahoula tuff: Greenish to pink tuff and tuffaceous clay	15
	55

East of this locality and just west of the Southern Natural Gas Co.'s pipe line is a northward-facing escarpment 20 feet high capped by caliche underlain by dark reddish-brown clay that contains a few grains of quartz, feldspar, and chert. The beds at this place are evidently stratigraphically equivalent to those of the chalcedony-capped knob in the preceding section.

South of the ranch road in sec. 37 is a conglomerate resting on tuff. This conglomerate contains pebbles as much as 3 inches in diameter, of which about 90 percent are chert coated with black manganese and possibly 10 percent are igneous rock. It has a thickness of about 20 feet and is in places firmly cemented by siliceous material.

South of Las Parillas Hills the Goliad outcrop is characterized by heavy gravel deposits more or less firmly cemented by caliche, and the surface is covered by a dense vegetation of guajillo, catclaw, black chaparral, and tasajillo cactus.

A contact between the Goliad and the Catahoula is seen on the north side of the small hill about half a mile east of Atravesada Hill (see pl. 6, *A*), where 2½ to 10 feet of light-buff to gray soft clayey sandstone grades downward at the base into 6 or 8 inches of conglomerate composed of sand and pebbles of tuff and chert, the largest of which are half an inch in diameter. The contact is very uneven, and below it lies soft white tuffaceous clay with brown tuffaceous clay nodules an eighth to a quarter of an inch in diameter.

Section in Finskey's quarry, half a mile northeast of Realitos

	Ft.	in.
Red sandy soil grading downward into flint gravel	3	10
Soft, porous white caliche with impurities of fine sand and clay	2	
Hard white-banded caliche, surface very uneven, containing many "potholes"		6
Hard, dense white sandy, calcareous clay	10	

The clay at the bottom has been considered by some geologists to be Lagarto clay. Lithologically it closely resembles Goliad clay. It is replaced near the south end of the quarry by gravel that is definitely Goliad gravel, and in wells nearby the basal Goliad gravel is encountered at about 140 feet. For these reasons the writer considers the clay to be of Goliad age.

Occurrence of ground water.—Supplies of water sufficient for stock and domestic use are obtained from the Goliad over most of its outcrop area, and in several places rather large supplies have been developed. At San Diego water-bearing beds have been encountered at three horizons. The first water-bearing bed is gravel at 40 to 42 feet, which yields rather salty water, according to Ramón Albarado, a local driller. At 100 feet in "sand or clay" a second bed is encountered, which also yields rather salty water. At 235 to 250 feet "good' water is obtained from a sandstone 20 to 30 feet thick. This water rises within 125 feet of the surface. The entire thickness of the formation has not been penetrated, and deeper water-bearing beds may exist.

At the Rosita ranch good water is encountered in sand at a depth of 50 feet.

At Benavides, according to F. Vaello, Jr., the first water is encountered at 45 to 60 feet; this water is rather highly mineralized. A second water-bearing bed is encountered at 90 to 110 feet, and the water rises to about 45 feet below the surface; this water is somewhat better in quality than the shallower water. A third bed at 215 to 275 feet yields the best water in the area; this water comes from a sandstone and rises within 60 to 70 feet of the surface. D. F. Rednor says that a fourth water-bearing bed occurs at 350 to 400 feet and yields water of excellent quality; this bed is apparently the same as is encountered in the water wells of the Texas Duval Sulphur Co., several of which yield from 100 to 150 gallons a minute.

At Realitos John Breiden reports salty water in small quantities in sand at about 50 feet. At 140 to 150 feet, however, sandstone and gravel yield good water sufficient for stock and domestic supplies, but no test has been made to determine the maximum quantity which beds at this horizon will yield.

At Sejita the first water is encountered in sand 3 or 4 feet thick at 35 to 40 feet, and the water is reported to be bitter. The second sand is encountered at about 100 feet and yields water of somewhat better quality. At 230 or 240 feet water of good quality is reported from sand. Well 291 was pumped at a rate of 50 gallons a minute for several hours.

In the southeast corner of the county are several wells that yield excellent water. In well 320 the first water was encountered at 80 feet and was cased off because it was salty; the second water was encountered at 180 feet, and the third at 302 to 341 feet. The two lower beds yield water of good quality, and the water level was 40 to 50 feet below the surface. This well was pumped for 2 days, yielding a stream of water that "completely filled a 2-inch pipe" (about 25 gallons a minute), with a resulting draw-down of 6 feet.

Quality of water.—Two-quart samples of water from 22 wells in the Goliad sand were analyzed, and the results are tabulated on pages 26–27. The waters analyzed differ widely in concentration of dissolved mineral matter, which ranges from 247 to 3,230 parts per million. This difference in total dissolved mineral matter depends almost entirely upon the content of sodium chloride or calcium chloride or of both. The bicarbonate content is nearly constant, ranging from 223 to 359 parts per million. In the waters of low mineral content—that is, below 800 parts per million—the calcium is not sufficient to combine with all of the bicarbonate, and consequently a part of the sodium combines with the remaining bicarbonate to form sodium bicarbonate, so that some of these waters contain black alkali. In the waters of high mineral content the calcium is sufficient to combine with all of the bicarbonate, the sulphate, and some of the chloride. In fact, well 31 contains water that is predominantly calcium chloride water. The sodium bicarbonate in the waters of low mineral content may be harmful to soils unless used with care on land with adequate drainage, and the sodium chloride in the waters of higher mineral content is likely to be injurious to crops.

In addition to the 2-quart samples collected for analysis in the laboratory, 6-ounce samples of water were collected from over 150 wells and analyzed in the field for chlorides, hardness, and sulphates. The chloride, sulphate, and hardness of all the samples analyzed, both in the field and in the laboratory, are shown in the table on pages 58–60. The wells are arranged in four groups—less than 100 feet deep, 100 to 200 feet deep, 200 to 400 feet deep, and more than 400 feet deep. In each group they are listed in order of increasing amount of chloride. The table shows that most of the waters are moderately mineralized and some are highly mineralized Only 8 samples contain less than 100 parts per million of chloride, 15 contain between 100 and 200 parts per million, and 10 contain between 200 and 250 parts per million. The average chloride content in the wells less than 200 feet deep is greater than the average in the wells over 200 feet deep: In the 48 wells less than 100 feet deep it is 655 parts per million, in the 51 wells between 100 and 200 feet deep it is 652 parts per million, and in the 54 wells between 200 and 490 feet deep it is 575 parts per million. Likewise, the proportion of wells yielding water of moderately low chloride content is greater in the wells less than 200 feet deep than in the wells between 200 and 400 feet deep.

The wells over 400 feet deep probably do not truly represent the character of the water in the sands of that depth. The drillers and well owners assert that the "first water" is commonly highly mineralized, whereas the water from the deeper beds is in most places likely to be "sweet water." The analyses appear to substantiate these statements.

Local structural conditions that prevent ready circulation of ground water may explain the high chloride content of some of the waters from the deeper beds. It is suspected, however, that the water from several of the deeper wells from which samples were taken for analysis is not representative because it is contaminated by water from shallow depths as a result of defective or leaky casings. Most of the deeper wells yield good water when first drilled, but several of them, such as wells 50, 308, 313, and 316, are reported to have suddenly "gone bad." It is believed that the sudden change in the character of the water was due to the corrosion of the casing by highly mineralized water at shallow depth, which allowed the water from the shallow depth to enter the well and contaminate the deeper water. In fact, the great diversity in the character of the water from the deeper wells suggests that a large number of these wells are contaminated by more or less highly mineralized water from shallow strata, although the contamination may have been slight at first and increased almost imperceptibly. In some wells, such as well 311, caving or the gradual filling of the well with sand may have completely shut off the deeper water, so that the well is now drawing entirely from the shallower beds. In some wells that have been constructed recently the seal between two strings of casing may be imperfect and the opening may admit highly mineralized shallow water into the well. Undoubtedly the proportion of wells over 200 feet deep showing high chloride content would be considerably lower if the samples from contaminated wells were eliminated.

A part of the explanation of the common occurrence of less mineralized water in the deeper water-bearing sands than in the shallower sands appears to lie in the fact that the deeper sands are more extensive. They are coarser and therefore have higher permeability and the water moves down dip through them rather readily, supplying the artesian wells to the east, whereas the shallower beds may be more or less lenticular, and the water in them does not circulate readily and has therefore dissolved a large amount of mineral matter. The presence of caliche over most of the outcrop area of the Goliad also appears to affect the quality of the water. By reducing the permeability of the surface soil and the formations immediately underlying the soil, it prevents the ready access of water from the surface to the water-bearing beds. Consequently the water in the shallower beds tends to be not only small in quantity but rather highly mineralized, because of the slow rate at which the formation receives fresh water. In certain places, however, where the formation is especially permeable and caliche is either absent or not abundant enough to form an impermeable barrier to the passage of water, a considerable amount of water finds its way from the surface into the formation, and wells in such areas (wells 37 and 72) yield water of low mineral content. These areas where caliche is absent are apparently much localized and may exist only where streams have cut through the caliche, where the caliche is absent as in the numerous "sinks", or where conditions for the formation of caliche have not been favorable. It is in these areas that the greatest proportion of the recharge to the water-bearing beds occurs.

Chloride, hardness, and sulphate in water from wells in Duval County

Wells less than 100 feet deep

Well no.	Depth (feet)	Year completed	Chloride (parts per million)	Hardness (parts per million)	Sulphate (parts per million)
272	100	(?)	22	278	10
184	90	(?)	23	474	22
286	20	(?)	24	393	----------
142	60	(?)	34	397	----------
37	90	1860	43	188	8
175	48	(?)	105	228	71
72	50	1931	114	159	32
73	40	(?)	130	357	44
288	30	(?)	225	420	----------
160	100	Old	250	375	----------
138	40	(?)	259	225	----------
190	90	(?)	305	465	131
194	95	(?)	338	867	----------
271	90	(?)	350	650	49
231	100	1916	360	321	50
219	100	(?)	368	483	----------
145	48	(?)	490	675	93
144	48	(?)	505	698	216
55	80	(?)	510	810	98
143	40	(?)	530	700	90
136	60	(?)	532	705	----------
153	96	1905?	540	546	250
173	80	(?)	560	1,290	95
258	81	1920	585	829	60
147	95	1925	590	480	60
152	90	1928	590	700	50
42	40	1932	625	700	200
230	----------	(?)	650	668	161
183	80	(?)	676	690	177
187	70	Old	715	825	105
290	100	(?)	720	795	153
189	100	1922	724	592	137
207	81	1910	795	798	25
135	60	(?)	810	772	----------
212	100	(?)	837	1,252	----------
302	80	(?)	910	870	499
185	90	Old	1,065	945	144
324	65	(?)	1,080	1,144	60
283	60	(?)	1,120	937	----------
211	93	1927	1,140	1,230	120
137	45	(?)	1,205	1,852	----------
304	90	Old	1,245	1,079	600
322	50	1910	1,260	1,110	500
321	90	1910	1,333	780	312
179	60	(?)	1,410	1,280	317
41	53	1932	1,440	1,300	350
31	70	(?)	[1] 1,564	2,165	405
289	80	(?)	1,735	1,095	286

[1] Probably draws water from the Lagarto.

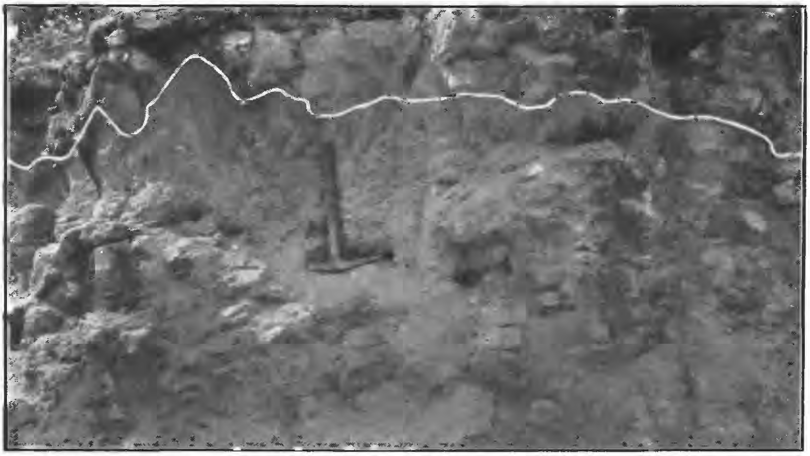
Wells 100 to 200 feet deep

Well no.	Depth (feet)	Year completed	Chloride (parts per million)	Hardness (parts per million)	Sulphate (parts per million)
209	156	1931	9	166	12
61	100+	(?)	10	282	21
53	150±	1932	39	240	15
163	110	(?)	105	606	----------
54	129	1932	105	240	15
38	120	(?)	107	166	56
220	120	(?)	168	183	84
232	150	1918	200	315	60
276	102	1914	240	352	84
172	130	(?)	246	615	----------
71	110	Old	270	420	61
165	185	1903	276	375	----------
273	120	1921	288	315	----------
251	180	1928	352	756	----------
245	150	1932	355	577	30
236	150±	1929	406	540	----------
188	130	1932	410	728	51
241	146	(?)	444	615	134
240	154	(?)	480	633	90
238	150±	1932	532	636	----------
246	157	1932	538	859	50
248	170	1916	567	1,002	----------
162	180	(?)	563	693	----------
158	132	(?)	585	810	75
266	196	(?)	600	630	----------

GOLIAD SAND EXPOSED IN PALO CREEK.

A. Shows the irregular character of the beds.

B. Near view of another part of the exposure of Goliad sand in Palo Creek, showing an irregular clay bed between two beds of sand. Note the numerous white concretionary masses of calcium carbonate.



A. GOLIAD-CATAHOULA CONTACT ON THE HILL HALF A MILE EAST OF ATRAVESADA HILL.

B. LEDGE OF GOLIAD CONGLOMERATE OVERLYING CHUSA TUFF A QUARTER OF A MILE SOUTHEAST OF SUTHERLAND RANCH HOUSE.

Chloride, hardness, and sulphate in water from wells in Duval County—Continued

Wells 100 to 200 feet deep—Continued

Well no.	Depth (feet)	Year completed	Chloride (parts per million)	Hardness (parts per million)	Sulphate (parts per million)
154	110	1929	600	650	120
191	107	1928	605	564	175
249	180	(?)	607	1,225	
59	150	(?)	670	975	71
281	117	1914	691	690	154
49	140	1916	700	700	100
247	190	1924	700	1,252	
161	176	1922	720	682	
214	140	(?)	742	1,132	
170	160	(?)	742	1,335	
196	115	1925	807	758	112
70	110	1926	825	1,275	202
256	117	(?)	864	1,387	
206	101	(?)	910	1,002	80
157	140	(?)	920	1,230	143
213	180	(?)	945	1,567	
292	(?)	(?)	960	1,012	277
201	125	1916	965	945	175
69	140	(?)	1,000	1,080	103
68	190	(?)	1,050	1,200	287
228	189	1915	1,095	924	240
217	180	(?)	1,390	1,612	
195	200	(?)	1,417	1,530	
287	170	(?)	1,545	1,005	330
296	108	(?)	1,815	1,650	140
171	150	(?)	1,971	2,100	

Wells 200 to 400 feet deep

Well no.	Depth (feet)	Year completed	Chloride (parts per million)	Hardness (parts per million)	Sulphate (parts per million)
43	240	1927	115	162	61
146	207	1928	144	168	45
168	240	1921	145	156	32
151	247	1928	172	160	40
40	240	1920	176	320	25
155	252	(?)	178	142	38
149	257	1927	186	152	40
325	295	1915	223	202	
320	341	(?)	227	244	89
255	350	(?)	227	438	
204	310	1927	229	240	103
178	230	(?)	244	342	40
307	300	(?)	240	321	
244	(?)	(?)	250	645	
45	245	1921	255	300	70
203	200+	(?)	262	267	100
229	200	(?)	266	297	70
306	283	(?)	269	330	
319	340	Old	272	309	80
312	304	Old	279	297	60
253	230	(?)	290	165	
202	327	(?)	300	318	60
254	251	1927	311	624	
318	260	Old	328	372	50
315	280	Old	338	427	80
250	200	1918	348	556	50
310	360±	(?)	360	315	40
47	263	1931	388	380	60
298	(?)	(?)	405	507	
305	300	(?)	444	543	
317	400±	(?)	472	600	160
216	200+	Old	480	681	
275	(?)	(?)	490	712	
48	300+	1916	500	380	70
235	(?)	(?)	502	885	
52	240	1910	515	427	75
301	280	1917	560	291	54
159	(?)	(?)	567	675	
156	225	1925?	615	600	120
274	(?)	(?)	616	690	
284	(?)	(?)	728	607	
46	305	1907	750	580	130
293	(?)	(?)	854	937	
234	208	(?)	882	1,080	100
285	(?)	(?)	952	1,020	
50	260	1900?	1,075	1,000	100
177	200	(?)	1,104	2,052	800

Chloride, hardness, and sulphate in water from wells in Duval County—Continued

Wells 200 to 400 feet deep—Continued

Well no.	Depth (feet)	Year completed	Chloride (parts per million)	Hardness (parts per million)	Sulphate (parts per million)
167	200	(?)	1,215	1,500	
313	300	1912	1,390	1,177	
308	283	1916	1,484	1,263	120
51	250	1900?	1,672	680	181
316	295	(?)	1,680	1,575	100
166	200	(?)	1,755	1,980	
297	200±	(?)	2,340	3,000	100
Wells more than 400 feet deep					
140	443	(?)	135	148	62
150	583	Old	695	[1] 927	120
311	600±	1905	720	[1] 885	350
323	623	1910	984	[1] 1,060	70

[1] Probably contaminated by shallow highly mineralized water that enters well through leaky casing.

Water levels in relation to recharge and chloride content.—An attempt was made to determine the character of the recharge of ground water in the Goliad by selecting widely spaced wells of different depths for periodic observation of the depth to water. It was believed that in areas where considerable recharge is taking place in the formation the water level of the wells would show wide fluctuation, whereas in areas in which recharge is small the water level would show little or no fluctuation. At the same time the water from wells in areas where recharge is great should be of much better quality than that in areas where recharge is small. Consequently, samples of water from the observation wells were collected for analysis. The following table gives the results of these observations on fluctuations of water level, the depth of the well, and the chloride content of the water in 1932–33, 1934, and 1936:

Fluctuations of water level in wells in Duval County

[Depth to water, in feet]

	55	59	61	68	69	70	71	72	73
Apr. 2, 1931								38.6	
June 8, 1931	75.0								
June 9, 1931		65.0				57.0	46.0		
Aug. 22, 1933	55.6	62.6		65.1		50.2	42.8	39.4	
Sept. 8–11, 1933	53.3	62.5		63.5		49.0	40.6	39.2	
Sept. 20–29, 1933	50.4	62.2	47.5	64.4	77.3	48.4	38.9	39.0	38.0
Oct. 10–19, 1933	49.7	61.8	46.1	63.8	77.7	48.3	40.8	38.8	38.1
Oct. 25 to Nov. 1, 1933	47.8		45.6	62.3	77.3	48.2	39.6	38.8	38.0
Nov. 11–22, 1933	48.5	61.7	45.0	62.3			40.5	38.6	37.4
Feb. 5–17, 1934	51.7		45.5	61.4	76.3	50.0	40.4	38.7	37.7
Dec. 5–17, 1934	59.2	64.6	52.6	64.0	77.4	54.2	43.0	39.8	39.2
Apr. 12–16, 1935	50.1	65.1	56.3	64.1	77.3		47.6	40.1	38.9
Jan. 31 to Feb. 2, 1936	41.4	58.2	32.5	57.3	65.7	46.9	43.3	38.6	37.5
Feb. 15–18, 1936	41.7	58.6		57.3	65.9	47.0	43.2	38.5	37.8
Maximum change in water level	+33.6	+6.9	+23.8	+8.8	+12.0	+10.1	+8.7	+1.6	+1.6
Depth of well ....feet	80	150	100	190	140	110	110	50	40
Chloride content (parts per million):									
1932–33								114	
1934	350	670	10	1,050	1,000	825	270		130
1936	460	660		1,140	690	820	338	125	114

Fluctuations of water level in wells in Duval County—Continued

[Depth to water, in feet]

	143	144	145	157	158	173	175	179	183
May 15, 1931	--	--	--	--	--	--	--	--	58.0
Aug. 22, 1933	--	--	--	--	--	--	--	--	56.6
Sept. 8–11, 1933	--	--	--	--	--	--	--	--	56.6
Sept. 20–29, 1933	42.7	46.0	46.3	93.8	96.9	47.8	51.4	49.1	56.4
Oct. 10–19, 1933	42.6	45.6	45.8	93.5	96.8	46.9	51.4	49.6	56.4
Oct. 25 to Nov. 1, 1933	42.9	45.5	45.4	--	96.9	46.8	49.1	48.9	56.3
Nov. 11–22, 1933	42.7	45.3	--	93.4	96.8	46.9	49.4	49.6	56.3
Feb. 5–17, 1934	42.0	45.1	45.9	93.7	97.9	48.2	49.4	--	56.3
Dec. 5–17, 1934	42.4	45.9	46.7	94.0	97.9	50.3	52.0	51.3	--
Apr. 12–16, 1935	42.6	46.2	46.9	94.1	97.9	51.1	53.2	51.5	--
Jan. 31 to Feb. 2, 1936	41.5	44.7	44.2	92.5	97.5	47.5	43.9	51.4	53.7
Feb. 15–18, 1936	41.6	--	44.4	92.6	97.5	47.6	44.1	51.4	53.8
Maximum change in water level	+1.4	+1.5	+2.7	+1.6	−1.1	+4.3	+9.1	−2.6	+4.3
Depth of well feet	40	48	48	140	132	80	--	60	80
Chloride content (parts per million):									
1932–33	530	--	--	--	--	--	--	--	676
1934	--	505	490	920	585	560	105	1,410	--
1936	522	865	600	920	585	580	152	1,745	630

	184	185	187	188	189	190	191	201	203
May 15, 1931	--	--	--	--	64.5	--	--	--	--
May 25, 1931	--	42.5	42.0	--	--	--	--	--	--
May 26, 1931	--	--	--	--	--	--	--	78.8	--
Jan. 7, 1933	--	--	--	--	--	--	--	--	49.0
Feb. 22, 1933	--	--	--	--	--	--	--	--	48.8
May 31, 1933	--	--	--	--	--	--	--	--	49.2
June 26, 1933	--	--	--	--	--	--	--	--	49.7
July 24, 1933	--	--	--	--	--	--	--	--	49.4
Aug. 10, 1933	--	--	--	--	--	--	--	--	49.1
Aug. 22, 1933	--	37.0	51.2	--	63.3	--	--	78.3	49.0
Sept. 8–11, 1933	--	36.4	--	--	63.4	--	--	78.2	48.6
Sept. 20–29, 1933	45.4	36.3	--	76.1	63.2	40.0	31.7	78.2	48.5
Oct. 10–19, 1933	45.8	36.1	--	76.2	63.2	40.8	33.6	78.3	--
Oct. 25 to Nov. 1, 1933	45.9	36.1	--	76.1	63.2	41.1	34.1	78.1	--
Nov. 11–22, 1933	45.9	36.2	--	76.1	--	41.8	--	78.1	--
Feb. 5–17, 1934	47.4	36.0	--	76.0	--	--	--	78.1	48.2
Dec. 5–17, 1934	48.4	36.2	43.9	75.9	62.8	45.3	--	--	49.5
Apr. 12–16, 1935	47.9	36.5	43.8	76.2	62.8	45.9	--	77.6	49.4
Jan. 31 to Feb. 2, 1936	41.9	--	--	75.8	62.4	44.1	--	76.2	48.4
Feb. 15–18, 1936	42.4	35.8	--	76.0	62.5	44.2	--	--	--
Maximum change in water level	+6.5	+6.7	−9.2	+.4	+2.1	−4.8	+1.3	+2.6	+1.3
Depth of well feet	90	90	70	130	100	90	107	125	200
Chloride content (parts per million):									
1932–33	--	--	--	--	724	--	--	--	262
1934	23	1,065	715	410	--	305	--	965	--
1936	132	1,060	--	410	750	147	605	--	--

	204	207	209	211	230	240	271	272	276	281
May 26, 1931	60.9	--	--	--	--	--	--	--	--	--
May 27, 1931	--	73.4	--	--	--	--	--	--	--	--
May 29, 1931	--	--	45.3	50.0	--	--	--	--	--	--
June 3, 1931	--	--	--	--	--	--	--	--	37.6	38.0
Dec. 9, 1932	63.6	--	--	--	--	--	--	--	--	--
Jan. 7, 1933	--	61.4	47.0	--	--	93.9	--	--	--	--
Feb. 22, 1933	--	61.8	46.6	--	--	94.5	--	--	--	--
May 31, 1933	--	62.0	46.5	--	--	94.2	--	--	--	--
June 26, 1933	--	63.2	43.2	--	--	94.3	--	--	--	--
July 24, 1933	--	63.9	45.9	--	--	94.3	--	--	--	--
Aug. 10, 1933	--	62.2	41.1	--	--	94.0	--	--	--	--
Aug. 22, 1933	61.3	62.1	36.0	47.3	--	94.2	--	--	38.4	36.0
Sept. 8–11, 1933	60.7	61.4	31.1	46.6	--	94.2	--	--	37.7	--
Sept. 20–29, 1933	60.7	60.5	30.1	45.3	60.0	94.0	76.4	84.1	36.1	35.0
Oct. 10–19, 1933	--	59.6	31.2	45.6	59.7	93.8	76.3	84.7	34.8	34.6
Oct. 25 to Nov. 1, 1933	--	59.3	32.3	45.1	59.7	93.7	--	84.3	34.2	34.1
Nov. 11–22, 1933	--	59.0	33.4	45.6	61.0	--	76.4	84.5	34.0	33.8
Feb. 5–17, 1934	60.3	58.5	39.3	45.0	61.7	--	--	84.9	32.9	32.1
Dec. 5–17, 1934	61.8	60.0	45.3	46.1	61.1	94.6	76.0	85.0	34.5	32.3
Apr. 12–16, 1935	61.6	60.3	44.9	46.4	61.8	94.6	76.0	84.9	35.5	33.1

Fluctuations of water level in wells in Duval County—Continued

[Depth to water, in feet]

	204	207	209	211	230	240	271	272	276	281
Jan. 31 to Feb. 2, 1936	60.6	54.2	30.7	41.4	59.6	94.2	75.9	85.0	35.4	
Feb. 15–18, 1936		54.2	31.2	41.6			76.5	85.1		
Maximum change in water level	+3.5	+19.2	+16.9	+8.6	+2.2	−.7	+.5	−1.0	+5.5	+5.9
Depth of well feet	310	81	156	93	60	154	90	100	102	117
Chloride content (parts per million):										
1932–33	229	795	9	1,140		480				691
1934			9		650		510	14	240	
1936		2,325	11	975			430	22	765	

	287	289	290	292	297	301	302
May 29, 1931				30.5	61.5	50.6	
May 30, 1931	50.3		54.0				
Mar. 30, 1933						50.0	
Aug. 22, 1933	50.7	47.7	54.2	31.0	54.0	51.0	
Sept. 8 to 11, 1933	50.6	47.6	54.2	30.6		50.6	
Sept. 20 to 29, 1933	50.3	47.6	54.1	29.8	53.8	50.8	32.5
Oct. 10 to 19, 1933	49.8	47.5	54.1	29.4			32.8
Oct. 25 to Nov. 1, 1933	49.4	47.4	53.9	29.1			32.9
Nov. 11 to 22, 1933	49.3	47.3	53.9	29.0	53.6		32.8
Feb. 5 to 17, 1934	49.1	47.0	53.6	28.3		50.1	33.1
Dec. 5 to 17, 1934	48.5	47.6	53.1	28.5	52.8	50.2	35.2
Apr. 12 to 16, 1935	49.4	47.1	53.2	29.4	53.9	50.2	35.5
Jan. 31 to Feb. 2, 1936	47.6	46.5		29.3	53.2	50.9	30.4
Feb. 15 to 18, 1936		46.5	52.5	29.3	53.2	50.8	30.4
Maximum change in water level	+3.1	+1.2	+1.1	+2.7	+8.7	+.9	+5.1
Depth of well feet	170	80	100		200	280	80
Chloride content (parts per million):							
1932–33				1,050	2,340	560	
1934	1,545	1,735	720	960			910
1936		1,860	720	990	1,550	940	835

	304	315	318	319	321	322
May 26, 1931			29.2			
May 27, 1931				24.6	40.7	
May 28, 1931	63.6					
Dec. 9, 1932		48.2				39.7
Jan. 7, 1933		48.6		24.8		39.6
Feb. 22, 1933		48.4		24.6		41.9
May 31, 1933		49.4		25.1		40.1
June 26		49.7		25.1		40.0
July 24, 1933		49.7		25.3		40.5
Aug. 10, 1933		49.6		25.0		39.9
Aug. 22, 1933	58.0	49.4	29.8	24.8	39.9	39.6
Sept. 8 to 11, 1933	58.1	49.0	29.3	24.4	39.5	39.4
Sept. 20 to 29	57.9	48.9		24.3	39.1	38.8
Oct. 10 to 19, 1933	57.7				38.4	38.7
Oct. 25 to Nov. 1, 1933	57.3					38.7
Nov. 11 to 22, 1933	57.2					38.6
Feb. 5 to 17, 1934		48.2		23.8		38.4
Dec. 5 to 17, 1934	55.8	48.2		24.7		39.3
Apr. 12 to 16, 1935	56.0	48.0		24.3		39.1
Jan. 31 to Feb. 2, 1936	54.6	48.4		24.1		38.4
Feb. 15 to 18, 1936	54.6					
Maximum change in water level	+9.0	−1.7	+.6	+1.5	+2.3	+3.5
Depth of well feet	90	280	240	340	96	50
Chloride content (parts per million):						
1932–33		338	328	272	1,333	1,260
1934						
1936	1,245					

It was not expected, of course, that wells deeper than 150 feet would respond as quickly to recharge as the shallower wells, because the water-bearing beds in these deeper wells are probably separated from the surface by one or more rather impermeable beds of clay, and their outcrop at the surface, where most of the recharge takes place, is several miles from the wells. The shallower wells, however, should respond rather quickly to recharge from precipitation, provided they are not separated from the surface by a more or less impermeable bed of caliche.

As was expected, some wells showed considerable fluctuation of water level, whereas other wells of similar depth showed very little or no fluctuation. Well 61 showed a fluctuation in the water level of 24 feet, whereas well 69, about 3 miles distant, showed a fluctuation of 12 feet. Well 145 showed a fluctuation of only 2.7 feet; well 175, 1 mile away, 9 feet. Some of the deeper wells, such as wells 68, 209, 287, and 297, showed greater fluctuations than many of the shallower wells. A few of the measurements may not represent a true static level because of possible high wind and consequently large pumpage for a considerable period prior to the measurement—the following measurements, for example: Well 55, on June 3, 1931, and December 11, 1934; well 187, on August 22, 1933; well 207, on May 29, 1931; well 297, on May 29, 1931; and well 304, on May 28, 1931. The fluctuations in wells 55, 68, 70, 71, 173, 175, 179, 184, 190, 209, 276, 281, 287, 292, and 302 indicate that they are located in areas in which the recharge is comparatively great, whereas wells 72, 73, 143, 144, 145, 157, 158, 201, 240, 271, 272, 289, and 290 appear to be in areas in which the recharge is comparatively slight. In 1930–33 the precipitation was more than normal, in 1934 about 5 inches less than normal, and in 1935 about 17 inches more than the average for the 25-year period 1911–35. The fact that the water level in most of the wells rose during the period 1931–33, declined in 1934, and rose rapidly in 1935 is evidence of recharge in 1933 before the 1933 measurements were made and in 1935 before the 1936 measurements were made. (See, for example, wells 173, 175, 190, 207, and 302.)

Chloride determinations were made on samples from some of the observation wells in 1932–33 and from most of the observation wells in 1934 and again in 1936. Four of the wells showed an increase in chloride content between 1932 and 1936, and five showed a decrease. Twelve showed an increase between 1934 and 1936, four showed a decrease, and eight showed no significant change.

The records disclose no apparent relationship between the chloride content of the water and the fluctuations in water levels. For example, wells 55 and 61 both show a large change in water level, but well 55 yields water that is moderately high in chlorides, whereas well 61 yields water very low in chlorides. Again, well 68 shows about the same amount of water-level fluctuation as well 71 but yields water that is very much higher in chlorides. In general, the chemical character of water from individual wells in other areas studied by the United States Geological Survey has been found to be relatively constant unless affected by peculiar conditions, such as the encroachment of salt water into the aquifer itself or leakage of salt water into the well through defective well casings.

This subject requires further investigation before an opinion is advanced concerning the reason for these changes in chloride concentration and their significance with respect to well-water supplies in the area.

QUATERNARY SYSTEM

PLEISTOCENE SERIES

LISSIE FORMATION

Name.—The Lissie formation was named by Deussen [90] for the town of Lissie, Wharton County, Tex. In 1924 [91] he traced this formation south as far as southern Duval County, where it is overlain by wind-blown sand. The formation is the same as that to which Dumble [92] applied the term "*Equus* beds." Dumble reported Pleistocene fossils from these beds in the vicinity of San Diego and placed the contact between the Reynosa and *Equus* beds (between the Goliad and the Lissie) about 1½ miles east of San Diego, on San Diego Creek. He considered the formations in this area typical of his *Equus* beds.

Character and general relations.—In Duval County the Lissie consists of fairly coarse-grained mottled reddish and chocolate-colored calcareous to clayey sand, with some chert gravel near the base. It overlies the Goliad unconformably as a rather thin veneer in the extreme southeastern part of the county. (See pl. 1.) It dips east at the rate of about 12 feet to the mile in the western part of its outcrop area, but the dip increases greatly toward the east. Cuttings from the Sullivan well, 5 miles south of Banquete, in Nueces County, which were examined by the writer, indicate that the base of the formation at that place is about 700 feet below the surface.

Occurrence of ground water.—The Lissie formation in Duval County is too thin to yield an appreciable quantity of water to wells, although in the counties to the east it is an important source of water supply.

TERRACE DEPOSITS

Gravel and sand deposits of possible Lissie age occur in many stream valleys in Duval County. On Agua Poquita Creek at the road crossing 2½ miles north of Concepcion thick gravel deposits containing several large, worn fragments of bone were found. These bones were sent to C. W. Gilmore, of the United States National Museum, who stated that they were not identifiable but that their

[90] Deussen, Alexander, Geology and underground waters of the southeastern part of the Texas Coastal Plain: U. S. Geol. Survey Water-Supply Paper 335, p. 78, 1914.

[91] Deussen, Alexander, Geology of the Coastal Plain of Texas west of Brazos River; U. S. Geol. Survey Prof. Paper 126, pp. 108–110, 1924.

[92] Dumble, E. T., op. cit., pp. 983–987, 1894.

size indicated that they were probably of Pleistocene age. Similar deposits were found on Agua Poquito Creek at the steel bridge on the Benavides-Concepcion road and on Concepcion Creek near Concepcion. Sandy deposits along San Diego Creek near the Labbe ranch yielded, according to A. L. Labbe, a 3-foot tusk from a well 28 feet deep, indicating that the sands are probably of Pleistocene age. So far as is known the terrace deposits do not yield water to wells.

RECENT SERIES

WIND-BLOWN SAND

In the southeastern part of the county, in an area extending from an east-west line drawn about 2 miles north of the Duval-Brooks County line southward into Brooks County, there is a thin veneer, possibly several feet thick, of fairly coarse light-buff wind-blown sand. This is part of the triangular area of wind-blown sand mapped by Deussen [93] as occupying Kenedy and Brooks Counties and parts of Jim Hogg and Hidalgo Counties.

Under natural conditions this sand is now fairly well anchored by grass and trees and is not moving, but in plowed fields it is often moved with sufficient velocity to cut off at the ground level young corn and cotton.

CALICHE

Name and general character.—The term "caliche" is applied by geologists of the Gulf Coastal Plain of Texas to a secondary deposit of calcium carbonate containing impurities of sand and clay and locally of gravel, which has an appreciable thickness and occurs at the surface or a few inches to a few feet below the surface. It is also applied to beds composed of rounded pebbles and boulders of calcium carbonate, apparently formed in open bodies of water, such as streams or lakes, by accretion of calcium carbonate around a nucleus, as a result of precipitation due to algal or bacterial action. Caliche also occurs as secondary deposits in sedimentary rocks in the form of small to medium-sized boulders of soft chalky calcium carbonate precipitated from the ground water. In places it forms beds which have the appearance of a conglomerate, composed of subangular pebbles of impure calcium carbonate that may have been formed by the erosion and transportation of previously existing beds of caliche or by precipitation from ground water in place.

Weeks [94] and Price [95] have given excellent summaries of the literature on caliche and have applied the principles set forth in this

[93] Deussen, Alexander, Geology of the Coastal Plain of Texas west of Brazos River: U. S. Geol. Survey Prof. Paper 126, pl. 8, 1926.

[94] Weeks, A. W., Lissie, Reynosa, and Upland Terrace deposits of the Coastal Plain of Texas between Brazos River and Rio Grande: Am. Assoc. Petroleum Geologists Bull., vol. 17, pp. 453–487, 1933.

[95] Price, W. A., Reynosa problem of south Texas and origin of caliche: Am. Assoc. Petroleum Geologists Bull., vol. 17, pp. 488–522, 1933.

literature to a study of the caliche in southern Texas. Weeks considered the caliche to be a stratigraphic unit, of Lissie or post-Lissie age but not younger than the Beaumont clay, formed by secondary deposition from ground water that carried calcium carbonate in a warm climate where rainfall is less than 30 to 35 inches a year. Price uses the term "caliche" in much the same sense and considers the widespread caliche deposits of southern Texas to be for the most part of Pleistocene age, although he recognizes that some of the caliche is probably younger. He applies to it the term "Upper Reynosa" to distinguish it from the deposits of sand, clay, and gravel of Pliocene (?) age which are now called Goliad but to which Deussen and Dumble applied the term "Reynosa." Price also includes under caliche the ferruginous, aluminous, siliceous, and nitrate deposits formed by precipitation from ground water by processes similar to those that cause the formation of calcium carbonate deposits, but he uses for each type the proper modifying adjective.

In this paper the writer restricts the term "caliche" to deposits of calcium carbonate, because the term is derived from the Latin word for lime (calx), and there appears to be no justification for its extension as a generic term to indicate a group of deposits formed in the same manner but different in composition.

The most prominent form of caliche occurring in Duval County is a dense layer of hard, resistant white calcium carbonate 1 to 4 inches thick, which grades downward into softer, less pure calcium carbonate and finally into calcareous sand or clay. The zone in which the calcium carbonate shows a concentration greater than that in the underlying bedrock should all be termed "caliche." (See pl. 7, *A*.) This zone appears to be about 4 to 8 feet thick in Duval County, and its thickness in southern Texas probably does not anywhere exceed the 20 feet reported by Hawker.[96]

In places the caliche is absent, as in "sink holes" (p. 10); in other places it is present only as a nodular layer in the soil; but on the whole it forms a very conspicuous member of the rock formations of the county.

The caliche should not be confused with the underlying rock, which in many places is a white calcareous sandy clay and has been called "caliche" by some geologists and many engineers. Caliche is commonly used as a binding material for roads, for which it is excellent. In many of the caliche pits from which road materials are hauled the underlying calcareous sandy clay is also used for road building.

The upper surface of the caliche is apparently everywhere gently undulating and in places shows pothole-like depressions. (See pl. 7, *B*.) The lower surface is extremely irregular and difficult to delimit, as the caliche grades downward into the underlying rock. In

[96] Hawker, H. W., A study of the soils of Hidalgo County, Tex., and the stages of their soil-lime accumulation: Soil Science, vol. 23, pp. 475–485, 1927.

some places it extends downward as columns along joint cracks and attains its maximum thickness. Price [97] remarks that in quarries at least two beds of caliche separated by sand or clay or loam may be found in a 20- to 40-foot section. However, the writer has not observed more than one bed of caliche in any of the quarries in Duval County.

Origin.—Johnson,[98] in discussing the cementation of the Tertiary beds of the High Plains, states that as the streams from the mountains emerge onto the High Plains their water is comparatively fresh, but as they begin to cross the High Plains area their water is slowly lost by absorption into the soil and by evaporation. The evaporation results in a concentration of the dissolved mineral matter, which is deposited as a powdery precipitate. Immediately after complete desiccation there will be arrest and return by capillarity of some portions of the downward-soaking water, with additions of its solution load to the surface deposits and to a shallow subsurface deposit. Flood waters may later dissolve much of this material, but the calcium carbonate will resist the solution because the streams doubtless already carry their full load of calcium carbonate. Rain water, however, may dissolve part of the calcium carbonate and carry it downward. Insofar as local rain percolates to the ground water the calcium carbonate will be carried there; the remainder will be deposited both at the surface and at a slight depth beneath by evaporation.

Johnson describes the "mortar beds" of the High Plains Tertiary deposits, which are apparently similar to the caliche beds of the Reynosa Plateau. The "mortar beds" are horizontal ledges of firmly cemented portions of the Tertiary deposits with looser material above and below. They consist of silt, sand, and gravel, and their cement is carbonate of lime. Several mortar beds may be encountered in a single well, and individual beds are rarely continuous for more than a mile. The upper surface of the mortar bed forms a sharp line of contact with the material above, but the lower surface is not so well marked, and the bed grades downward into the underlying material. The fact that the mortar beds cut across beds of sand and gravel, or in other words that an individual bed of sand and gravel may be continuous through the zone rich in calcium carbonate and extend through it into the practically uncemented material below, is considered by Johnson to be evidence that the mortar beds were not deposited at the same time that the sand and gravel was being deposited. He considers that each mortar bed marks a former level of the ground water and that the calcium carbonate in each mortar bed was precipitated at or near that level. The mechanics of this precipitation,

[97] Price, W. A., op. cit., pp. 492–493.

[98] Johnson, W. D., The High Plains and their utilization: U. S. Geol. Survey 21st Ann. Rept., pt. 4, pp. 639–651, 1901.

however, he does not explain. Johnson states that in the mortar beds the greatest concentration of calcium carbonate occurs in the coarsest materials and that the finer materials are usually less firmly cemented. The caliche of the Reynosa Plateau differs in this respect and in the fact that it is not known to occur in more than one bed and tends to follow the land surface rather faithfully. The caliche, however, like the mortar beds is discontinuous.

Trowbridge [99] states that the elevation of the Edwards Plateau and the area west of the plateau during the Pliocene epoch rejuvenated the streams of the area and in conjunction with increased precipitation caused the residual soil accumulated during the long preglacial period of peneplanation to be washed out and deposited on what is now the Coastal Plain. This rejuvenation also increased the circulation of ground water carrying in solution large quantities of calcium carbonate and other salts. He says:

> The limestone of the Reynosa was contributed mainly by ground water and perhaps to some extent by the streams. The ground water, rich in dissolved calcium carbonate, coming from the elevated western area with invigorated circulation, stood high in the pores of the rocks and close to the low surface of the eastern plain. Although precipitation was at least fairly abundant in the high plateau on the west, the Coastal Plain was arid or semiarid then as now, and evaporation caused the precipitation of the calcium carbonate to form the limestone. Some of the precipitation took place in the interstices of the gravel near the surface as the surface was built up by the deposition of the gravel. Some of the limestone, such as that near Hebbronville and elsewhere in the main belt of outcrop and that at Carrizo Springs and at Los Dos Hermanos, in Webb County, was precipitated at the surface from springs, forming both cones and terraces where the springs issued and deposits of bolson and alkali-flat types in shallow basins into which the spring water flowed and there evaporated. Perhaps also some of the stream water flowed into sloughs, bayous, resacas, and lagoons and into shallow flats, where it was evaporated and deposited its dissolved salts.

Trowbridge's explanation of the origin of the caliche in the Reynosa Plateau presupposes that the Goliad and Uvalde formations are contemporaneous and of such a nature as to allow the supposed ground-water circulation. It has been shown above, however, that the Uvalde is younger than the Goliad. There is no evidence to show that the Goliad ever extended as far inland as the Balcones escarpment, and in the Reynosa Plateau it is topographically higher than the nearest outcrop of the Uvalde gravel to the west. Thus it would not have been possible for ground water from the Edwards Plateau to circulate, either directly through the Goliad or through the Uvalde, as far eastward as the outcrop of the Goliad and thence through the Goliad toward the Gulf. However, a large amount of calcium carbonate was undoubtedly brought in by the streams that deposited the Goliad.

[99] Trowbridge, A. C., Tertiary and Quaternary geology of the lower Rio Grande region, Texas: U. S. Geol. Survey Bull. 837, pp. 201–203, 1933.

Hawker [1] ascribes the formation of caliche to the progressive leaching of the upper soil zone (zone A) with a concentration of calcium carbonate in a zone of accumulation a short depth beneath the surface (zone B).

Price [2] agrees with Hawker and explains the production of the thick beds of the caliche by supposing that "gradual leaching lowers the zone of accumulation, and erosion lowers the upper surface of the soil." Thus the zone of accumulation of calcium carbonate moves slowly downward and, with increasing material from the zone of leaching, becomes gradually thicker.

Meinzer [3] believes that caliche is characteristically formed near the surface in aggrading areas by deposition of calcium carbonate through evaporation of the soil moisture and that it is not generally related to the ground-water table. He believes that most of the calcium carbonate in the caliche of such areas was brought in solution in the flood waters from adjacent upland areas. The flood water, carrying its load of calcium carbonate, would sink into the ground a short distance and later evaporate, causing the deposition of its load of calcium carbonate as caliche. He believes that in an aggrading area there may be buried layers of caliche that may have been somewhat altered and disintegrated by later solution.

It appears likely that caliche is not all formed by identical processes. The writer believes that the caliche of the Reynosa Plateau is formed by the leaching of calcium carbonate from the lime-rich rock and soil of the Goliad during rainy periods by solutions that penetrate into the ground only a short distance and later ascend by capillarity during dry periods. Evaporation causes the deposition of the calcium carbonate in the soil, a short distance below the surface. It is not necessary for the water to descend to the ground-water table, and in most parts of the area where caliche is formed the ground-water table is so deep that any water reaching it is not withdrawn by capillarity.

The largest amount of evaporation will take place at a rather definite level at the top of the zone of accumulation, and consequently the largest amount of calcium carbonate will be deposited near the top of this zone. Deposition from solution may take place anywhere within the zone of evaporation, but the most rapid deposition will take place near the top of the zone and will result eventually in a hard, compact layer of caliche that is practically impermeable. The impermeable caliche prevents further passage of water downward into the underlying formation, and as a result the water entering the soil in areas where this impermeable layer is developed will

[1] Hawker, H. W., op. cit., pp. 478–482.
[2] Price, W. A., op. cit., p. 505.
[3] Meinzer, O. E., oral communication, Dec. 18, 1934.

move downward to the impermeable layer and will then migrate along its surface until it reaches a place where the hard caliche is interrupted, where it will again move downward. A certain amount of this water will be evaporated and will deposit its load of calcium carbonate on top of the impermeable layer, but as the material overlying the caliche will have been greatly leached during the formation of the caliche, the amount of calcium carbonate so added will be comparatively small. Thus the thickness of a single bed of caliche formed in this manner is limited by the formation of the impermeable top layer. In many parts of the area where caliche occurs at the surface the leached soil has probably been removed by erosion.

The first requisite for the formation of caliche in this area appears to be a subhumid to arid climate; the second is that the underlying formation must be calcareous; and the third that the underlying formation must be of such texture as to favor capillary movement of subsurface water. In southern Texas the area west of the coastal counties has a subhumid to semiarid climate, most of the formations are calcareous to a greater or less degree, most of them have a texture fine enough to favor capillary movement; consequently, on most of the formations caliche is found at or near the surface. Caliche is rare on the dominantly noncalcareous formations, such as the Carrizo sand and the Catahoula tuff, although even these formations contain a small amount of calcium carbonate, and in places caliche is found on their outcrop. Several deposits of coarse sand and gravel have been noted which, although calcareous, do not contain caliche, owing to the lack of capillary pores. On the other hand, in many places, the coarse gravel deposits of the Uvalde formation contain sufficient silt to provide capillary pores, permitting the formation of caliche.

Distribution.—Caliche appears to be most abundant on the outcrop of the Goliad sand, and in Duval County it occurs nearly everywhere on this formation.

In the course of a series of experiments to determine the presence or absence of caliche and its effects on recharge to the Goliad sand W. A. Lynch and J. C. Cumley made a series of tests with a 9-foot soil tube. In certain test holes carried to a depth of 9 feet in the vicinity of wells 55, 70, 71, 207, 209, 211, and 276 caliche was absent or was present only as chalky nodules. In adjacent test holes, however, the caliche was found to be present as a hard, impermeable layer either at the surface or within 9 feet of the surface. These wells show fluctuations of water level from 5 to 34 feet during the period in which water-level measurements were made. Recharge was believed to occur in the areas where the test holes indicated that caliche was absent. Near wells 289 and 290, which showed fluctuation of water level of less than 0.4 foot, every test hole encountered caliche at 2 to 8 feet below the surface.

The writer recognizes the fact that the absence of caliche in a test hole 9 feet deep does not necessarily indicate that caliche is not present at a greater depth, but its presence below 9 feet seems unlikely, because over so much of the county it is near the surface and appears to follow more or less faithfully the surface topography, being in general somewhat shallower in the valleys or appearing along the side of the valley as a hard ledge.

Age.—In much of the county, at least, the caliche appears to be later than the present topography. It is as likely to be present in the valleys as on the hills, and such profiles as were made from the test holes appear to indicate that in a general way the caliche follows the surface. It seems to be absent in the sink holes. It might be argued that the caliche in the valleys has been formed more recently than the caliche in the upland areas, but so far as the writer has been able to observe there is no evidence on this matter one way or the other.

Price [4] is of the opinion that a large part of the caliche on the Reynosa Plateau was formed prior to the deposition of the Lissie gravel and states that 50 to 100 feet of caliche is reported in wells by drillers who base their determination of the caliche on the milky color of the drilling water. If field or office examinations of drill cuttings from wells substantiated this opinion, there would be good reason to suppose that caliche was in process of formation on the surface on which the Goliad was being gradually deposited, possibly at several different times during the Goliad epoch. The available evidence, however, fails to support this conclusion. The Goliad includes several beds composed of white to light-gray calcareous clay containing more or less sand that would undoubtedly yield a milky water when penetrated by the drill. These beds, however, do not have the characteristics of caliche as it occurs at the surface in Duval County. The writer examined carefully the cuttings from the Sullivan oil test well, on the Simmonds & Perry ranch, 5 miles south of Banquete, and from the John F. Camp oil test well, 7 miles west of Banquete. Numerous rounded fragments and nodules of calichelike material were observed in beds supposed to be of Lissie and Goliad age, but no bed that appeared similar to the caliche on the Reynosa Plateau was encountered. There is some evidence that caliche may have been forming locally during the deposition of the Goliad in Palo Creek, in the northeastern part of Duval County, as at that locality fragments of calcium carbonate that have some resemblance to caliche occur in beds several feet thick.

[4] Price, W. A., Reynosa problem of south Texas and origin of caliche: Am. Assoc. Petroleum Geologists Bull., vol. 17, pp. 488–522, 1933.

But many of these fragments have subrounded to pitted irregular surfaces, such as might result from secondary deposition from waters bearing calcium carbonate within the formation, either at the time that it was being deposited or later. On the other hand, the pitted surfaces may be the result of partial solution of calcium carbonate pebbles after they were formed.

The writer is extremely doubtful whether a caliche surface such as that existing on the Reynosa Plateau at the present time can be traced down the dip beneath the younger formations and is inclined to consider that most of the caliche has been formed in post-Goliad time as a result of especially favorable conditions of climate and the calcareous and rather fine-grained character of the Goliad formation. Much more detailed field work is necessary in this area before definite conclusions regarding the age of the caliche can be reached.

CHALCEDONY KNOBS

Numerous siliceous hills or knobs occur in Duval and adjacent counties. They are all small, the largest having an area of possibly half an acre, and they rise 5 to 60 feet above the surrounding plain. Because of the flatness of most of the area they form rather prominent landmarks. Most of them occur either on the outcrop of the Catahoula or on the outcrop of the Goliad or Oakville close to the Catahoula. In many places in the area the lower parts of the Goliad or the Oakville are partly or completely silicified near the contact with the Catahoula, and because of the increased resistance due to silicification they form rather prominent hills, such as Atravesada Hill and Las Parillas Hills. Veins of fibrous calcite are found associated with several of the siliceous knobs.

Los Picachos Hills.—Los Picachos Hills are situated in the north-central part of Duval County. (See pl. 1.) They are a series of siliceous knobs of which the southernmost three are most prominent and rise 30 to 60 feet above the surrounding plain. They were described by Dumble,[5] who considered them to be silicified outliers of the Oakville sandstone, formed as a result of the infiltration of hydrous silica in hot solution with consequent alteration of the Tertiary marls. Deussen[6] considered them to be siliceous veins. In 1926 Bailey[7] described these hills in detail and ascribed their origin to infiltration of siliceous and calcareous waters along a fault zone. The relation of the hills to the underlying bedrock is obscured for the most part by loose fragments that have fallen from above to the base of the hills. The southernmost hill has the best exposures. According to Bailey it

[5] Dumble, E. T., Geology of southwestern Texas: Am. Inst. Min. Eng. Trans., vol. 33, pp. 970–971, 1902.

[6] Deussen, Alexander, Geology of the Coastal Plain of Texas west of Brazos River: U. S. Geol. Survey Prof. Paper 126, pp. 121–122, 1924.

[7] Bailey, T. L., The Gueydan, a new middle Tertiary formation from the southwestern Coastal Plain of Texas: Texas Univ. Bull. 2645, pp. 148–153, 172–173, 1926.

consists of several veins of chalcedony and opal from 1 to 15 feet across, which dip steeply northwestward, separated by beds or partings, from an inch to a few feet thick, of fine-grained, more or less silicified light yellowish-green to white argillaceous tuff or tuffaceous clay. About 20 feet east of the siliceous veins is a vein of fibrous calcite 6 feet thick at its widest part. About 100 feet east of the calcite vein a series of beds of Chusa tuff dip 20°–40° SE.

The other hills of this group are similar except that there is no calcite vein associated with them. Their general appearance is shown in plate 8, *A*. Bailey considered that these veins were due to mineral deposition by ascending silica-bearing solutions along a zone of faulting. The strong upward tilting of the beds of the Chusa tuff on the east side of the southernmost hill is evidence that movement has occurred as a result either of faulting or of the growth of the chalcedony. However, no trace of such a fault is seen in the outcrop of the Oakville-Catahoula contact at the place where the fault should pass in the area north of Los Picachos Hills, and most geologists who have worked in the area are of the opinion that no fault exists in this vicinity.

Most of the water in the Catahoula tuff is alkaline and is able to dissolve silica rather easily. The silica in the Catahoula tuff, especially in the Chusa member, is in a form readily dissolved by such waters. It is believed, therefore, that the alkaline ground water dissolved silica, which it carried upward along joint cracks and fractures and redeposited in the openings or at the surface. In this manner rocks of superior resistance to erosion were formed; later, as the surrounding rock was eroded away during the general erosion of the area, these siliceous knobs were left standing above the surrounding plains.

Sarnosa Hills.—South of Freer, in the western part of Duval County, are two rather prominent siliceous knobs known as Sarnosa Chiquita and Sarnosa Grande. These hills have an area of less than half an acre at the top, are between 30 and 40 feet high, and are steep-sided. Debris from above has collected around the base of the hills, obscuring the geologic relations. At the top they are composed of translucent to light cream-colored chalcedony that breaks with a smooth or conchoidal fracture. This type of chalcedony grades downward into gray chalcedony with a hackly fracture similar to that of indurated sandstone. On top of Sarnosa Chiquita and at about its center occurs a waxy-appearing chalcedony with drusy cavities partly to completely filled with calcite crystals. Viewed from a short distance the north side of Sarnosa Chiquita exhibits an obscure bedding with a gentle dip to the east. C. S. Ross, of the United States Geological Survey, who examined a thin section of the rock from the top of this hill, found it to be composed predominantly of chalcedony with a few widely scattered angular grains of quartz and expressed the opinion that the chalcedony was deposited by cold ascending silica-bearing ground water, which largely replaced with silica the existing rock, possibly a tuffaceous clay or clayey tuff. A similar knob about 10 feet high and much less conspicuous is found about a mile south of Sarnosa Grande.

Cedro Hill.—Cedro Hill, about 25 feet high, is 1½ miles southwest of the Sarnosa Hills. The mass of the hill is made up of light-gray to white tuffaceous clay or clayey tuff, which gives place toward the west to a thoroughly indurated gray tuffaceous sandstone. At the base of the east side of the hill is a sandy conglomerate composed largely of fragments of chalcedony and igneous rock firmly cemented with blue translucent chalcedony. The east side of the hill is formed by a dikelike body of dense, fine-grained, massive white halloysite, which breaks with a conchoidal fracture. It is about 25 feet high, 15 feet wide, and 50 feet long and trends N. 10° E. It is terminated on the south by a vein of reddish-brown opal from 1 foot to several feet thick, which trends west-northwest. North of the halloysite dike is a vein of fibrous calcite from a few inches to 10 feet in width, which trends east-northeast and extends with one interruption for a distance of about 800 feet east of the ranch road that passes near the base of the hill. The relation of these veins is shown in figure 3.

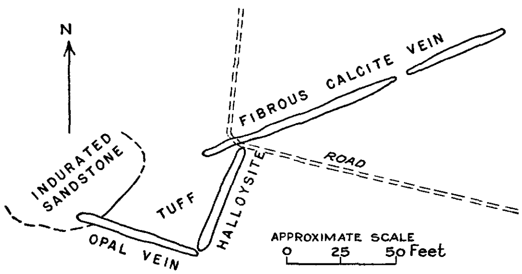


FIGURE 3.—Sketch map of Cedro Hill, showing relation of veins.

Las Parillas Hills.—The three groups of small chalcedony knobs known as "Las Parillas Hills", in the extreme western part of Duval County, have a linear arrangement and a northeast trend. (See pl. 8, *B*.) The group farthest west occurs along an escarpment that marks the contact of the Goliad sand with the Catahoula tuff. On the south hill of this group, which shows the best exposures, a knob that rises about 5 feet above the general level of the hill is composed of fine-grained white to gray mottled chalcedony, which breaks with a smooth to conchoidal fracture and contains drusy cavities. In thin sections it is seen to be composed of small scattered angular quartz veins embedded in a matrix of chalcedony that C. S. Ross believes has almost completely replaced a clay matrix. Underlying the knob is about 30 feet of completely silicified sandstone, which grades downward into a more argillaceous sandstone containing numerous rounded fragments of chert and pellets of tuffaceous clay. Thin sections of the sandstone show that it is composed dominantly of rounded to

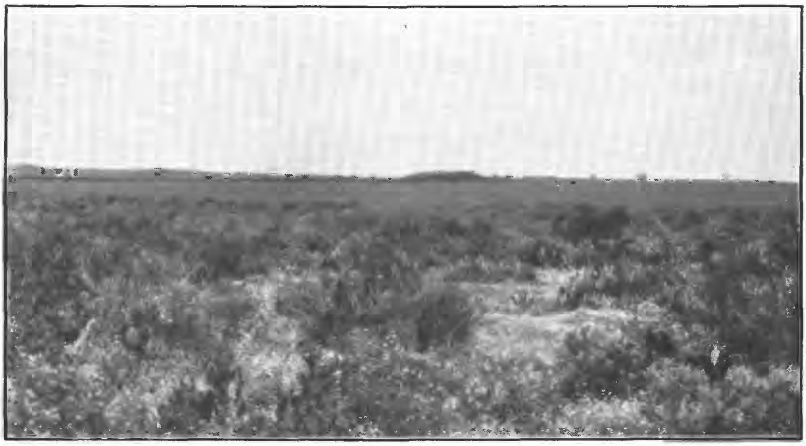
A. VIEW ALONG THE SAN DIEGO-HEBBRONVILLE ROAD ABOUT 4 MILES SOUTHWEST OF REALITOS.

Note the thin mantle of soil, underlain by a layer of hard caliche (near hammer head), which grades downward into Goliad sand.

B. CALICHE AND GOLIAD SAND IN FINSKEY'S QUARRY, NEAR REALITOS.

Note the three pockets of gravel in the caliche surface near center of picture. Hard caliche grades downward into calcareous, sandy clay and gravel.

A. NORTHERN KNOB OF LOS PICACHOS HILLS, SHOWING RESISTANT CHALCEDONY.



B. VIEW LOOKING SOUTH ACROSS PART OF THE SUPPOSED ANCIENT VALLEY OF THE NUECES RIVER.

Area is underlain by the Catahoula tuff. Note the escarpment formed by Las Parillas Hills capped by Goliad sand. The smaller hill to the west is a small chalcedony knob.

subangular quartz grains with some grains of chert, the interstices having been partly or completely filled with chalcedony. The base of the sandstone marks the contact between the Chusa and the Goliad. The top of the Chusa here is a light yellowish-green tuffaceous clay or clayey tuff almost completely replaced by calcium carbonate and containing medium-sized to large irregular boulders of chalcedony, apparently formed in place by infiltration of siliceous water and partial replacement of the tuff by chalcedony. (See pl. 5, *B*.)

On the west side of the pipe-line road 2 miles southeast of Las Parillas Hills a sandy clay occurs beneath the caliche at the top of the hill and overlies an unsilicified sandstone. This sandy clay occurs at the same horizon as the upper 5 feet of the chalcedony knob just described. It is probable that the knob is a silicified portion of this clay and that it represents an erosion remnant left by virtue of its greater resistance. The chalcedony deposited in the interstices of the sandstone probably had its source in the silica of the underlying Catahoula tuff, which was dissolved by ascending ground water and redeposited in the sandstone.

The other hills of these groups are similar. The only evidence for the belief that these knobs mark the trace of a fault plane is their linear arrangement, which suggests localization of ascending meteoric waters along a fault plane.

PRESENT DEVELOPMENT OF WATER SUPPLIES FROM WELLS

Extreme northwestern part of Duval County.—The extreme northwestern part of Duval County, the area lying northwest of a diagonal line connecting a point 12 miles east of the northwest corner of the county with a point 20 miles south of that corner, is almost entirely a stock-raising area, having few houses and only one small oil-pool camp. The Frio clay and the lower part of the Fant member of the Catahoula tuff crop out in this area and are underlain at moderate depths by the Jackson formation. Only two wells were found in the area, one of which yields rather highly mineralized water from a sand in the lower part of the Frio clay, and the other yields water from either the base of the Frio or probably from a sand stratum in the upper part of the Jackson. It is possible that other wells drilled near the contact of the Frio clay and Catahoula tuff will encounter the water-bearing bed at about 300 feet. Several wells drilled into the lower part of the Fant member were unsuccessful.

Area adjacent to the Bordas escarpment.—The area adjacent to the Bordas escarpment is devoted mainly to stock raising but contains a few small farms, and near Freer, in the vicinity of the escarpment, there has been active oil development in the last few years. The well water is used for stock and households and for drilling and pumping operations incidental to the development of the oil pools. East of the line mentioned above as delimiting the extreme northwestern part of Duval County the writer knows of only two unsuccessful water wells (nos. 91 and 11), and probably well 91 would have been successful if it had been drilled deeper. West of the Bordas escarpment, in a belt 6 to 8 miles wide, water is encountered in sands in the upper part of the Fant member and in the Soledad and Chusa members of the Catahoula tuff. Most of the water wells in this belt are 300 feet or less in depth, but two in the Government wells field are about 600 feet deep. For a short distance east of the Bordas escarpment the water wells pass through the Goliad and Oakville formations and obtain their water supplies from the Catahoula at depths of less than 300 feet.

In the Government Wells oil field and vicinity several of the water wells supplied by the Soledad and Chusa members yield 10 to 15 gallons a minute. A well in the extreme southeastern part of the Soledad ranch is reported to yield 225 gallons a minute. Well 97, on the Soledad ranch about 3 miles south of the ranch headquarters, is reported to have yielded 20 gallons a minute during a pumping test. Well 102 is reported to have been pumped continuously for 24 hours at the rate of about 65 gallons a minute. Several other wells in this area are reported to yield supplies sufficient for drilling and for use in oil-field camps. Most of the wells in this belt, however, yield only enough water for stock and domestic use. On the whole, the water in this belt, although rather highly mineralized, has been found to be fairly satisfactory for drinking and stock use and for boilers.

La Gloria ranch and vicinity.—The part of the county in the vicinity of the La Gloria ranch is devoted chiefly to ranching but contains a few small farms. Water is obtained from wells of widely varying depths. On the Labbe ranch, in the valley of San Diego Creek, water is encountered in sands that are probably Oakville in wells 30 to 60 feet deep. On the Driscoll ranch, 1½ miles southeast of La Gloria, well 26, which is 53 feet deep, yields a satisfactory supply for domestic and stock use. Other wells in the area, mostly on higher land, range in depth from 220 to 400 feet. Well 64 is 400 feet deep and probably draws its water from the Oakville. The other wells are almost all less than 300 feet deep and draw water from the Goliad.

Bess and vicinity.—In the vicinity of Bess supplies of water for stock and domestic use are obtained from wells that range from 70 to 200 feet in depth. Logs of nearby oil-test wells indicate the presence of a water-bearing sand at a depth of 300 to 350 feet, but this sand has not been tested in any water well found by the writer. Samples of water were taken from two wells in this area. One sample came from well 31, 70 feet deep, 1½ miles north of Bess, used for stock and households. It was highly mineralized, containing 3,230 parts per million of dissolved solids. This well may draw water from the Lagarto. The other sample came from well 37, 90 feet deep, 6 miles south of Bess, used for stock and households and for irrigating a small garden. This water was unusually good, containing only 443 parts per million of dissolved solids.

Rosita ranch and vicinity.—Most of the water in the vicinity of the Rosita ranch comes from the Goliad formation, but wells 74 and 67, west and north of the ranch, are believed to draw water from the Oakville at depths of 104 and 200 feet, respectively. In the immediate neighborhood of the ranch the wells are 50 to 190 feet deep, and all yield rather good water.

San Diego and vicinity.—In and around San Diego highly mineralized water is usually encountered in gravel at a depth of about 40 feet and in sand at about 100 feet, but water of better quality is found between 120 and 300 feet. An analysis of water from well 38, about 120 feet deep, 4½ miles north of San Diego, showed that it contained only 565 parts per million of dissolved solids. Water from well 52, 240 feet deep, in San Diego, contained 1,247 parts per million of dissolved solids. Field tests of samples from several other wells in the town, from 150 to about 300 feet deep, show that the waters differ widely in quality and point to the probability that the water from shallow beds is rather highly mineralized, whereas the water from relatively deep beds is of better quality; but several of the relatively deep wells in the town are contaminated by shallow ground water as a result of defective or poorly installed casing. Contamination of this kind in the town is further indicated by the fact that several well owners report that wells which at first yielded water of good quality have since "gone bad." The shallow water may enter a well directly through holes in the casing or through the deeper water-bearing beds as a result of leakage from neighboring wells. It is believed that in this vicinity the water in the beds from 150 to 300 feet deep is of comparatively good quality, and that if wells sunk into these beds are properly drilled and cased supplies suitable for municipal and industrial use can be obtained.

Benavides and vicinity.—In the southeastern part of the county more than half of the land is in ranches, although the proportion of farms to ranch land is higher than in other parts of the county. In the vicinity of Benavides three water-bearing beds are reported. The uppermost bed is a sand that is usually penetrated at 90 to 120 feet and yields water that is hard and somewhat salty. A bed of sand yielding small amounts of highly mineralized water is also encountered at 40 to 50 feet. The second bed consists of sand and gravel and is reached at 200 to 250 feet; it yeilds water that contains much less mineral matter than the shallower bed.

An analysis of a sample from well 155, in the town, which derives water from the second bed, showed only 640 parts per million of dissolved solids. Water from well 168, 240 feet deep, about 5 miles south of Benavides, was of comparatively good quality, having only 499 parts per million of dissolved solids. A garden and a small grove of citrus, fig, and banana trees are irrigated with the water from this well. The third bed occurs at depths of 300 to 400 feet, but less information is available in regard to it. D. F. Rednor, a local driller, reports that he has drilled wells 700 feet deep in this area but has encountered no water below 400 feet. At the sulphur plant on the Palangana salt dome of the Duval Texas Sulphur Co., 7 miles south of the Rosita ranch and about 6 miles north of Benavides, there are 16 wells that draw water from the base of the Goliad at a depth of about 350 feet. Some of these wells, according to report, have been pumped for considerable periods at a rate of over 100 gallons a minute. The wells are about half a mile west of the salt dome, and the water is of fair quality, having about 800 parts per million of dissolved solids, according to an analysis. The water from sands of the Goliad formation, directly over the salt dome, is too highly mineralized to be satisfactory for use in the company's boilers. Numerous wells in Benavides are reported to have yielded good water for a time and then to have "gone bad." This occurrence, as at San Diego, is believed to be due to deterioration of the casing and entrance into the wells of water from the shallow water-bearing beds.

Realitos and vicinity.—Most of the wells near Realitos are about 150 to 160 feet deep, and the water level is about 130 to 140 feet below the surface. The first water-bearing bed is encountered at 40 to 50 feet. This water is not usually abundant enough to supply wells pumped by windmills. The second water is encountered at 135 to 155 feet below the surface, usually in sand but in some wells in gravel and sand. A sample of water from well 241, 146 feet deep, about 3 miles north of Realitos, contained 1,174 parts per million of dissolved solids.

Crestonio and vicinity.—At Crestonio there is a 1,600-foot flowing well (no. 269), which draws water from the Catahoula tuff at a depth between 1,300 and 1,400 feet. This water is used in the houses, in the cotton gin, for livestock, and to irrigate a small citrus grove. Other wells in the area range from 195 to 251 feet in depth, and all yield potable water.

Extreme southwestern part of Duval County.—The extreme southwestern part of Duval County is dominantly a ranch area, but there are a few farms. Wells are comparatively few and widely spaced. The water is used chiefly for stock. The area includes part of the Cole and Kohler oil and gas fields and also the pumping stations of the United Gas. Co. and the Houston Oil Co. The wells of the oil and gas fields and pumping stations are 400 to 500 feet deep, and the water is used for boilers and for drilling operations. Near the west boundary of the area all water wells pass through the Goliad, and the water-bearing formation appears to be the Catahoula tuff. Most of the wells are drilled, but there are at least two dug wells over 200 feet deep. Farther east the wells are mostly drilled; they are from 172 to 200 feet deep and probably draw water from the Goliad formation. Near the south boundary two of these wells are reported to yield "sulphur water."

Sejita and vicinity.—The wells in the vicinity of Sejita range in depth from 117 to 250 feet. The first water-bearing bed is encountered about 35 to 40 feet below the surface and is reported to yield bitter water; the second is encountered at about 100 feet and yields fairly good to highly mineralized water; the third is encountered below 200 feet and apparently yields fairly good water. A sample of water from well 281, 117 feet deep, which is open to both the first and second beds, contained 1,582 parts per million of dissolved solids, whereas a sample from well 229, 200 feet deep, in which the upper water-bearing bed was cased off, contained only 826 parts per million. Well 291, 250 feet deep, 2 miles east of Sejita, which formerly belonged to Dr. Danby, is said to have been pumped at the rate of 50 gallons a minute for several hours without appreciably lowering the water level.

Concepcion, Santa Cruz, La Copita, and vicinity.—Wells in the area surrounding Concepcion, Santa Cruz, and La Copita, range in depth from 50 to 600 feet. Over most of the area the first water is encountered in sand at depths of 50 to 90 feet. This water, according to field tests, is usually very hard and rather salty. Other water-bearing beds occur at 180–200 feet, at about 300 feet, and at about 600 feet. The 300-foot water-bearing bed is undoubtedly Goliad, and it seems likely that the 600-foot bed is also Goliad, but this cannot be verified without well cuttings. In the neighborhood of La Copita, about 9 miles southeast of Concepcion, there are two wells (nos. 311 and 323), 600 feet deep. In the extreme eastern part of the area there are several wells 300 to 350 feet deep, one of which (no. 320) yields a plentiful supply of water that contains 758 parts per million of dissolved solids, and another (no. 204) yields water that contains 771 parts per million. According to field tests, the water from several wells in the area 250 to 350 feet deep is somewhat harder and more saline than the water from these wells. Most of the wells are old, and it is not unlikely that some of them are admitting salty water through holes in the casing. A well at Concepcion (no. 204), 156 feet deep, yields water that contains only 247 parts per million of dissolved solids. The wells of the area are pumped by windmills or gasoline engines or by hand, and the water is used chiefly for households and stock, although several supply water to irrigate small gardens or a few citrus trees. Immediately east of the county line irrigation is practiced on a commercial scale with water from wells, several citrus orchards and small truck farms being irrigated.

POSSIBILITIES OF DEVELOPING WATER SUPPLIES FROM WELLS FOR IRRIGATION

The best prospects for developing ground water for irrigation are afforded by the Goliad sand. The sands of the Jackson formation contain small supplies of water, which is generally too highly mineralized for domestic use or even for stock and which undoubtedly would be unsatisfactory for irrigation. Sands in the lower part of the Frio clay yield small supplies of highly mineralized water that can be used for stock but probably would not be suitable for irrigation. Beds of sand and gravel in the middle (Soledad) and upper (Chusa) members of the Catahoula tuff are fairly permeable, and some of the wells that derive water from these materials yield 10 to 100 gallons a minute of rather highly mineralized water that is satisfactory for stock, is fairly well suited for domestic supplies, and has been used successfully in boilers in oil-well drilling. The water in the Catahoula is believed to be generally unsuited for irrigation, but some of the least highly mineralized water yielded by a few wells could probably be used successfully on lands that have good natural drainage. The Oakville sandstone furnishes sufficient water for stock and for domestic use, but the water is rather highly mineralized, and the supply is not believed to be very large. The Lissie formation in Duval County is thin and does not carry much water.

The Goliad sand covers about three-fourths of the county and contains several fairly persistent beds of permeable sand and gravel interbedded with clay and sandy clay, which in several localities yield water that is suitable for irrigation as well as for domestic use and stock. Although there has been very little attempt in the county to develop large supplies of water from the Goliad, the yield of the wells of the Duval Texas Sulphur Co., north of Benavides, and the yield under pumping tests of several domestic and stock wells indicate that considerable water can be obtained from that formation if the wells are properly constructed. This conclusion is strengthened by the fact that in southern Jim Wells County, immediately east of this county, orchards of citrus fruit and truck gardens are being successfully irrigated from wells in the Goliad.

In the greater part of the area in Duval County in which the Goliad formation crops out the water levels in wells are from 75 to 150 feet below the surface, according to the topographic situation of the wells. Under present economic conditions the cost of pumping from such levels might be prohibitive. However, in an area of about 250 square miles in the southeastern part of the county the water in the wells rises comparatively close to the surface. At Benavides the water level in the deeper wells stands at a depth of about 60 feet. Thence southeastward the depth to water gradually lessens, except on the higher lands, and in the southeast corner of the county the water in the deeper wells stands only about 25 feet below the surface. The ground water in this area apparently constitutes a valuable resource for irrigation, which probably will eventually be developed to its fullest extent.

It is desirable to determine in advance the amount of water that can be pumped each year from the underground reservoir without seriously depleting the supply. The amount that can be safely pumped in any given area depends upon the amount of water that enters the underground reservoir at the outcrop of the water-bearing sand and gravel and upon the capacity of these materials to transmit the water from the outcrop to the wells. In some parts of southern Texas, as in Dimmit and Zavala Counties, valuable information as to the amount of the annual recharge has been obtained by mapping the outcrop area of the water-bearing formation and then studying the penetration of rainfall and seepage losses from streams on the outcrop. In Duval County this method is less applicable, because here ground-water recharge is quite clearly confined to those areas where the caliche either is very thin or is absent, and the extent of such areas is not readily determinable because of the soil cover. However, information as to the amount of the annual recharge can be obtained by a critical study of fluctuations of water level in wells. Accordingly, in connection with the investigation in Duval County and similar investigations in Jim Wells and Brooks Counties, groups of properly spaced wells are being measured once a year or oftener. These observations, which were started recently, should be continued for a considerable period of years.

The widespread occurrence of hard, salty water in shallow wells in the outcrop area of the Goliad sand indicates that in a large part of the area there is relatively little ground-water recharge. On the other hand, there are areas in which recharge does occur, and the total recharge may be large in the aggregate, especially in wet years. On the basis of the information now available it cannot be assumed that the supply of water is very great, and therefore no large development should be made until the adequacy of the supply has been tested. This can be done by pumping at first from only a small number of wells and watching the effects of the pumping on the water levels in the observation wells. If the water levels hold up reasonably the development can proceed further.

Some lowering of head, indicated by decline of pressure in flowing wells or decline of water levels in wells that do not flow, takes place wherever water is withdrawn, either by artesian flow or by pumping.

If the rate of withdrawal does not exceed the rate at which the underground supply can be replenished by natural processes, the rate of decline in the artesian head gradually becomes less until virtual equilibrium is reached. However, if there is overdraft the decline continues indefinitely or until the water levels fall so low that pumping from some of the wells is no longer practicable.

WELL LOGS

Drillers' logs of wells in Duval County

Well 2 (Duval County Ranch Lands Co.)

	Thickness (feet)	Depth (feet)
Catahoula tuff:		
Surface	4	4
Caliche	56	60
Sand and shale	65	125
Frio clay:		
Blue shale	75	200
Pyrite and sand	15	215
Blue shale	5	220
Pyrites	5	225
Sandy shale and pyrites	80	305
Pyrites	3	308
Hard sandy shale	27	335
Pyrite and shale	5	340
Frio clay—Continued.		
Shale	11	351
Shale and sand	23	374
Hard shale	21	395
Sticky shale	21	416
Sand and shale	19	435
Do	21	456
Hard sand and shale	23	479
Hard shale	62	541
Jackson formation:		
Rock	3	544
Shale	110	654

Total depth 654.4 feet. No water.

Well 3 (S. R. C. & Vacuum Oil Co. No. 2 Duval County Ranch Lands Co.)

	Thickness (feet)	Depth (feet)
Catahoula tuff and Frio clay:		
Clay	50	50
Broken sand and clay	59	109
Broken sand and shale	88	197
Sand	18	215
Shale	25	240
Sand and shale	160	400
Sticky shale	273	673
Shale	316	989
Jackson formation:		
Limerock	14	1,003
Sticky shale	15	1,018
Gumbo	20	1,038
Shale	20	1,058
Gumbo	161	1,219
Sticky shale and gumbo	189	1,408
Gumbo	27	1,435
Jackson formation—Continued.		
Gumbo and sticky shale	82	1,517
Gumbo	44	1,561
Sticky shale and gumbo	121	1,682
Gumbo	22	1,704
Lignite	2	1,706
Gumbo	4	1,710
Shale and gumbo	76	1,786
Shale and lignite	23	1,809
Shale and boulders	20	1,829
Sticky shale	21	1,850
Shale and shells	14	1,864
Sandrock	4	1,868
Sand	12	1,880
Shale	18	1,898
Hard sandrock	8	1,906

Well 4 (water well of S. R. C. Co.)

	Thickness (feet)	Depth (feet)
Catahoula tuff and Frio clay:		
Surface clay	15	15
Caliche	1	16
Hard sandrock	84	100
Pyrites	2	102
Hard sandrock	38	140
Sand (water seep)	10	150
Sticky brown shale	5	155
Hard sandrock, some pyrites	17	172
Blue shale	68	240
Hard sandrock	12	252
Shale, red and blue	30	282
Hard rock with pyrites	3	285
Red and blue shale	32	317
Sandrock	3	320
Blue shale	17	337
Catahoula tuff and Frio clay—Continued.		
Sandrock, some lime	4	341
Blue shale	13	354
Sandrock	3	357
Red and blue shale	18	375
Limerock	3	378
Sandy blue shale	10	388
Red and blue sticky shale	61	449
Blue sticky shale	81	530
Hard shale	30	560
Rock	1	561
Sticky shale	15	576
Jackson formation (?):		
Water sand	36	612
Shale	5	617

Drillers' logs of wells in Duval County

Well 7 (water well of Magnolia Petroleum Co.; A. A. Broadbeck, owner)

	Thickness (feet)	Depth (feet)
Catahoula tuff:		
Surface sand	4	4
Caliche clay	13	17
Sandrock	1	18
Clay	27	45
Sandrock	2	47
Pack sand	23	70
Gravel and sand (water)	40	110
Blue shale	25	135
Catahoula tuff—Continued		
Gravel and sand	60	195
Shell	2	197
Blue shale	53	250
Gravel	5	255
Shale	15	270
Sand (water)	10	280
Shale	7	287

Well 14 (Humble Oil & Refining Co. No. 1 Wood & Welder)

	Thickness (feet)	Depth (feet)
Catahoula tuff and Frio clay:		
Surface sand	99	99
Blue gummy shale	4	103
Loose shale	37	140
Shale and boulders	30	170
Loose shale	62	232
Hard sand and shale	6	238
Hard sand	13	251
Sandrock	29	280
Hard sand	7	287
Sand and boulders	7	294
Hard sand	2	296
Gumbo	41	337
Hard shale, boulders, and pyrite	53	390
Gumbo and lime	10	400
Shale and lime	20	420
Gumbo, shale, and lime	5	425
Hard lime	7	432
Limy gumbo and streaks of hard lime	19	451
Gumbo, streaks of hard lime	19	470
Gumbo, shale, and lime	17	487
Gumbo and lime	5	492
Gumbo with streaks of hard lime	26	518
Gumbo and shale	9	527
Gumbo and lime	17	544
Shale and lime	7	551
Sand and streaks of shale	5	556
Shaly sand	2	558
Gumbo and streaks of hard lime	15	573
Gumbo and lime	10	583
Shale and lime	17	600
Gumbo, shale, and lime	24	624
Gumbo and boulders	14	638
Sandy shale	7	645
Limy gumbo	17	662
Gumbo, shale, and lime	14	676
Pack sand and shale	7	684
Gumbo, streaks of shale, and lime	14	698
Gumbo and lime	5	703
Gumbo, shale, and hard lime	41	744
Hard shale	50	794
Hard shale and sand	5	799
Gumbo	5	804
Limerock	8	812
Sandrock, with streaks of shale, lime, and sand boulders	5	817
Sandrock, broken	12	829
Sandrock with soft streaks	16	845
Shale and clay	33	878
Shaly lime	6	884
Limy gumbo	26	910
Sticky shale and lime	54	964
Gumbo with streaks of hard lime	43	1,007
Gumbo, with streaks of hard sand and lime	52	1,059
Sandrock	4	1,063
Gumbo	25	1,088
Gumbo, shale, streaks of hard lime	26	1,114
Catahoula tuff and Frio clay—Continued.		
Gumbo and shale	15	1,129
Hard shale and lime	7	1,136
Gumbo	15	1,151
Gumbo and shale with streaks of hard lime	26	1,177
Gumbo, shale, and lime	30	1,207
Gumbo	40	1,247
Gumbo, shale, and lime	9	1,256
Limy shale and streaks of gumbo	31	1,287
Pack sand and streaks of shale	9	1,296
Limy gumbo	28	1,324
Gumbo and shale	19	1,343
Gumbo with streaks of shale	36	1,379
Sand	19	1,398
Shale with hard streaks	12	1,410
Gumbo and shale	8	1,418
Sand, streaks of shale	6	1,424
Sand	6	1,430
Hard sand	2	1,432
Jackson formation:		
Sand	28	1,460
Sandrock	8	1,468
Hard sand	3	1,471
Rock and sand. broken	5	1,476
Sand, shell, and shale	1	1,477
Rock	1	1,478
Gumbo	17	1,495
Sticky shale	9	1,504
Sand and shale	3	1,507
Soft sand	4	1,511
Loose sand with packed streaks	41	1,552
Hard sand	2	1,554
Sand	4	1,558
Hard shale	22	1,580
Shale	13	1,593
Sand and shale	2	1,595
Hard shale	1	1,596
Light shale	15	1,611
Shale	11	1,622
Hard sand and shale	1	1,623
Rock	1	1,624
Packed sand and shale with hard streaks	19	1,643
Broken sand	13	1,656
Rock	1	1,657
Mixed shale and gumbo	279	1,936
Mixed shale, gumbo, and lime	24	1,960
Sandy shale and sand	3	1,963
Gumbo, shale, and lime	11	1,974
Gumbo and shale	7	1,981
Sandy shale	2	1,983
Shale and gumbo	21	2,004
Gumbo, shale, and lime	53	2,057
Shale and streaks of lime	3	2,060
Shale and lime	14	2,074
Gumbo, shale, and lime	31	2,105
Sandy shale and lime	5	2,110
Sandy shale	24	2,134
Packed sand	3	2,137

Initial production none. Completed drilling Nov. 15, 1925.

Drillers' logs of wells in Duval County—Continued

Well 16 (Humble Oil & Refining Co. No. 2 Dilworth)

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Goliad sand: Sand and gravel	68	68	Catahoula tuff and Frio clay—		
Oakville sandstone: Sand and			Continued.		
shale	103	171	Sand and shale	10	1,623
Catahoula tuff and Frio clay:			Gumbo	4	1,627
Sticky shale	10	181	Gumbo and lime	163	1,790
Clay and lime	65	246	Hard sand and shale	6	1,796
Sand and shale	150	396	Sticky shale	4	1,880
Loose sand	50	446	Sand and shale	46	1,926
Shale	85	531	Sticky shale	131	2,057
Lime	15	546	Jackson formation:		
Gumbo with streaks of hard			Sand	2	2,059
lime	172	718	Sand and shale	10	2,069
Gumbo shale and lime	36	754	Sticky shale and lime	15	2,084
Hard sand	20	774	Hard sand	3	2,087
Gumbo and lime	39	813	Sand and shale	7	2,095
Rock	21	834	Sticky shale	9	2,104
Limerock	20	854	Sandy shale	26	2,130
Gumbo and lime	10	864	Sticky shale	4	2,134
Gumbo	38	902	Sticky shale and sand	3	2,137
Gumbo and boulders	99	1,003	Hard sand	14	2,139
Gumbo and lime	78	1,081	Sand, shale, and shell	7	2,153
Shale and lime	59	1,140	Sticky shale and sand	25	2,160
Sticky shale	68	1,208	Pack sand	3	2,185
Shale and lime	14	1,222	Sand and shale	3	2,188
Hard sand	6	1,228	Sand	15	2,203
Shale and lime	20	1,248	Sandrock	2	2,205
Hard lime	34	1,282	Pack sand	8	2,213
Shale	3	1,285	Sand and shale	16	2,229
Sticky shale and lime	315	1,600	Sandy shale	12	2,241
Gumbo	13	1,613	Sticky shale	5	2,246

Well 19 (Dixie Oil Co., Gray No. 1 Farmer's Life Insurance Co.)

Surface clay	20	20	Catahoula tuff and Frio clay—		
Oakville sandstone:			Continued.		
Volcanic ash (?) and clay	220	240	Shale	9	1,210
Black sand and boulders	20	260	Water sand	6	1,216
Catahoula tuff and Frio clay:			Red gumbo	24	1,240
Shale, soft	480	740	Red gumbo and boulders	60	1,300
Water sand	60	800	Shale and boulders	22	1,322
Shale, sticky	120	920	Rock	2	1,324
Sticky shale and boulders	40	960	Shale	13	1,337
Shale and boulders	40	1,000	Rock	3	1,340
Sticky shale	10	1,010	Shale	3	1,343
Shale	40	1,050	Broken shale	68	1,411
Water sand	4	1,054	Lime and shale	24	1,435
Shale	46	1,100	Sticky shale	18	1,453
Water sand	4	1,104	Broken shale and lime	44	1,497
Shale	86	1,190	Lime and shale	53	1,540
Water sand	10	1,200	Shale, lime, and boulders	648	2,188
Rock	1	1,201	Jackson formation (top)	--------	2,188

Total depth 3,129 feet. Initial production none. Completed July 27, 1927.

Well 25 (Grey Oil & Gas Co. No. 1 Farmer's Life Insurance Co.)

Caliche	6	6	Catahoula tuff and Frio clay—		
Goliad sand: Hard gray sandstone	42	48	Continued.	5	1,120
Oakville sandstone:			Gumbo	10	1,130
Brown shale	16	64	Sand	52	1,182
Red rock	14	78	Gumbo	27	1,209
Brown shale	57	135	Shale, rock, boulders	6	1,215
Brown clay	10	145	Hard rock, pyrites	38	1,253
Gray shale	35	180	Blue gumbo		
Sandrock	3	183	Red sticky shale, streaks of	135	1,388
Yellow clay	110	293	sand	2	1,390
Gas sand	2	295	Limerock		
Catahoula tuff and Frio clay:			Hard and soft streaks of red		
Hard brown clay	39	334	lignite, pyrites, gypsum, gas	12	1,402
Red shale, hard	11	345	Sand	12	1,412
Red shale and boulders	45	390	Gumbo	28	1,440
Hard shale	22	412	Shale	63	1,503
Light-brown shale	21	433	Rock, hard and soft, gas and		
Hard shale	20	453	oil showing	6	1,509
Sandy shale	631	1,084	Gumbo, sand, shale, lime-		
Blue gumbo	31	1,115	rock	997	2,506

Top of Jackson formation at 2,506 feet. Top of Yegua formation at 3,541 feet.
Total depth 4,007 feet.

Drillers' logs of wells in Duval County—Continued

Well 32 (Magnolia Petroleum Co. No. 1 R. H. Corbitt)

	Thickness (feet)	Depth (feet)
Goliad sand:		
Surface	10	10
Clay	10	20
Caliche and gravel	21	41
Sand and gravel	9	50
Pack sand	35	85
Shale	73	158
Sand; water	16	174
Shale	49	223
Sand; water	15	238
Lagarto clay and Oakville sandstone:		
Broken water sand	100	338
Broken shale	232	570
Hard sand, cored	10	580
Sticky shale	95	675
Hard shale and boulders	52	727
Sandy shale	25	752
Shale and broken sand	33	785
Hard sand	21	806
Lagarto clay and Oakville sandstone—Continued.		
Rock	2	808
Sticky shale	22	830
Sand	15	845
Sticky shale	29	874
Shale	93	967
Catahoula tuff and Frio clay:		
Broken shale	333	1,300
Sticky shale	43	1,343
Sand, cored	13	1,356
Sticky shale	14	1,370
Hard shale, cored	15	1,385
Sticky shale	57	1,442
Hard shale	18	1,460
Sticky shale	18	1,478
Brittle shale, cored	7	1,485
Sticky shale	65	1,550
Shale, lime, and sand	1,582	3,132

Top of Jackson formation at 3,132 feet. Top of Yegua formation at 4,560 feet. Total depth 4,913 feet.

Well 34 (Gulf Production Co. No. 1 Mrs. R. Shaeffer)

	Thickness (feet)	Depth (feet)
Goliad sand:		
Red clay and caliche	45	45
Sandrock	2	47
Red clay	24	71
Rock	1	72
Red clay, streaks of hard sand	20	92
Red clay and hard sand	12	104
Rock	2	106
Red clay and caliche, hard sand	49	155
Sandrock	2	157
Red clay, sticky	43	200
Pink clay, sticky streaks of sand	65	265
Sandrock	1	266
Hard sand and boulders	10	276
Lagarto clay:		
Gumbo and lime	44	320
Sand	11	331
Gumbo	7	338
Sand	6	344
Rock	1	345
Sandrock	5	350
Gumbo and lime	51	601
Gumbo	60	661
Red gumbo	69	730
Gumbo and lime	42	772
Red clay, gumbo, cored	58	830
Oakville sandstone:		
Sand	10	840
Red gumbo and boulders	29	869
Sand, cored	3	872
Oakville sandstone—Continued.		
Brown sandy shale, cored	8	880
Gumbo and lime	27	907
Limerock	2	909
Gumbo	53	962
Sand, cored	1	963
Red gumbo	44	1,007
Blue shale and sand	8	1,015
Sand	68	1,083
Gumbo, cored	2	1,085
Gumbo	15	1,100
Shale	10	1,110
Boulders	1	1,111
Gumbo	47	1,148
Brown clay, gumbo, and lime	83	1,231
Gumbo and lime	19	1,250
Brown shale, sticky	30	1,280
Gray sand	3	1,283
Gumbo	69	1,352
Catahoula tuff and Frio clay:		
Sand, red	14	1,368
Gumbo, cored red sand	27	1,395
Gumbo	25	1,420
Red sand	10	1,430
Shale, brown, sticky	15	1,445
Gumbo, streaks of lime, cored red sand	8	1,462
Gumbo	48	1,510
Hard brown lime, boulders cored	5	1,515
Gumbo and lime	43	1,558

Total depth 2,709 feet. Initial production none. Completed Feb. 2, 1931.

Well 36 (Houston Oil Co. No. 1 Beall)

	Thickness (feet)	Depth (feet)
Goliad sand:		
Surface	7	7
Brown sand	13	20
White limerock	72	92
Red clay	68	160
Water sand	5	165
Red clay	20	185
Water sand	5	190
Lagarto clay and Oakville sandstone:		
Red clay, tough	55	245
Gray sand; slight gas odor	7	252
Hard red gumbo	43	295
Sand, showed little gas	7	302
Lagarto clay and Oakville sandstone—Continued.		
Limestone boulders	8	310
Red and brown gumbo	50	360
Shale	60	420
Red gumbo	180	600
Blue shale	30	630
Red gumbo	40	670
Blue shale	10	680
Hard blue water sand	4	684
Brown shale	38	720
Blue shale	20	740
Red gumbo	80	820
Cored blue sand; water	5	825

Total depth 2,444 feet. Initial production none. Completed Aug. 6, 1926.

Drillers' logs of wells in Duval County—Continued

Well 63 (Houston Oil Co. No. 1 Wood & Welder)

	Thickness (feet)	Depth (feet)
Goliad sand:		
Limerock	62	62
Caliche	15	87
Sandy clay	12	99
Hard sand, streaks of gravel	87.	186
Oakville sandstone:		
Clay	7	193
Gumbo	40	233
Sandy shale; little gas show	10	243
Gumbo	10	253
Sand and gravel	20	273
Shale	22	295
Hard sand and streaks of gravel	18	313
Gumbo	313	426
Sand and gravel	19	445
Sand	50	495
Gumbo	7	502
Shale	24	526
Gumbo	22	548
Hard sand	35	573
Gumbo	63	636
Catahoula tuff and Frio clay:		
Shale	214	850
Shale, streaks of gumbo	125	975
Gumbo, lime, streaks of shale	66	1,041
Shale, streaks of gumbo	100	1,141
Shale	85	1,216
Gumbo	35	1,251
Sand	4	1,255
Gumbo, broken lime	48	1,293
Hard sand	2	1,295
Hard sandy shale and lime, cored	2	1,297
Gumbo, streaks of lime, and shale	28	1,325
Gummy shale and lime	31,	1,406
Gummy shale	5	1,411
Gumbo, lime	32	1,443
Hard sandy shale	3	1,446
Sand, shale, cored	3	1,449
Shale, streaks of gumbo	92	1,541
Sand, shale, gumbo, and lime	976	2,517

Top of Jackson formation at 2,517 feet.
Total depth 3,488 feet. Initial production none. Completed Apr. 26, 1928.

Well 65 (Mar-Tex Oil Co. No. 1 A. J. Ridder et al.)

	Thickness (feet)	Depth (feet)
Oakville sandstone:		
Top soil, black and soft	6	6
Yellow soft sand	20	26
Yellow-gray sandrock, hard	12	38
Yellow sandrock, hard	4	42
Yellow clay, soft, blue shale with yellow	16	58
Blue shale, soft	60	118
Blue shale and conglomerate with iron pyrites, hard	19	137
Shale with iron pyrites, soft	39	176
White rock, hard blue shale, iron pyrites, hard	4	180
Blue shale, soft	49	229
White rock, medium soft	9	238
Blue shale, soft	1	239
Blue shale	39	279
Blue-white lime conglomerate, hard	16	295
Gray-black sand, soft; gas showing	4	299
Blue-white lime conglomerate, hard	2	301
Gray-black sand, intermixture of shale, soft	64	365
Blue muck, soft	26	391
Oakville sandstone—Continued.		
Gray-blue sandrock, hard	19	410
Black sand, soft; water	6	416
White hard rock	1	417
Blue soft shale	33	650
Catahoula tuff and Frio clay:		
Soft gray sand	297	947
Blue shale, soft	127	1,074
Soft blue and brown mixed shale	35	1,109
Blue shale, soft	101	1,210
Blue gumbo, soft, stiff, and sticky to drill	45	1,255
Shale and conglomerate	8	1,263
Soft blue gumbo	67	1,330
Red and blue mixed shale, soft	10	1,340
Blue gumbo, hard, tough drilling	60	1,400
Blue hard shale	1	1,401
Hard blue-white rock	1	1,402
Blue hard shale	37	1,439
Blue shale and sand, hard	61	1,500
Sand, shale, and gumbo	1,160	2,660
Jackson formation (top)		2,660

Top of Jackson formation at 2,660 feet. Total depth 3,582 feet.

Well 75 (Maurer & Duggan No. 1 Hoffman)

	Thickness (feet)	Depth (feet)
Goliad sand:		
Surface sand	3	3
Sandy lime cap	7	10
Hard dry sand	180	190
Oakville sandstone:		
Sandy lime, shale	24	214
Limerock	2	216
Water sand	6	222
Sticky shale	28	250
Tough gumbo	20	270
Shale	70	340
Gumbo	18	353
Shale	46	404
Gumbo	12	416
Hard sand	9	425
Catahoula tuff and Frio clay:		
Shale	20	445
Gumbo	13	458
Shale	52	510
Gumbo	20	530
Shale	32	562
Catahoula tuff and Frio clay—Continued.		
Rotten brown shale	28	890
Gumbo	28	918
Shale	176	1,094
Gumbo	21	1,115
Shale	60	1,175
Gravel	3	1,178
Shale	42	1,220
Sandy shale	3	1,223
Sand	20	1,243
Shale	37	1,280
Boulders	3	1,283
Shale	50	1,333
Red and white sand	2	1,335
Red sandy shale and boulders	95	1,430
Sticky shale	20	1,450
Gumbo	15	1,465
Shale	43	1,508
Sand	3	1,511
Shale, gumbo, and sand	1,139	2,640

Top of Jackson formation at 2,640 feet. Total depth 3,696 feet.

Drillers' logs of wells in Duval County—Continued

Well 81 (H. B. Schlesinger Trustees No. 1 C. W. Hahl)

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Catahoula tuff and Frio clay:			Catahoula tuff and Frio clay—Continued.		
Surface sand	4	4	Broken lime and shale	22	1,346
Sand and clay	8	12	Shale	24	1,370
Red clay	4	16	Broken shale and lime	22	1,392
Sand and shale	82	98	Shale	41	1,433
Sand and fine boulders	122	220	Gumbo	49	1,482
Sand	20	240	Shale	38	1,520
Sand and shale	40	280	Broken lime and shale	44	1,564
Sand	32	312	Gumbo	7	1,571
Sandrock	37	349	Sticky shale	37	1,608
Broken sand and lime	83	422	Broken lime	25	1,633
Shale	86	508	Shale and lime	44	1,677
Red and blue shale	122	630	Gumbo	2	1,679
Limerock	8	638	Shale, sticky	12	1,691
Sand	4	642	Shale and soft lime	28	1,719
Shale	288	920	Jackson formation:		
Gumbo	4	924	Sand	6	1,725
Shale	284	1,208	Sandy shale, hard	21	1,746
Broken shale and lime	24	1,232	Shale, sticky	23	1,769
Gumbo shale	8	1,240	Shale	52	1,821
Shale	30	1,270	Sticky shale	20	1,841
Broken lime and shale	22	1,292	Sand	9	1,850
Shale	32	1,324			

Total depth 3,010 feet.

Well 82 (Magnolia Petroleum Co. No. 7 "B" C. W. Hahl)

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Catahoula tuff and Frio clay:			Catahoula tuff and Frio clay—Continued.		
Surface	5	5	Sandy lime	20	1,105
Clay, sand, and gravel	220	225	Gummy shale	25	1,130
Rock	3	228	Sticky shale	45	1,175
Hard pack sand	37	265	Gummy shale	35	1,210
Sand and gravel	15	280	Sandy shale	30	1,240
Broken shale and sand	125	405	Broken shale	200	1,440
Pink shale	75	480	Sticky shale	10	1,450
Broken sand	50	530	Gummy shale	35	1,485
Broken shale	40	570	Shale, lime, and shells	23	1,508
Sand	45	615	Shale	112	1,620
Broken shale	103	718	Jackson formation:		
Hard sandy shale	30	748	Sand and rock	8	1,628
Broken shale	22	870	Sandrock	2	1,630
Rock	2	872	Sand	5	1,635
Hard shale	28	900	Hard sand	5	1,640
Sand, shale, and lime	70	970	Sandrock	2	1,642
Sticky shale	30	1,000	Sand	6	1,648
Shale and boulders	85	1,085			

Total depth 5,370 feet.

Well 83 (water well of Magnolia Petroleum Co.; C. W. Hahl, owner)

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Catahoula tuff:			Catahoula tuff—Continued.		
Surface sand	3	3	Brown shale	35	175
Caliche, clay	37	40	Sandy shale	30	205
Clay	15	55	Gravel	5	210
Gravel	30	85	Brown shale	20	230
Sandrock	5	90	Sandy shale	10	240
Pack sand	40	130	Sand (water)	10	250
Sand	10	140	Blue shale	10	260

Drillers' logs of wells in Duval County—Continued

Well 85 (Magnolia Petroleum Co. No. 1 Lundell)

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Catahoula tuff and Frio clay:			Catahoula tuff and Frio clay—Continued.		
Surface	5	5	Shale, broken	50	1,100
Caliche	11	16	Hard shale and lime boulders	10	1,110
Shale	59	75	Hard sand	4	1,114
Broken sand and gravel	75	150	Shale	81	1,195
Shale	50	200	Sticky shale	51	1,246
Broken sand and shale	30	230	Sand	14	1,260
Shale	194	424	Shale	150	1,410
Sand	14	438	Hard sand	3	1,413
Shale	119	557	Hard shale	37	1,450
Sand and gravel	18	575	Sticky shale	45	1,495
Broken sand and sandy shale	35	610	Hard shale	25	1,520
Shale	87	697	Broken shale	75	1,595
Sand	17	714	Jackson formation:		
Shale	34	748	Sand and sandy shale	19	1,614
Broken shale	207	955	Shale	38	1,652
Sandy shale	15	970	Sand	18	1,670
Sticky shale	40	1,010			
Hard sandy shale	40	1,050			

Total depth 5,858 feet.

Well 88 (Magnolia Petroleum Co. No. 1 J. O. Wilson)

Catahoula tuff and Frio clay:			Catahoula tuff and Frio clay—Continued.		
Soil	6	6	Sticky shale	20	815
Clay and sand	34	40	Shale	169	984
Gravel	15	55	Sand	12	996
Shale and gravel	20	75	Shale	55	1,051
Gravel and shale	349	424	Shale, hard, sticky, lime streaks	242	1,293
Sand	18	442	Shale	92	1,385
Shale	41	483	Sticky shale	23	1,408
Sand	13	496	Sticky shale and boulders	131	1,539
Shale	84	580	Rock	2	1,541
Sand	14	594	Jackson formation: Sand, cored	18	1,559
Rock	3	597			
Shale	145	742			
Shale and boulders	53	795			

Total depth 2,250 feet.

Well 93 (water well of Magnolia Petroleum Co.; M. Ruiz, owner)

Catahoula tuff:			Catahoula tuff—Continued.		
Soil	2	2	Gravel	15	155
Caliche clay	38	40	Sandrock	9	164
Sandrock	10	50	Sand and gravel; water	10	174
Pack sand	30	80	Shale	51	225
Gravel	15	95	Sand, dry	10	235
Pack sand	13	108	Shale	65	300
Sandrock	7	115	Sand; water	15	315
Sand; water	5	120	Shale	25	340
Brown shale	20	140			

Well 98 (Gordon, Folwell & Dickson No. 1 Duval County Ranch Lands Co.)

Catahoula tuff:			Catahoula tuff—Continued.		
Surface soil	10	10	Sandrock	11	319
Sandy clay	15	25	Sand	9	328
Clay	7	32	Shale	52	380
Brown sandy shale	58	90	Sandy shale	32	412
Water sand	60	150	Sticky shale	18	430
Gravel	25	175	Sandy shale	6	436
Sand	100	275	Sticky shale	64	500
Blue shale	33	308			

Total depth 3,520 feet.

Drillers' logs of wells in Duval County—Continued

Well 106 (United States Gas & Oil Co. No. 1 W. R. Peters)

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Goliad sand:			Catahoula tuff and Frio clay—Continued.		
Surface soil	3	3	Hard gray lime shale	96	170
Lime clay, light color	3	6	Mixed sandy shale	23	193
Fine gray lime shale	13	19	Fine blue sandy shale	44	237
Hard gray lime shale and coarse gravel	12	31	Hard blue shale, thin streaks sandy lime	253	490
Catahoula tuff and Frio clay:			Blue gumbo	11	501
Hard fine greenish shale and fine gravel	37	68	Shale, sand, gumbo, and lime	490	991
Brown clay	6	74			

Top of Jackson formation at 991 feet.
Total depth 2,814 feet.

Well 109 (Humble Oil & Refining Co. (Reiter-Foster) No. 1 Kohler)

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Goliad sand:			Catahoula tuff and Frio clay—Continued.		
Surface sand	3	3	Sticky shale	16	476
Sand and gravel	12	15	Sand and boulders	15	491
Catahoula tuff and Frio clay:			Shale and lime	50	541
Rock	7	22	Sand and boulders	50	591
Clay	20	42	Shale and lime	49	640
Sandy clay	35	77	Gumbo	98	738
Sand and lime	75	152	Hard sand and pyrites	11	749
Sandy clay	75	227	Gumbo	55	804
Sand and lime	40	267	Shale	50	854
Shale and lime	48	315	Sand and boulders	24	878
Gumbo and lime	10	325	Shale	12	890
Hard lime	6	331	Sand and boulders	12	902
Gumbo and lime	9	340	Shale and lime	44	946
Shale and lime	10	350	Gumbo	15	961
Sand	15	365	Sandy shale and pyrites	20	981
Shale	18	383	Hard shale	41	1,022
Sand	8	391			
Shale and lime	69	460			

Total depth 3,075 feet.

Well 112 (water well of Humble Oil & Refining Co.)

Goliad sand: Gravel	65	65	Catahoula tuff—Continued.		
Catahoula tuff:			Sandy clay	5	405
Red clay	335	400	Sand; water	15	420

Well 115 (Humble Oil & Refining Co. No. 3 Kohler)

Goliad sand:			Catahoula tuff and Frio clay—Continued.		
Surface clay	30	30	Shale	10	612
Sand and shale	35	65	Sticky shale	157	769
Shale	25	90	Sandy shale and boulders	30	799
Sand and shale	20	110	Shale	5	804
Sand	24	134	Sand, shale, and boulders	71	875
Catahoula tuff and Frio clay:			Sandrock	2	877
Shale and gravel	25	159	Sticky shale	10	887
Shale	65	224	Hard sand	10	897
Sand and boulders	20	244	Shale and lime	23	920
Shale and boulders	115	339	Sand and boulders	30	950
Sand and boulders	28	367	Shale	31	981
Hard sand	2	369	Sticky shale	50	1,031
Shale	40	409	Shale and boulders	78	1,109
Gumbo	35	444	Shale	180	1,289
Shale and sand	20	464	Sticky shale and lime	112	1,401
Sandrock	2	466	Shale and lime	109	1,510
Shale	80	546	Sticky shale and lime	71	1,581
Shale and lime	56	602	Shale and lime	202	1,783

Top of Jackson formation at 1,783 feet.
Total depth 3,056 feet.

Drillers' logs of wells in Duval County—Continued

Well 116 (J. T. Dinn, owner)

	Thickness (feet)	Depth (feet)
Goliad sand and Catahoula tuff:		
Gravel, caliche, and red clay	270	270
Sand; water	12	282

Well 131 (Callahan, Howard & Smith No. 1 Luby)

	Thickness (feet)	Depth (feet)
Goliad sand:		
Yellow sand	40	40
Hard gravel and sand, sticky	3	43
Sandrock	38	81
Yellow clay	23	104
Clay and hard sticky sand	26	130
Sand, water	20	150
Oakville sandstone:		
Sticky shale and sand	12	162
Clay, sticky	18	180
Yellow and brown sticky clay	30	210
Hard sand and clay	4	214
Yellow sticky shale	6	220
Brown sticky clay	25	245
Shale	23	268
Brown sticky shale	7	275
Water, sand, and gravel	22	297
Catahoula tuff and Frio clay:		
Loose shale	7	304
Gray clay	5	309
Catahoula tuff and Frio clay—Continued.		
Yellow sticky clay and sand	45	354
Yellow clay and sand	10	364
Shale and sand	16	380
Pink sticky shale	14	394
Shale, sand, and gravel	66	460
Yellow clay, sticky	10	470
Sand, shale, and gravel	60	530
Yellow sticky clay	130	660
Clay streaks, sand	30	690
Sand and shale	40	730
Sticky shale	61	791
Hard sticky shale	69	870
Pink fine shale	36	906
Hard sticky shale	34	940
Sandy shale	20	960
Hard sticky shale	61	1,021
Gumbo, shale, and sand	1,273	2,294

Top of Jackson formation at 2,294 feet. Top of Yegua formation at 3,935 feet. Total depth 4,024 feet.

Well 133 (National Oil Co. No. 1 Ball)

	Thickness (feet)	Depth (feet)
Goliad sand:		
Soil	2	2
Red clay	3	5
Caliche	79	84
Gray shale	6	90
Sandrock	15	105
Red shale	90	195
Water sand	60	255
Pink shale	67	322
Water sand	41	363
Lagarto clay and Oakville sandstone:		
Pink shale	11	374
Sandrock	2	376
Shale	24	400
Shale and boulders	9	409
Red gumbo	23	432
Lagarto clay and Oakville sandstone—Continued.		
Limerock	1	433
Red gumbo	187	620
Broken lime	14	634
Sticky gray shale	46	680
Gummy lime	40	720
Rock	2	722
Red gumbo and shale	308	1,030
Limerock	1	1,031
Shale and boulders	13	1,044
Sticky red shale	26	1,070
Shale and boulders	70	1,140
Broken lime	42	1,182
Red gumbo	150	1,332
Catahoula tuff and Frio clay:		
Sand and gumbo	1,912	3,144

Top of Jackson formation at 3,144 feet.
Total depth 4,009 feet. Initial production tested 2,000,000 cubic feet of gas at 3,864–3,867 feet.

Well 140 (Duval-Texas Sulphur Co.'s No. 4, water well)

	Thickness (feet)	Depth (feet)
Goliad sand:		
Surface soil	10	10
Sand	22	32
Caliche, hard	12	44
Red sticky clay	135	179
Sand	8	187
Red clay, sticky	28	215
Sand	39	254
Sandy clay	10	264
Goliad sand—Continued.		
Clay, tough	28	292
Sand	95	387
Lagarto clay:		
Red clay, tough	5	392
Sand, very fine and white	11	403
Clay	5	408
Sand	5	413
Tough red clay	30	443

Drillers' logs of wells in Duval County—Continued

Well 165 (A. Parr, owner)

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Soil	6	6	Goliad sand—Continued.		
Goliad sand:			Red clay	113	165
"Limestone"	34	40	Sand; water	5	170
(?)	6	46	Gravel	8	178
Brown sandstone; water	6	52	Sand and gravel; water	7	185

Well 209 (W. S. Evans, owner)

Pleistocene gravel: Gravel and white rock	20	20	Goliad sand—Continued.		
Goliad sand:			Clay	63	125
			Sand; water	4	129
Gravel	30	50	Clay	16	145
Clay	10	60	Sand and gravel; water	11½	156½
Sand	2	62			

Well 218 (R. A. Thompson No. 1 Parr)

Goliad sand:			Lagarto clay—Continued.		
Surface	8	8	Sticky shale	60	978
Lime	70	78	Sticky red shale	102	1,080
Break of pack sand	14	92	Oakville sandstone:		
Lime	53	145	Hard dry brown shale	103	1,183
Breaks of sand and shale	46	191	Sandy shale	10	1,193
Red shale	24	214	Sandy shale, anhydrite	28	1,221
Sand and gravel; fresh water	20	234	Sticky shale	29	1,250
Lagarto clay:			Sandy shale	25	1,275
Shale and boulders	41	375	Sticky shale with small streaks of shell and boulders	113	1,388
Sand; oil show	12	387	Sand, cored	3	1,391
Shale, sticky	21	408	Sand, cored; fresh water	4	1,395
Sand, cored	8	420	Sand, cored	7	1,402
Broken shale	265	685	Sandy lime and gumbo	128	1,530
Broken shale, hard	15	700	Broken sandy shale	57	1,587
Sticky red shale	130	830	Sand, cored	11	1,598
Sticky brown shale with few hard shale boulders	88	918			

Top of Catahoula tuff at 1,598 feet.
Total depth 5,015 feet. Initial production none.

Well 225 (P. McBride, owner)

Goliad sand:			Goliad sand—Continued.		
Sand	6	6	Rock	3	296
Sand and boulders	32	38	Sand and gravel	41	337
Rock, soft, white	23	61	Lagarto clay and Oakville sandstone:		
Sand	6	67			
Soft rock	23	90	Rock	5	342
Sand	5	95	Sand	17	359
Rock, soft	35	130	Rock	6	365
Sand and gravel	16	146	Sand and gravel	33	398
Red clay	84	230	Sand, clay, and gravel	692	1,090
Sand and gravel	19	249	Catahoula tuff (?):		
Rock, soft	19	268	Gumbo, sandrock, and clay	1,185	2,275
Hard sand	25	293	Sand (water flow)	57	2,275

Top of Jackson formation at 3,006 feet.
Total depth 3,084 feet.

Well 243 (Hoffer & Smith No. 1 King)

Goliad sand:			Lagarto clay and Oakville sandstone—Continued.		
Surface sand, shale	26	26			
Shale and sand	94	120	Pink shale	21	716
Gravel	15	135	Broken lime	24	740
Sand and gravel	61	196	Gumbo	45	785
Lagarto clay and Oakville sandstone:			Pink shale	18	803
			Sticky shale	50	853
Gravel	35	231	Gumbo pink	59	902
Sticky shale	299	530	Sticky shale, pink	57	959
Gumbo	10	540	Hard sand	2	961
Pink shale	120	660	Sandy shale	2	963
Gumbo	35	695			

Top of Catahoula tuff at 963 feet. Total depth 2,534 feet. Initial production none.

Drillers' logs of wells in Duval County—Continued

Well 252 (F. H. Zock No. 1 King)

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Goliad sand:			Lagarto clay and Oakville sandstone:		
Surface soil	10	10	Pink shale	10	250
Gravel and sand	75	85	Sandy shale	270	520
Gravel	20	105	Pink gummy shale	110	630
Red clay	35	140	Sand; water	60	690
Loose gravel	30	170	Pink shale	10	1,000
Pink shale	37	207			
Gummy shale	18	225			
Sand; fresh water	15	240			

Top of Catahoula tuff at 1,000 feet. Top of Jackson formation at 2,948 feet.
Total depth 4,011 feet. Initial production none.

Well 257 (Southern Crude Oil Purchasing Co. No. 1 Dunn)

Goliad sand:			Largarto clay—Continued.		
Caliche rock	6	6	Clay	101	308
Dry sand	18	24	Sandy shale	68	375
Gravel	11	35	Green shale	25	400
Dry sand	30	65	Pink gummy shale	133	533
Gravel	60	125	Blue shale	12	545
Sand	10	135	Oakville sandstone:		
Gravel rock	5	140	Sulphur water	30	575
Gravel	30	170	Brown shale and lime	180	725
Rock	5	175	Green shale	15	740
Lagarto clay:			Pink gummy shale	140	880
Pink shale	32	207	Sandy shale	52	932

Top of Catahoula tuff at 932 feet. Top of Jackson formation at 2,920 feet.
Total depth 4,002 feet. Initial production none.

Well 261 (Cole Petroleum Co. No. 75 Rosa Benavides)

Goliad sand:			Catahoula tuff and Frio clay:		
Surface sand	1	1	Limy shale	60	500
Broken lime	29	30	Sandy shale	40	540
Gravel	5	35	Shale	70	610
Sand	75	110	Sticky shale	70	680
Oakville sandstone (?):			Limy shale	120	800
Red shale	80	190	Sticky shale	60	860
Limy shale	50	240	Sandy shale	50	910
Sandy shale	70	310	Broken lime shale	50	960
Gravel and sand	10	320	Sticky shale	20	980
Shale	40	360	Sandy shale	30	1,010
Gravel	30	390			
Shale	40	430			
Gravel	10	440			

Top of Jackson formation at 1,815 feet. Top of Yegua formation at 4,052 feet. Top of Cook Mountain formation at 4,550 feet.
Total depth 6,393 feet. Initial production tested gas in several sands. Plugged and abandoned.

Well 262 (Moody Oil Corporation No. 1 Mesquite Ranch)

Goliad sand:			Oakville sandstone—Continued.		
Hard lime	2	2	Sand and gravel; water	15	270
Conglomerate	13	15	Clay	140	410
Hard limerock	20	35	Catahoula tuff and Frio clay:		
Sand	16	51	Shale	130	540
Oakville sandstone:			Shale and boulders	260	800
Yellow clay	169	220	Sticky shale	135	935
Clay and boulders	15	235	Sand	3	938
Clay	20	255	Sand and boulders	132	1,070

Top of Jackson formation at 1,970 feet.
Total depth 2,549 feet.

Drillers' logs of wells in Duval County—Continued

Well 263 (L. E. Conway (Mesquite Oil Co. No. 2 El Mesquite Grant)

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Goliad sand:			Oakville sandstone—Continued.		
Surface rock	10	10	Sand and clay	232	330
Gravel and red clay	40	50	Boulders, sand, and clay	10	340
Gravel, sand, and clay	25	75	Sand and clay	75	415
Sand and red clay	5	80	Gravel, sand, and clay	11	426
Oakville sandstone:					
Sand and clay; water	5	85			
Small boulders and clay	13	98			

Top of Catahouia tuff at 426 feet. Top of Jackson formation at 2,147 feet. Total depth 2,159 feet.

Well 269 (Melvine Irrigation & Cattle Co.)

Goliad sand:			Catahoula tuff:		
Soil	4	4	Pink soft clay	3	717
Yellow clay	20	24	Sand	18	735
Sandy clay and small rocks	65	89	Blue gumbo	65	800
Soft sandy clay	90	179	Red gumbo	50	850
Gravel and water	20	199	Blue gumbo	88	938
Fine sand with some gravel	17	216	Pink clay	21	959
Oakville sandstone:			Sand	31	990
Blue sticky gumbo	135	351	Hard rock	2	992
Fine sand run in; little water	6	357	Gumbo	15	1,007
Blue gumbo, very sticky, cavy	70	427	Sticky blue clay	195	1,202
Pink clay, soft, cavy	63	490	Pink clay	113	1,315
Blue gumbo, cavy, sticky	40	530	Gravel, sand; water that flowed 15 gallons a minute	1	1,316
Yellow clay, mixed with soft white "chalky" rock	60	590	Sandy	5	1,321
Gravel, sandy clay; water came within 120 feet of surface	10	600	Red, sticky mud	79	1,400
Green sand, coarse grit	10	610	Sand	8	1,408
Pink clay, soft, cavy	80	690	Red clay	8	1,416
Sand and fine gravel	8	698	Hard rock	2	1,418
Cemented gravel, very hard	9	707	Red clay	90	1,508
			Blue gumbo	60	1,568
			Blue clay, sandy	7	1,575
			Shale	25	1,600

Well 314 (Sun Oil Co. (Maddox-Goodman) No. 1 Carlisle)

Goliad sand:			Lagarto clay and Oakville sandstone—Continued.		
Surface clay and sand	12	12	Gumbo, light blue	112	820
Caliche (lime)	68	80	Gumbo, streaks with gypsum	40	860
Sand, medium hard	55	135	Gumbo, light blue	60	920
Gumbo, red	35	170	Sand; water	14	934
Shale, sandy	84	254	Gumbo, light blue	206	1,140
Sand; water	86	340	Sand, streaked with gumbo	7	1,147
Shale, gray	110	450	Gumbo and shale streaks	273	1,420
Hard sand	40	490	Shale, sandy	20	1,440
Shale	90	580	Sand	25	1,465
Sand, broken; water	35	615			
Lagarto clay and Oakville sandstone:					
Shale	55	670			
Shale, sand	38	708			

Total depth 2,760 feet.

WELL

Records of wells in

[All wells are drilled unless

Well no.	Location	Owner	Driller	Date completed	Depth (feet)	Diameter (inches)	Method of lift [1]
1	10 miles west-northwest of Freer.	Duval County Ranch Lands Co.			300	7	W
2	9½ miles west-northwest of Freer.	do			654		
3	8½ miles northwest of Freer.	do	S. R. C. Co	1930	1,906	10	
4	9 miles northwest of Freer	do	do	1931	617		P
5	3½ miles west-northwest of Freer.	do			300	5	W
6	3½ miles north-northwest of Freer.	D. M. Johnson		Old		60	W, P
[3] 7	2 miles north-northeast of Freer.	A. A. Broadbeck	Magnolia Petroleum Co.	1932	287	6⅝	P
8	do	do	do	1932	305	6⅝	P
[4] 9	1¾ miles north-northeast of Freer.	J. T. Johnson		1926	124	8	W
10	3 miles northeast of Freer	G. Ruiz estate			212	6	W
11	4¾ miles northeast of Freer.	Wood & Welder			314	6	W
12	5 miles northeast of Freer	do		Old	370	4	W
13	5 miles north of Freer	Duval County Ranch Lands Co.				5	W
14	8½ miles north-northeast of Freer.	Wood & Welder	Humble Oil & Refining Co.	1925	2,137	6⅝	
15	do	J. B. Wood		Old	196	6	W
16	12¾ miles north-northeast of Freer.	—— Dilworth	Humble Oil & Refining Co.	1927	2,246		
17	11 miles northeast of Freer	G. Lichtenberger			232+	6	W
18	8½ miles northeast of Freer.	W. Davidson (?)		Old	220±	4	W
19	11 miles northeast of Freer	Farmer's Life Insurance Co.	Dixie Oil Co	1927	3,129	10	
20	13 miles northeast of Freer	A. L. Labbe			300	6	W
21	13½ miles northeast of Freer.	do			35	6	W
22	13 miles east-northeast of Freer.	Farmer's Life Insurance Co.			100		
23	do	A. L. Labbe			60		
24	14 miles east-northeast of Freer.	Farmer's Life Insurance Co.			140+	7	W
25	10 miles north of Rosita ranch.	do	Grey Oil & Gas Co.		4,007		
26	do	R. Driscoll		Old	53+	72	W

See footnotes at end of tables.

TABLES

Duval County, Tex.

otherwise stated under "Remarks"]

Principal water-bearing bed		Water level					
Depth (feet)	Geologic formation	Below benchmark (feet)	Date of measurement	Height of benchmark above ground level (feet)	Use of water [2]	Remarks	Well no.
194–291	Frio	130	Mar. 13, 1931	1.5	S	Perforated 2½-inch casing at 104–291 feet. Water salty.[3]	1
	Frio and Jackson	None				No water	2
						S. R. C. & Vacuum Oil Co. No. 2, Duval County Ranch Lands Co.; oil test, no production.	3
576–612	Jackson?				P	S. R. C. Co.'s water well. Cased to 576 feet. Water must be treated before it can be used.	4
	Catahoula	24.6	Mar. 11, 1931	0	N	2 wells drilled close together. Water is reported as "bad."	5
	do	39.8	Apr. 21, 1931	2.5	S		6
270–280	do	50			D, P	Casing perforated at 115–195 and 245–287 feet; yields 700 barrels a day. Other water-bearing sands at 70–110 and 135–195 feet.	7
260–285	do	50			D, P	Casing perforated at 110–158 and 260–285 feet; well cased to 305 feet.	8
104–124	do	62.5	Apr. 29, 1931	.5	D, S	Another water-bearing bed at 75–85 feet.	9
	do	141.5	May 2, 1931	2	S		10
	do	220	May 5, 1931		N	Does not yield enough water for stock.	11
	do	187	May 12, 1931	1.3	S	Water level rose 13 feet in 20 minutes after pump was stopped.	12
	do	83	May 1, 1931	1.5	S	Water impregnated with hydrogen sulphide.[3]	13
						Humble Oil & Refining Co.'s No. 1 Wood & Welder; oil test, no production.	14
	Catahoula	116	May 12, 1931	1.9	S	When pump was stopped water level rose 11 feet in 30 minutes.	15
						Humble Oil & Refining Co. No. 2 Dilworth; oil test, no production.	16
	Catahoula	225	May 12, 1931	2.0	S		17
	do	220	May 5, 1931	1.5	S		18
						Dixie Oil Co. No. 1 Farmer's Life Insurance Co.; no production. Altitude, 595 feet.	19
	Catahoula	[3] 50			S	Well almost dry	20
	Oakville	33		0	S	do	21
	do						22
	do					Dug well. Fresh water was struck at 25 feet, salt water at 65 feet.	23
	do	130	Sept. 4, 1932	0	S		24
						Grey Oil & Gas Co. No. 1 Farmer's Life Insurance Co.; oil test, no production.	25
	Oakville	50	Sept. 4, 1932	1.5	D, S	Dug well, with gas well passing through its center.	26

Records of wells in Duval

Well no.	Location	Owner	Driller	Date completed	Depth (feet)	Diameter (inches)	Method of lift [1]
[4] 27	11 miles north of Rosita ranch.	G. B. Baker	Sam Smithwick			6	W
28	17 miles north of Rosita ranch.	J. G. Lowe		1932	208+	6	W
29	do	Clegg ranch		Old	187+	6	W
30	16 miles north of San Diego.	Claude McGill		Old	200+	6	W
[4] 31	16 miles north of San Diego.	M. B. Rodríguez		Old	70	36	W
32	14½ miles north of San Diego.	R. H. Corbitt	Magnolia Petroleum Co.	1929	4,913	12½	
33	12 miles north of San Diego.	Joe Crow			160±	4	W
34	11½ miles north of San Diego.	Mrs. R. Shaeffer	Gulf Production Co.	1931	2,709	6⅝	
35	11 miles north-northwest of San Diego.	J. M. García		Old		6	W
36	11 miles north-northwest of San Diego.	W. H. Beall	Houston Oil Co.	1926	2,444	6⅝	
[4] 37	8½ miles north of San Diego.	Pedro García		1860	90	42	W
[4] 38	4½ miles north-northwest of San Diego.	Vicente Moya		Old	120	6	W
[3,5] 39	3 miles north of San Diego.	N. A. Hoffman			185	5 3/16	W
[6] 40	San Diego	A. H. Compton		1920	240±	6	P
[6] 41	do	P. Arredondo	P. Gonzales	1932	53	5 3/16	H
[6] 42	do	G. Pérez	L. Sólez	1932	40	6	W
[4,6] 43	do	A. Garza Martínez	D. Ramires	1927	240	4	P
44	do	Charles Muil	Francisco García	1910	250	8	P
45	Corner of Mier St. and Gravis Ave., San Diego.	N. A. Hoffman	—— White	1921	245	10	W
[6] 46	San Diego	Martínez Bros. gin		1907	305	6	P
[6] 47	do	San Diego School District.	D. F. Redner	1931	263	6	P
[6] 48	do	Duval County Courthouse.		1916	300+	6	P
[6] 49	do	A. García, Jr		1916	289	6	W
[6] 50	do	T. Pérez		1900?	260±	6	W
[4,6] 51	do	A. L. Muil	Albert Ashwood	Old	250		W
[4,7] 52	do	Bruno Ríos		1910	240	6	P
[6] 53	do	J. R. Lopez		1932	150	5 3/16	W
54	do	Gabriel Ramírez	G. Méndez		129	6½	W
55	3½ miles west of San Diego.	A. Inguancia			80	72	W
[8] 56	4 miles west of San Diego.	Cristóbal Ibáñez		Old	80	60	W
[8] 57	3½ miles west of San Diego.				112	5 3/16	W
[8] 58	4½ miles west of San Diego.	T. M. Hernandes		Old	60		H
59	6 miles west of San Diego.	Candelario Cuellar			150	5	W

See footnotes at end of tables.

County, Tex.—Continued

Principal water-bearing bed		Water level					
Depth (feet)	Geologic formation	Below benchmark (feet)	Date of measurement	Height of benchmark above ground level (feet)	Use of water [2]	Remarks	Well no.
	Oakville	53.5	May 14, 1931	1.5	D, S	Water is reported as "fresh at one time but becoming more salty."	27
	do	150	Sept. 4, 1932	0	S		28
	do	174.7	Apr. 8, 1931		S	Water level rose 12 feet in 8 minutes after pump stopped. Water impregnated with hydrogen sulphide.	29
	Lagarto?		do		D, S		30
	do.?	32	do	0.9	D, S	Dug well.	31
						Magnolia Petroleum Co. No. 1 R. H. Corbitt; oil test, no production.	32
	Goliad	158.5	Apr. 7, 1931	1.5	D, S		33
						Gulf Production Co. No. 1 Mrs. R. Shaeffer; oil test, no production.	34
	Lagarto?	157	May 15, 1931	2	D, S		35
						Houston Oil Co. No. 1 Beall; oil test, no production.	36
	Goliad	69.5	Apr. 7, 1931	1	D,S,I	Dug well. Irrigates a garden plot.	37
	do	118	May 14, 1931	1.1	D, S		38
	do	30	1928	0	D, S		39
	do	40	Dec. 14, 1932		D, S	Well cased to 240 feet.	40
	do	[3] 42	do		D, S		41
	do	[3] 37	do		D, S		42
	do	[3] 40	do		D, S	Well cased to 240 feet.	43
	do	103	1928		D		44
230–245	do	28	do		D	Water sands cased off at 50–60 and 90 feet.	45
240–?	do		Dec. 14, 1932		D,S,P		46
	do		do		D		47
	do		do		D		48
	do	96.45	do	1	S	About 1924 caved to 140 feet and water became bad.	49
	do				S	Water reported to have become salty about 10 years after drilling.	50
	do	30	1928	0	D, S		51
235–240	do	140	do	0	D, S	Water sands cased off at 90 and 120 feet.	52
	do	48.9	Dec 14, 1932	2	D, S	Fresh water at 35 feet cased off.	53
	do		do		D, S	Well cased to 20 feet.	54
	do	75	June 8, 1931	0	D, S	Dug well. Water slightly salty.	55
	do	74.53	Dec. 7, 1933	0	D, S	Dug well.	56
	do	45	Dec. 9, 1933	2	S	do	57
	do	35.03	do	0	D, S	do	58
100–?	do	65	June 9, 1931	1	D,S	Water level dropped 2 feet in 5 minutes after pumping started.	59

Records of wells in Duval

Well no.	Location	Owner	Driller	Date completed [1]	Depth (feet)	Diameter (inches)	Method of lift [1]
60	5½ miles west-northwest of San Diego.	J. M. Sepulveda		Old	120	4	W
61	7¼ miles west-northwest of San Diego.	do			100±	60	H
62	8½ miles northwest of San Diego.	M. Serna estate		Old	200	6	W
63	7 miles north-northeast of Rosita ranch.	Wood & Welder	Houston Oil Co	1928	3,488	12½	
64	7 miles north of Rosita ranch.	do			400		W
65	7½ miles north of Rosita ranch.	do	Mar-Tex Oil Co	1920	3,582	10	W
66	5½ miles north of Rosita ranch.	do			126	5	W
67	3¾ miles north of Rosita ranch.	Fabian Fernandez			200	6	W
68	3 miles east of Rosita ranch.	Cantu estate			190	5	
[8] 69	1½ miles east of Rosita ranch.	Juan Peralez	G. Mendez		140	6⅝	H
70	2½ miles east of Rosita ranch.	M. Cantu		1926	110	5	W
71	1 mile east-southeast of Rosita ranch.	Helena de Pena		Old	110	60	W
[4] 72	Rosita ranch	Fiulio Valerio		1931	50	6	H
[8] 73	do	S. Ranjel			40	60	H
[4] 74	2½ miles west-northwest of Rosita ranch.	J. Ruiz			104	6	W
75	5½ miles west-southwest of Rosita ranch.	W. K. Hoffman	Maurer & Duggan	1926	3,696		
76	6.7 miles southeast of Freer.	G. Ruiz estate			194	6	W
77	6 miles east-southeast of Freer.	L. T. Scholars			98	60	W
78	9.2 miles south of Freer	Candelario Cuellar		Old	220	5	W
79	6 miles south of Freer	D. Ruiz			280	5	W
80	3¾ miles south-southeast of Freer.	M. C. Hubbard		1870	200	72	W
81	1.7 miles south of Freer	Bishop Duval Land Co.	H. B. Schlesinger, trustee.	1927	3,010	10	W
82	1.2 miles southwest of Freer.	C. W. Hahl	Magnolia Petroleum Co.	1929	5,370	12½	
83	1 mile southwest of Freer	do	do	1932	260	6⅝	P
84	1¼ miles southwest of Freer.	Magnolia Petroleum Co.	do	1930	600		P
85	2 miles southwest of Freer.	H. A. Lundell	do	1930	5,858	12½	
86	2½ miles south-southwest of Freer.	P. E. White			225		W
87	3½ miles south of Freer	Bishop Cattle Co			200	5$\frac{3}{16}$	W

See footnotes at end of tables.

County, Tex.—Continued

Principal water-bearing bed		Water level					
Depth (feet)	Geologic formation	Below benchmark (feet)	Date of measurement	Height of benchmark above ground level (feet)	Use of water[2]	Remarks	Well no.
100–?	Goliad	97	June 9, 1931	1.5	D,S	Water level rose 4 feet in 5 minutes after windmill was shut off. Dug well 5 feet square to 50 feet; drilled well 4 inches in diameter 50 to 120 feet.	60
	do	47.46	Sept. 26, 1933	2	D,S		61
	Oakville?	100	Sept. 4, 1932		D,S		62
						Houston Oil Co. No. 1 Wood & Welder; oil test, no production.	63
	Oakville		June 12, 1931		S	Blue shale 300–400 feet probably Oakville.	64
			do		S	Mar-Tex Oil Co. No. 1 A. J. Ridder et al.; oil test, no production.	65
	Oakville	100	do	1.5	D,S		66
	do	125	Sept. 3, 1932	0	D,S		67
	Goliad	80	Sept. 9, 1931	1	D,S	Water level rose 7 feet in 10 minutes after pump was shut off.	68
	do	77.29	Sept. 26, 1933	2.5	D,S	Well cased to 10 feet	69
	do	57	June 9, 1931	1	D,S		70
	do	46	do	2.5	D,S	Dug well	71
	do	38.6	Apr. 2, 1031	0	D	Struck water at 30 feet	72
	do	38.02	Sept. 26, 1933	3	D,S	Dug well	73
	Oakville	89	Sept. 9, 1931	1.5	D,S		74
						Maurer & Duggan No. 1 Hoffman; oil test, no production. Altitude above sea level, 555 feet.	75
	Catahoula	22	June 9, 1931	1.5	D,S		76
	do	91	June 10, 1932	2	S	Dug well	77
	do	108	Apr. 3, 1931	2.5	D,S		78
	do	123	Apr. 4, 1931	.8	D,S	Well cased to 240 feet	79
	do	43	Apr. 3, 1931	2.5	S	Dug well	80
	do	158	do	.6	S	H. B. Schlesinger, trustee, No. 1 C. W. Hahl; oil test, no production. Pulled back casing to make a water well.	81
						Magnolia Petroleum Co. No. 7 "B" C. W. Hahl; oil test, no production. Altitude 590 feet.	82
230–250	Catahoula		Dec. 8, 1932		P	2 wells together. Water sands also at 120–140 feet.	83
	do				D, P	2 wells close together; the other one is 180 feet deep. Each well yields about 15 gallons a minute.[3]	84
						Magnolia Petroleum Co. No. 1 Lundell; oil test yielded 15,000,000 cubic feet of gas and 300 barrels of oil at 23.28 feet. Altitude, 595 feet.	85
	Catahoula				D, S		86
	do	186	Mar. 5, 1931	1.5	S		87

Records of wells in Duval

Well no.	Location	Owner	Driller	Date completed [1]	Depth (feet)	Diameter (inches)	Method of lift [1]
88	4 miles south-southwest of Freer.	Bishop Duval Land Co.	Magnolia Petroleum Co.	1931	2,250	12½	------
89	4.7 miles southwest of Freer.	P. E. White		------	98	------	------
90	4½ miles southwest of Freer.	Bishop Cattle Co.	Duval Oil Corporation.	1931	440	------	P
91	5 miles south-southwest of Freer.	do		------	160	6	------
92	6¾ miles south of Freer	M. Ruiz		------	177+	5	W
93	6½ miles south-southwest of Freer.	do	Magnolia Petroleum Co.	1932	185 340	6⅝ 6⅝	P
94	6¼ miles southwest of Freer.	do		------	120	5	------
95	6½ miles southwest of Freer.	Duval County Ranch Lands Co.		Old	125	6±	W
96	6 miles west-southwest of Frier.	do		------	195	6	W
[4]97	8¼ miles south-southwest of Freer.	do		------	105	7	W
98	do	do	Gordon, Folwell & Dixon.	1926	3,520	10	None
99	10½ miles southwest of Freer.	do		------	125	6	W
100	11¼ miles south-southwest of Freer.	do		------	255	6¾	W
101	10¾ miles south-southwest of Freer.	A. Weil and others	J. W. O'Byrne Co.	1931	------	------	------
102	11¼ miles south-southwest of Freer.	Sternes & Akin	Monroe Whitman	1923	208	8	P
103	12½ miles southwest of Freer.	Duval County Ranch Lands Co.		------	300+	5⅞	W
[4]104	14 miles southwest of Freer.	do		------	800	5⅞	W
105	15 miles south-southwest of Freer.	W. R. Peters		------	------	5	W
106	14½ miles south-southwest of Freer.	do	U. S. Gas & Oil Co.	1926	2,814	8¼	------
107	4½ miles north of Kohler ranch.	do		------	300	8	W
108	do	do		------	200	5	W
109	5 miles northwest of Kohler ranch	V. Kohler estate	Humble Oil & Refining Co.	1927	3,075	6⅝	------
[3]110	4¾ miles northwest of Kohler ranch.	do	do	------	410	7	W
[3]111	4½ miles northwest of Kohler ranch.	do	do	------	520	------	------
112	3½ miles west-southwest of Kohler ranch.	do	do	------	420	7	P
113	do	do	do	------	420	7	P
114	do	do	do	1927	420	7	P
115	3¾ miles southwest of Kohler ranch.	do	do	1927	3,056	6⅝	------
116	3 miles north of United Gas Co. pumping station.	J. T. Dinn	E. R. David	------	282	------	------
117	2¾ miles north of United Gas Co. pumping station.	do		------	300	------	------
[4]118	United Gas Co. pumping station.	United Gas Co.		------	438	6	------

See footnotes at end of tables.

County, Tex.—Continued

Principal water-bearing bed		Water level					
Depth (feet)	Geologic formation	Below benchmark (feet)	Date of measurement	Height of benchmark above ground level (feet)	Use of water [2]	Remarks	Well no.
						Magnolia Petroleum Co. No. 1 J. O. Wilson. Initial production, 25,000,000 cubic feet of gas.	88
	Calahoula				S	Water salty	89
200–?	do				P	Yields 800 to 900 barrels a day.	90
	do				N	Not enough water to warrant pumping.	91
	do	141.9	Apr. 5, 1931	1.9	S		92
164–180; 164–174	do	340			P	2 wells together	93
	do	90.5	Mar. 16, 1931	1	S		94
	do		Mar. 2, 1931		D, S		95
	do		do		S		96
92–105	do	60.8	do	1.5	S		97
90–150	do	60.3	do	1	N	Yield of 700 barrels a day reported by Ab Rutledge.	98
	do		Apr. 17, 1931		S		99
	do	118	Apr. 22, 1931	1.2	S		100
240–300	do	[5] 40				Drilled as an oil test. Water encountered also at 140–280 feet.	101
	do	99.5	Apr. 16, 1931	1	D, S, P.	Reported yield, 550 barrels a day.	102
	do	137.5	Apr. 17, 1931	1	S	Water salty [3]	103
	Jackson	98	Mar. 5, 1931	1	S		104
	Catahoula	114	Sept. 24, 1931	0	S		105
				0		U. S. Gas & Oil Co. No. 1. W. R. Peters; oil test, no production. Tested as a water well at 300 feet but bailed dry.	106
	Catahoula	232	Aug. 16, 1932	1.5	S	Water slightly salty [3]	107
	do	146.5	Aug. 22, 1931	1	S		108
				0		Humble Oil & Refining Co. No. 1 Kohler; oil test, no production. Altitude, 75 feet.	109
383–400	Catahoula	320	June 6, 1931	0	S	Water tastes bad	110
518–520	do	120	do	0	N	Yielded 2,000 barrels a day. Water impregnated with hydrogen sulphide.	111
405–420	do	[3] 125	do	0	D, P	Yields 42 gallons a minute. Cased to 420 feet.	112
405–420	do	125	do	0	D, P		113
405–420	do	125	do	0	D, P		114
				0		Humble Oil & Refining Co. No. 3 Kohler; oil test, no production.	115
270–280	Catahoula	50	Aug. 30, 1932		P		116
?–270	do	80	Aug. 9, 1932	0	D, S		117
	do	200	June 6, 1931		P	Well cased to 438 feet	118

Records of wells in Duval

Well no.	Location	Owner	Driller	Date completed	Depth (feet)	Diameter (inches)	Method of lift [1]
119	3½ miles east of United Gas Co. pumping station.	J. T. Dinn			140	6	P
120	4 miles east-northeast of United Gas Co. pumping station.	do	E. R. David		200	8	P
121	4½ miles northeast of United Gas Co. pumping station.	R. López and others.			105	60	P
122	Kohler ranch	V. Kohler estate			260	6	W
123	2 miles southeast of Kohler ranch.	do		Very old.	223	60	W
124	4½ miles east-southeast of Kohler ranch.	J. Carillo		Old	172	6	W
125	6 miles southeast of Kohler ranch.	Robert Driscoll			190	6	W
126	5 miles south of Sutherland ranch.	do			82?	6	W
127	Peters ranch	W. R. Peters			200	70	P
128	2 miles west-northwest of Sutherland ranch.	G. Sutherland	W. L. Benedum	1926	3,003	12½	
129	Sutherland ranch	do			200	6	W
130	3½ miles east of Sutherland ranch.	do			200‡	6	W
131	5 miles east of Sutherland ranch.	J. M. Luby	Callahan, Howard & Smith.	1930	4,024		
132	7 miles west of Benavides.	Francisco Vaello		1924	200	4	W
133	6 miles southwest of Benavides.		National Oil Co.	1928	4,009	10	
134	3½ miles west of Benavides.	J. Carrillo			123	7	W
[8]135	4¾ miles west-northwest of Benavides.	D. Ruiz			60	48	W
[8]136	5½ miles west-northwest of Benavides.	do			60±		W
[8]137	6 miles west-northwest of Benavides.	Pedro López			45		W
[8]138	6¼ miles west-northwest of Benavides.	M. B. de Gonzales.			40		W
139	5 miles northwest of Benavides.	W. Wyatt				4	W
[8][4]140	5½ miles north of Benavides.	Duval-Texas Sulphur Co.			443	6⅝	P
141	3½ miles northwest of Benavides.	Mary Luby		Old		6	W
[8]142	2 miles northwest of Benavides.	Pancho Vaello			60	60±	W
[8]143	Benavides	S. Ruiz			40	36	H
[8]144	do	P. Coronado			48		P
[8]145	do	T. Ramírez			48		W
[6]146	do	José Garza	D. F. Redner	1928	207	5 3/16	W
[6]147	do	Louise Torres	D. C. Whitman	1925	95	6½	W
148	do	—— Salinas			217		W

See footnotes at end of tables.

County, Tex.—Continued

Principal water-bearing bed		Water level					
Depth (feet)	Geologic formation	Below benchmark (feet)	Date of measurement	Height of benchmark above ground level (feet)	Use of water [2]	Remarks	Well no.
	Goliad	40	Aug. 22, 1932		D, S		119
	do	[3] 50	Aug. 30, 1932		D, S		120
	do	50	Aug. 22, 1932		D, S	Dug well	121
{189-? 260-?}	Catahoula	200	June 5, 1931	0	D, S		122
	do	119	do	0	S	Dug well	123
	do	150	1931	0	D		124
	do	129	June 5, 1931	1.5	D, S	Water level rose 9 feet in 10 minutes after pump was stopped.	125
	Oakville?	77.5	June 10, 1931	.5	S	No appreciable lowering of the water level after 5 minutes pumping.	126
	Catahoula	91	do	3	D, S	Dug well	127
						W. L. Benedum No. 1 Sutherland; oil test, no production.	128
	Catahoula	144	June 10, 1931	.5	D, S	Pumping lowered the water level 5 feet in 5 minutes.	129
	do	80	Apr. 24, 1934	1	S		130
						Callahan, Howard & Smith No. 1 Luby; oil test, no production.	131
	Goliad?	160	June 10, 1931	2.5	D, S	Water sands reported at 130 and 275 feet. Altitude, 565 feet.	132
						National Oil Co. No. 1 Ball, block 16, Ball subdivision. Oil test; produced 2,000,000 cubic feet of gas. Altitude, 445 feet.	133
	Goliad	110	June 10, 1931	1.5	D,S		134
	do	49.5	Mar. 21, 1933	0	D,S	Dug well	135
	do	50	Mar. 24, 1933		D,S	do	136
	do	40	Mar. 21, 1933	0	S	do	137
	do	33	do	0	D,S	do	138
	do	43	Apr. 15, 1931	2.3	S		139
292-387	do	[3] 113	Aug. 30, 1932		P	Well representative of 16 wells within a radius of ¼ mile. Cased 440 feet, of which 82 is perforated. Other water bearing beds at 10-32, 178-187 and 215-254 feet. Yields 120 gallons a minute.	140
	do	71	Aug. 15, 1931	.4	S		141
	do	52	Mar. 21, 1933	0	D,S	Dug well	142
	do		Dec. 14, 1932	0	D,S	do	143
	do	46	Sept. 19, 1933	1.5	D,S	do	144
	do	46.28	do	1	D,S	do	145
	do		Dec. 14, 1932		D,S		146
	do		do		D,S		147
	do		do			Reported as yielding good water when drilled, became bad later.	148

Records of wells in Duval

Well no.	Location	Owner	Driller	Date completed	Depth (feet)	Diameter (inches)	Method of lift [1]
[3] [5]149	Benavides	F. Vaello Puig	D. F. Redner	1927	254	6	P
[4]150	do	Texas Mexican Ry.			582	6	P
[6]151	do	Coronado Motor Co.	D. F. Redner	1928	247	4¼	W
[6]152	do	M. Cuellar	G. Méndez	1928	90	6⅝	W
[5]153	do	Benavides Milling & Gin Co.		1905	96	6	P
[6]154	do	J. A. Heras	D. F. Redner	1929	110	6	W
[4] [5]155	do	F. Vaello, Jr.			252½	4½	W
[6]156	do	F. E. Whitaker	D. F. Redner	1928?	225	5³⁄₁₆	W
[3] [8]157	2½ miles southwest of Benavides.	Francisco Vaello			140	5³⁄₁₆	W
[8]158	1¾ miles south-southwest of Benavides.	Marcos Gómez			132	5³⁄₁₆	H
[8]159	2 miles south of Benavides.	Francisco Vaello				5³⁄₁₆	W
160	2½ miles south of Benavides.	Juan Carrillo		Old	100	6	W
[8]161	3¾ miles south of Benavides.	J. B. Ancina		1922	176	4¼	
[6]162	do	A. Parr			180	4¼	W
[8]163	3¾ miles south-southeast of Benavides.	do			110	4	W
[8]164	4½ miles south-southeast of Benavides.	do			180	6⅝	
165	4½ miles south of Benavides.	do	J. J. White	1903	185	6	P
[8]166	5¼ miles south-southeast of Benavides.	do			200	5³⁄₁₆	W
[8]167	5¾ miles south of Benavides.	do			200	5³⁄₁₆	W
[4]168	6¼ miles south of Benavides.	do	D. F. Rednor		240	6	W
[8]169	6¾ miles south of Benavides.	do				5³⁄₁₆	W
[8]170	7½ miles south of Benavides.	do			160	4¼	W
[8]171	6½ miles south-southeast of Benavides.	do			150	8	W
[8]172	do	do			130	4¼	W
[8]173	2½ miles east of Benavides.	Ismael García			80±	48	
174	2 miles east of Benavides	W. R. Peters			200±	6	W
[8]175	1 mile east of Benavides	Mrs. Tom Cavanaugh.				48	W
176	2 miles northeast of Benavides.	C. A. Tinney	Gulf Production Co.	1927	4,005	10	
177	2.8 miles northeast of Benavides.				200	6	W
178	5.3 miles northeast of Benavides.	Halff estate			230	6	W
[8]179	5½ miles east-northeast of Benavides.	J. Halff			60	48	W
180	4¼ miles north-northeast of Guajillo.	W. Hoffman		Old	237	6	W
[8]181	3½ miles north-northeast of Guajillo.	Hilario García		1927	125	5³⁄₁₆	H
[4]182	do	do			45	48	
183	2½ miles north-northeast of Guajillo.	Lazaro Vela			80	7	W

See footnotes at end of tables.

County, Tex.—Continued

Principal water-bearing bed: Depth (feet)	Principal water-bearing bed: Geologic formation	Water level: Below benchmark (feet)	Water level: Date of measurement	Water level: Height of benchmark above ground level (feet)	Use of water [2]	Remarks	Well no.
	Goliad	60	1928		D,S,I	Well cased to 250 feet. Yields 20 gallons a minute. Other water-bearingbeds at 50 and 90 feet.	149
	Oakville?	60	Dec. 18, 1932	1.5	RR		150
232-247	Goliad	63.37	Dec. 14, 1932	2	D,S		151
75-90	do		do		D,S		152
{40-45, 90-96}	do	45	1928		D,S,P	Well cased to 90 feet	153
90-110	do		Dec. 14, 1932		D,S		154
240-252	do	60	1928			Well cased to 252 feet. Bottom joint of casing perforated.	155
			Dec. 14, 1932		D,S		156
		93.77	Sept. 27, 1933	1	D,S	Water slightly salty	157
		96.95	do	1	D,S		158
			Mar. 21, 1933		D,S		159
	Goliad	76	June 3, 1931	2	D, S		160
	do		Mar. 21, 1933		D, S		161
	do		Mar. 22, 1933		S		162
	do	58	do	3	D, S		163
	do	74	do		N	Water reported so highly mineralized that well was abandoned.	164
{50-165, 180-185}	do	86	Sept. 2, 1932		D, S, I	Well cased to 20 feet. Yields 75 gallons a minute with a drawdown of 20 feet. Other water-bearing beds at 50 feet and 165 feet.[3]	165
	do	110	Mar. 22, 1923	1	S		166
			do		S		167
	Goliad	120	Sept. 2, 1932		D, S		168
	do	116	Mar. 22, 1933	3	S		169
	do		do		S		170
	do	76	do	1	S	Water salty [3]	171
	do		do		S		172
	do	47.25	Sept. 28, 1933	0	N	Dug well	173
	do	75			D, S		174
	do	51.43	Sept. 27, 1933	1	D, S	Dug well	175
						Gulf Production Co. No. 1 Tinney; oil test.	176
	Goliad				S		177
	do	135.5	Dec. 10, 1932	1.5	S	Water salty	178
	do	49.13	Sept. 27, 1933	2	S	Dug well	179
	do	100	May 15, 1931	2	D, S		180
	do	43.09	Sept. 16, 1933	1	S	Water salty [3]	181
	do	34.33	Sept. 17, 1933	0	N	Dug well [3]	182
	do	58.0	May 15, 1931	.5	D, S		183

Records of wells in Duval

Well no.	Location	Owner	Driller	Date completed	Depth (feet)	Diameter (inches)	Method of lift [1]
[8]184	2½ miles north-northeast of Guajillo.	E. Alanis			90	72	H
185	Guajillo	C. Moreno	Antonio García	Old	90	6	W
[8]186	do	A. G. de Sáenz	Cervando Sáenz	1922	40	48	H
187	3 miles east-southeast of Guajillo.	F. López		Very old.	70	36	W
[8]188	1 mile north of San Jose	Encarnación Peña	Hinojosa	1932	130	8	H
[4]189	San Jose	Pedro López		1922	100	6	W
[8]190	½ mile south of San Jose	Margarita López			90	60	W
191	2 miles west-southwest of San Jose.	Pedro Basan	Domingo Ramírez	1928	107	4	W
192	3 miles south-southwest of San Jose.	Mrs. M. T. Lowell				6	W
193	3½ miles south-southwest of San Jose.	J. Baredo		Old	100	6	W
[8]194	5 miles south of San Jose	A. Parr			95	5$\frac{3}{16}$	W
[8]195	6 miles south of San Jose	do			200	5$\frac{3}{16}$	W
[4]196	5 miles south of San Jose	A. Sáenz		1925	115	6	W
197	6 miles north of Santa Cruz.	J. M. Gonzales	Fermín Sauceda		318		W
198	5½ miles north of Santa Cruz.	B. Sáenz		1923	90	5	W
199	5 miles north of Santa Cruz.	P. G. Canales			260		W
200	4½ miles north-northeast of Santa Cruz.	A. Canales			305		W
201	1.2 miles north of Santa Cruz.	Marco Villareales	José Bareda	1916	125	4	W, P
202	½ mile west-northwest of Santa Cruz.	Amos Madison			327	8	W
203	Santa Cruz	N. E. Martínez	Fermín Sauceda		200+	4	W
204	1 mile south of Santa Cruz.	Hilario Sáenz	do	1927	310	7	W, P
205	1¼ miles south-southeast of Santa Cruz.	J. M. Martínez		1933	311		W
206	1 mile south of Santa Cruz.	Incarnación Martínez.			101	5	W
207	2 miles east of Concepcion.	G. Silva	G. Pérez	1910	81	6	W
[8]208	1½ miles east of Concepcion.	M. C. de Sáenz	Guillermo Pérez	1913	103	4	W
[4]209	Concepcion	W. S. Evans	do	1931	156.5	6	P
[8]210	do	C. Y. Hinojosa		1911	101	5$\frac{3}{16}$	W
211	1.3 miles north of Concepcion.	J. Carrillo	Santiago Bareda	1927	93		W
[8]212	3 miles north-northwest of Concepcion.	J. Salinas			100	4¼	W
[8]213	6¼ miles north-northeast of Concepcion.	A. Parr			180	4¼	W
[8]214	5¾ miles north of Concepcion.	do			140		W
215	6¼ miles north of Concepcion.	do			170	6	W
216	5¾ miles north of Concepcion.	do			200	+6	W
217	6 miles north of Concepcion.	do			180	+5	W
218	5½ miles north-northwest of Concepcion.	do			5,015		
[8]219	5 miles northwest of Concepcion.	C. G. de Rodríguez			100	5$\frac{3}{16}$	W
[4,8]220	4¾ miles northwest of Concepcion.	E. García			120	4¼	W
221	5 miles west-northwest of Concepcion.	R. Méndez		1915	105	6	W

See footnotes at end of tables.

County, Tex.—Continued

Principal water-bearing bed: Depth (feet)	Principal water-bearing bed: Geologic formation	Water level: Below benchmark (feet)	Water level: Date of measurement	Water level: Height of benchmark above ground level (feet)	Use of water [2]	Remarks	Well no.
	Goliad	45.45	Sept. 28, 1933		D, S	Dug well	184
	do	42.5	May 25, 1931	1.5	D, S	Water slightly salty [3]	185
	do		Nov. 17, 1933	2	D, S	Dug well	186
	do	42.0	May 25, 1931	0	D, S	do	187
	do	76.11	Sept. 28, 1933	1.5	D, S		188
	do	64.5	May 15, 1931	1.5	D, S		189
	do	40.05	Sept. 28, 1933	3	D, S	Dug well	190
70–72, 105–107	do	31.66	May 28, 1931	2	D, S		191
	do	97.5	May 26, 1931	2	D, S		192
	do	67.5	do	1.5	D, S		193
	do		Mar. 22, 1933		S	Dug well	194
	do		do		S	Water "bad" [3]	195
	do	56.3	May 26, 1931	1	D, S	Well cased to 5 feet. Capacity of pump 1½ gallons a minute.	196
	do	[3] 40			D, S		197
	do	45	May 26, 1931	.5	D, S	Well cased to 20 feet. Water salty.[3]	198
	do				S		199
	do	40	Sept. 1, 1932		D, S		200
	do	78.9	May 26, 1931	1	D, S	Well cased to 30 feet	201
	do		Dec. 9, 1932		D, S		202
	do	49.05	do	3	D		203
	do	60.9	May 26, 1931	2.5	D, S	Well cased to 300 feet. Water level rose 2.6 feet in 5 minutes after pumping stopped.	204
	do		Oct. 30, 1933				205
	do	77.81	Dec. 9, 1932	2	D, S		206
	do	73.4	May 27, 1931	1.3	D, S	Well cased to 20 feet	207
	do	56.2	Oct. 28, 1933	1.5	D, S	do	208
145–156	do	45.3	May 29, 1931	1	P	Cased to 20 feet. Fair water reported at 60–65 feet, better water at 125 feet, and good water at 145 feet.	209
	do	43.95	Nov. 11, 1933	2	N		210
45–50, 90–93	do	50	May 29, 1931	.5	D,S	Cased 3 feet. Water salty [3]	211
	do		Mar. 21, 1933		D,S		212
	do		Mar. 22, 1933		S		213
	do		do		S		214
	do	90	Sept. 2, 1932	0	S	Salty water [3]	215
	do	90	do	0	S		216
	do	70	do	0	S		217
						R. A. Thompson No. 1 Parr oil test; no production.	218
	Goliad		Mar. 21, 1933		D,S		219
	do		Apr. 5, 1933		D,S		220
40–105	do	85	June 2, 1931	1	D,S	Salty water [3]	221

Records of wells in Duval

Well no.	Location	Owner	Driller	Date completed	Depth (feet)	Diameter (inches)	Method of lift [1]
[8] 222	4¼ miles west of Concepcion.	C. Sandoval	Alfonso Cantu	1927	100	6	W
[8] 223	3 miles west of Concepcion.	A. Lozano	Cleofus Ramírez	1926	110	4	W
224	5 miles east of Realitos	R. Mêndez			120	6	W
225	2½ miles east of Realitos	P. McBride	Producers Oil Co	1911	3,006	10	Flow
226	2.2 miles east of Realitos	do			181	6	W
[3] 227	3 miles southeast of Realitos.	R. J. Turner	—— Coleman		200	6	W
[6] 228	4¾ miles southeast of Realitos.	Wilbur Bub	do	1915	189	6	W
[4] 229	do	Karl Mann	John Brieden		200	6	W
[8] 230	3½ miles south of Realitos.	San Antonio Loan & Trust Co.				48	W
[6] 231	3 miles south of Realitos	W. Jenkins	W. Jenkins	1916	100	5 3/16	W
[6] 232	do	do	do	1918	150	5 3/16	W
[5] 233	3.2 miles north-northeast of Crestonio.	Milton Dubose	J. David		195	6	W
234	4 miles north-northeast of Crestonio.	E. J. Rodgers			208	5⅞	W
[8] 235	Realitos	Texas Mexican Ry.					W
[6] 236	do	Realitos School	D. F. Redner	1929	150		P
[7] 237	do	Felipe Ramírez	Albert Ashwood	1909	140	5	W
238	do	J. M. Benavides		1932	150		W
239	do	Guillermo Guerra	C. Ramírez	1927	134	6	W
240	1½ miles northeast of Realitos.	Gus Minges			154		W
[4] 241	3 miles northwest of Realitos.	J. S. Barnes	J. S. Barnes		146	6	W
242	4 miles northwest of Realitos.	G. W. Haynor	do		143	6	W
243	4½ miles west-northwest of Realitos.	W. R. King	Hoffer & Smith		2,534		
[8] 244	3½ miles west of Realitos	do				4¼	W
[6] 245	2½ miles west of Realitos	A. C. Rabe	E. R. David	1932	150	5 3/16	W
[6] 246	2¾ miles west-southwest of Realitos.	Mrs. C. Rabe		1932	157	5 3/16	W
[8] 247	4¼ miles west-southwest of Realitos.	G. B. Barfield		1924	190	4¼	W
[6] 248	4½ miles west of Realitos	Alfred Person	—— Coleman	1916	170	4¼	W
[8] 249	do	W. M. Person			180	5 3/16	W
250	do	do	—— Coleman	1916	200	5 3/16	W
[8] 251	4 miles west of Realitos	C. A. R. Weid		1928	180	5 3/16	W
252	5 miles west of Realitos	W. R. King	F. H. Zock		4,011		
253	do	do			230		
254	5¼ miles west of Realitos	W. R. King, F. H. Zock.	Archie Long	1927	251		P
255	7¾ miles west of Realitos	J. Dunn			350	5 3/16	W
256	5 miles northwest of Crestonio.	do			117	5 3/16	W
257	3¾ miles northwest of Crestonio.	do	Southern Crude Oil Purchasing Co.		4,002	10	
258	9¾ miles west of Realitos	A. E. Rouse	A. E. Rouse		81		W
[8] 259	10½ miles north of Hebbronville.	P. F. Baker				4¼	W
[3] 260	Houston Oil Co. station.	Houston Oil Co			306	6	P
261	1½ miles south-southeast of Houston Oil Co. station.	Rosa Benavides	Cole Petroleum Co		6,393	6⅝	

See footnotes at end of tables.

County, Tex.—Continued

Principal water-bearing bed		Water level					
Depth (feet)	Geologic formation	Below benchmark (feet)	Date of measurement	Height of benchmark above ground level (feet)	Use of water [2]	Remarks	Well no.
	Goliad	63.97	Oct. 30, 1933	1	D,S	Well cased 40 feet	222
70–110	do	51.9	do		D,S	Well cased to 60 feet	223
	do	79	June 2, 1931	2	D,S	Salty water.[3]	224
2,275–2,332	Catahoula	[3] Flows.	1911	0		Water reported hot. Rises 20 feet above ground level.	225
	Goliad	100	June 2, 1931	2.1	S		226
	do	100	do	2.5	D,S		227
	do	[3] 68	Jan. 6, 1933		D,S		228
160–168	do	55	June 2, 1931	0	D,S		229
	do	60	Sept. 28, 1933	2	D,S	Dug well	230
	do	68.51	Jan. 6, 1933	1	D,S	Well cased 2 feet	231
	do	[3] 73	do		D,S	Well cased 40 feet	232
189–195	do	140	Feb. 29, 1928		D,S	Irrigates satisfactorily most crops except potatoes.	233
200–208	Goliad	168½	June 2, 1931	1.5	D, S		234
	do		Mar. 20, 1933		RR		235
	do		Mar. 14, 1933		D		236
120–140	do	115	1913	0	D, S		237
	do		Mar. 14, 1933				238
132–134	do	112	1928	0	D, S		239
		100	Sept. 2, 1932		D, S		240
143–146	Goliad	143	June 4, 1931	0	D. S	Small seep at 125 feet	241
127–143	do	[3] 143	do		D, S		242
						Hoffer & Smith No. 1 King; oil test, no production. Altitude, 540 feet.	243
	Goliad	14	Mar. 21, 1933		S		244
	do	140	Jan. 6, 1932		D, S		245
	do		do		D, S		246
	do	180	Mar. 21, 1933		D, S		247
	do		Jan. 6, 1932		D, S		248
	do	[3] 150	Mar. 21, 1933		D, S		249
	do		Jan. 6, 1932		D, S		250
	do	164	Mar. 21, 1933		D, S		251
						F. H. Zock No. 1 King; oil test, no production.	252
	Goliad	148	Mar. 21, 1933		N		253
205–220	do	[3] 50	Aug. 27, 1932			Capacity of pump, 10 gallons a minute.	254
	do				S		255
	do		Mar. 21, 1933		D, S		256
						Southern Crude Oil Purchasing Co. No. 1 Dunn; oil test, no production. Altitude, 595 feet.	257
78–81	Goliad	78	Aug. 27, 1933		D, S		258
		76	Mar. 21, 1933		D, S		259
	Catahoula	50	June 6, 1931		D, S	4 wells; 1 yields 20 gallons a minute, the other 3 yield very little. Water bitter.	260
				0		Cole Petroleum Co. No. 75 Rosa Benavides; oil test, no production. Altitude, 725 feet.	261

Record of wells in Duval

Well no.	Location	Owner	Driller	Date completed	Depth (feet)	Diameter (inches)	Method of lift [1]
262	4.3 miles south-southeast of Houston Oil Co. station.	J. Benavides	Moody Oil Corporation.	------	2,549	6⅝	------
263	4½ miles southeast of Houston Oil Co. station.	do	Mesquite Oil Co.	------	2,159	------	------
264	5 miles north-northwest of Hebbronville.	J. V. Cuellar	E. R. David	------	182	6	W
[3] 265	4 miles north-northwest of Hebbronville.	E. Trevino	do	------	164	6	W
266	3½ miles north-northwest of Hebbronville.	E. R. David	do	------	196	6	W
267	2½ miles west of Crestonio.	W. R. King	D. F. Redner	------	465	------	W
268	1¼ miles southwest of Crestonio.	Henry Weid	S. Douglas	1914	235	6	W
[4] 269	Crestonio	Melvine Irrigation & Cattle Co.	------	------	1,600	4	F
270	6¼ miles south of Realitos.	Karl Mann	------	------	180	6	W
[8] 271	5½ miles south-southeast of Realitos.	J. Mann	------	------	90	5³⁄₁₆	H
[8] 272	4¼ miles northwest of Sejita.	San Antonio Loan & Trust Co.	------	------	100	60	P
[8] 273	3½ miles northwest of Sejita.	T. Sundstrom	------	1921	120	------	------
[8] 274	3¼ miles west-northwest of Sejita.	J. S. Ayala	------	------	------	------	W
[8] 275	2¼ miles west-northwest of Sejita.	San Antonio Loan & Trust Co.	------	------	------	------	W
276	4 miles west of Sejita	Hermann Dammier	T. M. Coleman	1914	102	6	W
277	4¾ miles west of Sejita	Wm. E. Hailer	------	------	------	4¼	------
[8] 278	4½ miles west-southwest of Sejita.	J. H. Miller	------	------	------	4¼	------
[8] 279	do	Wm. Fleurnoy	------	------	------	4¼	H
[8] 280	4 miles west of Sejita	V. Canales	------	------	------	4¼	H
[4] 281	2 miles southwest of Sejita.	G. A. Nieft	T. M. Coleman	1914	117	6	W
[8] 282	Sejita	Wm. Fleurnoy	do	------	90	4¼	H
[8] 283	3 miles north-northwest of Sejita.	D. C. Kinnie	------	------	60	------	H
284	2½ miles north of Sejita	M. Derike	------	------	------	------	W
[8] 285	2¾ miles north of Sejita	Juan Carbajal	------	------	------	------	
[8] 286	3¼ miles north-northeast of Sejita.	Mrs. J. Canay	------	------	20	------	W
[8] 287	4 miles west-southwest of Concepcion.	Virginia J. Ramírez	------	------	170	6	W
[8] 288	3½ miles north-northeast of Sejita.	R. R. de Chapa	------	------	30	------	W
[8] 289	3¼ miles northeast of Sejita.	Adolfo Garcia	------	------	80	4¼	W
290	3 miles northeast of Sejita	A. García	------	------	100±	6	W
291	2 miles east of Sejita	E. Morgan	------	------	250	5	W
292	1 mile east of Sejita	Rafael Flores	------	------	------	6	W
[8] 293	1¾ miles east-southeast of Sejita.	San Antonio Loan & Trust Co.	------	------	------	------	W
[8] 294	3¾ miles east-southeast of Sejita.	Leopoldo García	------	------	------	------	W
[8] 295	do	Elia García	------	------	------	------	W
[6] 296	6½ miles east-southeast of Sejita.	Lasater Estate	Adolfo Calderón	1915	127	5³⁄₁₆	W
297	do	San Antonio Loan & Trust Co.	------	1931	------	6	W

See footnotes at end of tables.

County, Tex.—Continued

Principal water-bearing bed		Water level					
Depth (feet)	Geologic formation	Below benchmark (feet)	Date of measurement	Height of benchmark above ground level (feet)	Use of water [2]	Remarks	Well no.
						Moody Oil Corporation No. 1. Mesquite ranch; oil test, no production. Altitude, 675 feet.	262
						Mesquite Oil Co. No. 2 El. Mesquite ranch; oil test, no production. Altitude, 658 feet.	263
	Goliad?	50	Aug. 30, 1932	0	D, S	Water impregnated with hydrogen sulphide gas.[3]	264
	do	50	do	0	D, S	Water impregnated with hydrogen sulphide gas. Capacity of pump 8 gallons a minute.	265
	do	50	do		D, S	Not a very strong well, as cylinder must be set in 50 feet of water; capacity of pump 8 gallons a minute.	266
400–465	Oakville?	16	Sept. 2, 1932		S		267
	Goliad	[3] 225	1928	0	D, S		268
1315–1316	Catahoula?	Flows	June 12, 1931	0	D, S, I	Altitude, 483 feet. Water rises 30 feet above ground level; flows 15 gallons a minute.[8]	269
	Goliad	66.5	May 30, 1931	2	D, S		270
	do	76.37	Sept. 28, 1933	.5	D, S		271
	do	84.14	do	.3	D, S	Dug well	272
80–120	do				D, S		273
	do		Mar. 15, 1933		D, S		274
			do		D, S		275
	Goliad	37.6	May 30, 1931	1	D, S	Well cased to 20 feet	276
	do	50.97	Nov. 2, 1933	.5	D, S		277
	do		do		D, S		278
	do	66.13	do	2	D, S		279
	do	42.57	do	2	D, S		280
	do	38	May 30, 1931	1.5	D, S	Cased 20 feet. Salty water at 65 feet; bitter water at 85 to 87 feet. Good water at 117 feet	281
		34.8	Nov. 1, 9133	1	D		282
	do		Mar. 15, 1933		D, S		283
	do		do		D, S		284
	do						285
	Goliad		Mar. 15, 1933			Dug well	286
	do	50.3	June 3, 1931	2		Water salty [3]	287
	do		Mar. 15, 1933		D,S	Dug well	288
	do	47.69	Aug. 23, 1933	2	N		289
	do	54	June 3, 1931	2	D,S		290
	do		Dec. 1, 1932				291
	do	30.5	May 29, 1931	2	D,S	Well cased 20 feet	292
	do		Mar. 15, 1933		D,S		293
	do		Dec. 15, 1932		S		294
	do		do				295
110–127	do	57.02	Dec. 8, 1932	1	S		296
200	do	61.5	May 29, 1931	1	D,S	Water salty [3]	297

Record of wells in Duval

Well no.	Location	Owner	Driller	Date completed	Depth (feet)	Diameter (inches)	Method of lift [1]
[6]298	6½ miles east of Sejita	A. A. Cosby					W
[6]299	6 miles east of Sejita	J. Nassiff					W
300	6 miles south of Concepcion.	A. Canales			240		W
[4]301	4¾ miles south of Concepcion.	Hilario García		1917	280	6	W
[6]302	4½ miles south of Concepcion.	Rafael García			80	4¼	H
[6]303	do	Dolores García	G. Pérez		82	4¼	H
304	3 miles south of Concepcion.	R. García		Old	90	6	W
305	5½ miles south-southeast of Concepcion.	Chevrolet Gardner			300		W
[6]306	6¼ miles south-southeast of Concepcion.	D. B. Cooper			300		W
[6]307	2 miles north-northwest of La Copita.	P. A. Burdett			300±		W
308	1½ miles northwest of La Copita.	M. S. McGahey	—— Foster		283±	5 3/16	W
309	1½ miles west-northwest of La Copita.	San Antonio Loan & Trust Co.	Adolfo Calderón	1915	300+	5 3/16	S W
[6]310	1 mile west of La Copita	E. G. Henderson			360		W
[6]311	½ mile south of La Copita.	George Frank	O. S. Caldwell	1905	674		W
[6]312	La Copita	Eliborio Villareal			304	4	W
[6]313	¼ mile north of La Copita	Porfirio Ayarzagoitia		1912	300		W
314	1½ miles north of La Copita.	—— Carlisle	Sun Oil Co	1926	2,760	12½	
315	do	Ruben Schultz			280	6	W
[6]316	3 miles north-northeast of La Copita.	Val Stockton		1916	295	5 3/16	W
317	4¼ miles north-northeast of La Copita.	W. N. Buchanan		1912	400±		W, P
318	3½ miles south of Santa Cruz.	Manuel Escobar			240	4	W
319	3¾ miles northeast of La Copita.	San Antonio Loan & Trust Co.			340	6	W, P
[4]320	3½ miles northeast of La Copita.	J. D. Moore	Fermin Sauceda		341	6	W
[4]321	1¾ miles east-northeast of La Copita.	Hilario Garza	do	1910	90	6	W
322	¾ mile east of La Copita	Santona Hinoyosa		1910	50	6	W
[6]323	2¾ miles east-southeast of La Copita.	Lasater estate			623	5 3/16	W
[6]324	3 miles east-southeast of La Copita.	J. E. Jameson			65	5 3/16	W
[6]325	3 miles east of La Copita	Val Stockton		1915	295	5 3/16	W
[6]326	3½ miles east-southeast of La Copita.	A. A. Cosby			400±	5 3/16	H

[1] W, windmill; P, power lift—gasoline or electric motor and pump jack, or air lift; H, hand lift.
[2] S, Stock; D, domestic; RR, railroad locomotives; I, irrigation; P, public, industrial, and well-drilling purposes; N, not used.
[3] Reported by driller or owner.
[4] For analysis of water see table on pp. 26–27.

County, Tex.—Continued

Principal water-bearing bed		Water level					
Depth (feet)	Geologic formation	Below benchmark (feet)	Date of measurement	Height of benchmark above ground level (feet)	Use of water [2]	Remarks	Well no. [2]
	Goliad		Mar. 15, 1933				298
	do		do		S		299
	do		Sept. 2, 1932			Water very salty [3]	300
250–280	do	50.6	May 29, 1931	1	D,S	First water at 70 feet, salty; water also at 150 feet. Well cased to 80 feet. [3]	301
	do	32.55	Sept. 29, 1933		D,S		302
	do	41.55	Nov. 1, 1933	2	S		303
	do	63.6	May 28, 1931	1	D,S		304
	do		Mar. 15, 1933		D,S		305
	do		do		D,S		306
	do		Mar. 13, 1933		D,S		307
250–283	do	54.00	Jan. 1, 1932		D,S	"Gyppy" water at 250 feet cased off; well deepened in 1914 to 283 feet, where sulphur water was encountered in black sand.[3]	308
243–269	do	71	1915		D,S	Water sand also at 65–85 feet.	309
	do		Dec. 15, 1932		D,S		310
643–664	do	8	Dec. 9, 1932	2.5		Screens set at 409–451, 589–629, and 643–664 feet. Reported to have flowed 75 gallons a minute in 1905.	311
	do		Dec. 15, 1932		D, S		312
300–?	do		Mar. 15, 1933				313
						Sun Oil Co. No. 1 Carlisle; oil test, no production. Water also at 254 and 580 feet.	314
	Goliad	48.2	Dec. 9, 1932	.6	D, S		315
	do	39.05	Jan. 6, 1933	2.5	D, S		316
	do				D, S		317
	do	29.2	May 26, 1931	2.5	D, S		318
300–340	do	24.6	May 27, 1931	1.5	D, S	Cased to 340 feet. Water also at 180 feet. Draw-down 0.05 foot in 5 minutes when pumped 2 gallons a minute.	319
302–341	do	40	do		D, S	Cased to 341 feet; water at 80 feet cased off; casing perforated below 60 feet, water also at 180 feet. Well was pumped for 2 days with a 2-inch pipe full; and water level lowered 6 feet.[3]	320
60–?	do	40.7	do	1	D, S		321
	do	39.67	Dec. 9, 1932	2	D, S	Formerly about 600 feet deep but has caved to 50 feet.	322
585–623	do	32.28	Dec. 8, 1932	1		Water-bearing sands also at 420–470 feet.	323
	do		Dec. 14, 1932		S		324
	do	39.05	Jan. 6, 1932	2.5	D, S	Water reported as being fine up to 4 or 5 years ago, when it became bad.	325
	do		Nov. 2, 1933		D, S		326

[5] Data furnished by S. S. Nye.
[6] Data furnished by S. F. Turner.
[7] Data furnished by Alexander Deussen.
[8] Data furnished by J. C. Cumley.

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