TEXAS WATER COMMISSION

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BULLETIN 6210

GROUND-WATER GEOLOGY OF BANDERA COUNTY, TEXAS

Prepared in cooperation with the Geological Survey
United States Department of the Interior
and the City of San Antonio

May 1962

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GROUND-WATER GEOLOGY OF BANDERA COUNTY, TEXAS

By

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United States Geological Survey

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GROUND-WATER GEOLOGY OF BANDERA COUNTY, TEXAS

ABSTRACT

Bandera County, in southwest-central Texas, is underlain by,a basement complex of Paleozoic rocks on which a wedge of Lower Cretaceous sedimentary rocks was deposited. After the Cretaceous rocks were deposited, structural deformation and erosion created a high plateau surface in the northwestern part of the county, capped by limestones of the Fredericksburg and Washita groups. Erosion has dissected the plateau in the remainder of the county so that only the interstream areas and high hills are capped by resistant remnants of these limestones. The Glen Rose limestone of the Trinity group forms the rest of the land surface except for minor alluvial deposits along stream valleys. The other Cretaceous formations, the Hosston, Sligo, and Pearsall. formations, do not crop out in the county, but occur in the subsurface overlying the truncated surface of Paleozoic rocks.

The regional dip of the rocks is southward or southeastward at a low angle, which steepens near the south edge of the county where small normal faults displace the beds. The general trend of the faulting is northeastward, parallel with the main development of the Balcones fault zone.

The limestones of the Fredericksburg and Washita groups yield small to moderate supplies of water of good chemical quality to wells and provide much of the low flow of the major streams through springs issuing from the base of the unit.

The Glen Rose limestone yields small quantities of water to many wells and springs in the county. Most of the water in the lower member is of good chemical quality; however, the water in the upper member is generally saline, being contaminated by sulfate-bearing water associated with anhydrite beds in the member.

Two members of the Pearsall formation, the .Cow Creek limestone member and the Hensell shale member, are aquifers in the county. The Cow Creek limestone member yields small to moderate quantities of water in most parts of the county. The Hensell shale member yields moderate to large supplies of water to wells in the northern part of the county. The water-bearing sandstone and conglomerate of the Hensell become shaly and thin in the southern part of the county. Consequently, the yields are small in the southern part, and the water becomes saline.

Sandstone and conglomerate of the Hosston and Sligo formations yield small to large quantities of water to a few wells in the county.

The principal use of ground water in Bandera County is for domestic and stock purposes in the rural areas. The city of Bandera has the only municipal supply in the county, and a few wells are used for supplementary irrigation in

the stream valleys. No wells are used for industrial purposes. It is estimated that the total use of ground water in the county is about 800,000 gallons per day. This probably is only a small percentage of the potential available for development.

GROUND-WATER GEOLOGY OF BANDERA COUNTY, TEXAS

INTRODUCTION

Purpose and Scope of Investigation

The investigation in Bandera County was made as part of a program of investigations to determine the occurrence of ground water along the south edge of the Edwards Plateau. The work was done by the U.S. Geological Survey in cooperation with the Texas Water Commission [formerly the Texas Board of Water Engineers] and the city of San Antonio. The purpose of the investigation was to obtain data pertaining to the composition, depth, and thickness of the water-bearing formations of the area, their capacities as aquifers, and the chemical quality of the ground water. The fieldwork was done at intervals during the period 1953-59.

The surface geology of Bandera County was mapped on aerial photographs and later transferred to a base map. Outcrops of geologic formations were measured to determine lithologic characteristics and thickness of individual beds for purposes of correlation with subsurface equivalents and with geologic units of surrounding counties. The subsurface study of lithology and correlation of the formations were effected through microscopic examination of well cuttings and the study of electric and radioactivity logs. The fossil identifications were made by the authors.

Measurements were made of the depth to water in wells and pumping data were collected where feasible to determine the hydrologic characteristics of the aquifers. Altitudes of wells were determined by either spirit or barometric leveling.

Records of 337 wells and springs (Table 2) and drillers' logs of 13 wells (Table 3) were collected during the investigation. Water samples were taken from 85 wells and springs (Table 4) and were analyzed in the laboratory of the Geological Survey in Austin, Texas.

Plate 1 shows the location of wells and springs in Bandera County for which records are available. For purposes of numbering the wells, the county has been divided into quadrangles, each embracing 10 minutes of latitude and longitude. The quadrangles are labeled alphabetically, beginning in the northern part of the county, and the wells are numbered consecutively within each quadrangle.

The investigation was made under the administrative direction of A. N. Sayre and P. E. LaMoreaux, successive chiefs of the Ground Water Branch of the U.S. Geological Survey, and under the supervision of R. W. Sundstrom, district engineer in charge of ground-water investigations in Texas.

Location and Areal Extent

Bandera County is in southwest-central Texas at the south edge of the Edwards Plateau between longitudes 98°45' and 99°37' W. and latitudes 29°33' and 29°54' N. (Figure 1). Adjacent bounding counties are Kerr on the north, Kendall on the northeast, Bexar on the southeast, Medina and Uvalde on the south, and Real on the west. The town of Bandera, the county seat, is about 38 miles northwest of San Antonio. The county has an area of approximately 765 square miles.

History and Economic Development

Bandera County was created by legislative action in 1856, 2 years after the colonization of the first settlement near the present town of Bandera. The name Bandera is the Spanish word for "flag." According to popular belief, in 1752 a troop of Spanish cavalry was ambushed by Apache Indians in the narrows near the headwaters of Bandera Creek. After the battle, the victorious Spanish placed flags on the surrounding heights to serve either as a warning to future marauders or to delineate the boundary between Spanish and Indian lands.

Development of the area started in 1854 with the establishment of saw and shingle mills along the watercourses where giant cypress timber flourished. The first community, consisting of Mormon settlers, was located in 1854 in an area now covered by the impounded water of Medina Lake.

In 1856, U.S. Cavalry troops set up camp on Verde Creek to protect the area from recurrent Indian raids. By 1860 flour mills, improved sawmills, and a cotton gin were located at the town of Bandera, the commercial center of widespread ranching activities.

After the timber resources were depleted, most of the activities were directed to stockraising, and today Bandera County is primarily ranching country. The predominately rough and rolling land is used for the raising of livestock, mohair and wool being the principal products. Most of the farming is limited to the cultivation of feed and grain crops on river terraces. Most of the land is dry farmed. Supplementary income is derived from the leasing of hunting acreages and the operation of dude ranches.

Bandera had a population of 1,036 in 1960. Other communities are Medina, population 475; Pipe Creek, population 220; Bandera Falls, population 30; Medina Lake, population 250; Tarpley, population 40; and Vanderpool, population 30. The total population of the county in 1960 was 3,892.

Previous Investigations

Prior to the present study the geology and ground water of Bandera County had received little attention. Two small occurrences of igneous rocks were described by Kirby, Dawson, and Hanna (1927). Broadhurst, Sundstrom, and Rowley (1950, p. 21) collected data on the wells used for the public water supply of Bandera. The present study of the geology of Bandera County was facilitated by similar investigations in neighboring counties. Included in these are the works of Long (1958) in Real County, Welder and Reeves (1960) in Uvalde County, Holt (1956) in Medina County, and Arnow (1959) in Bexar County.

Texas Water Commission in cooperation With the U.S. Geological Survey and the city of San Antonio — Figure 1

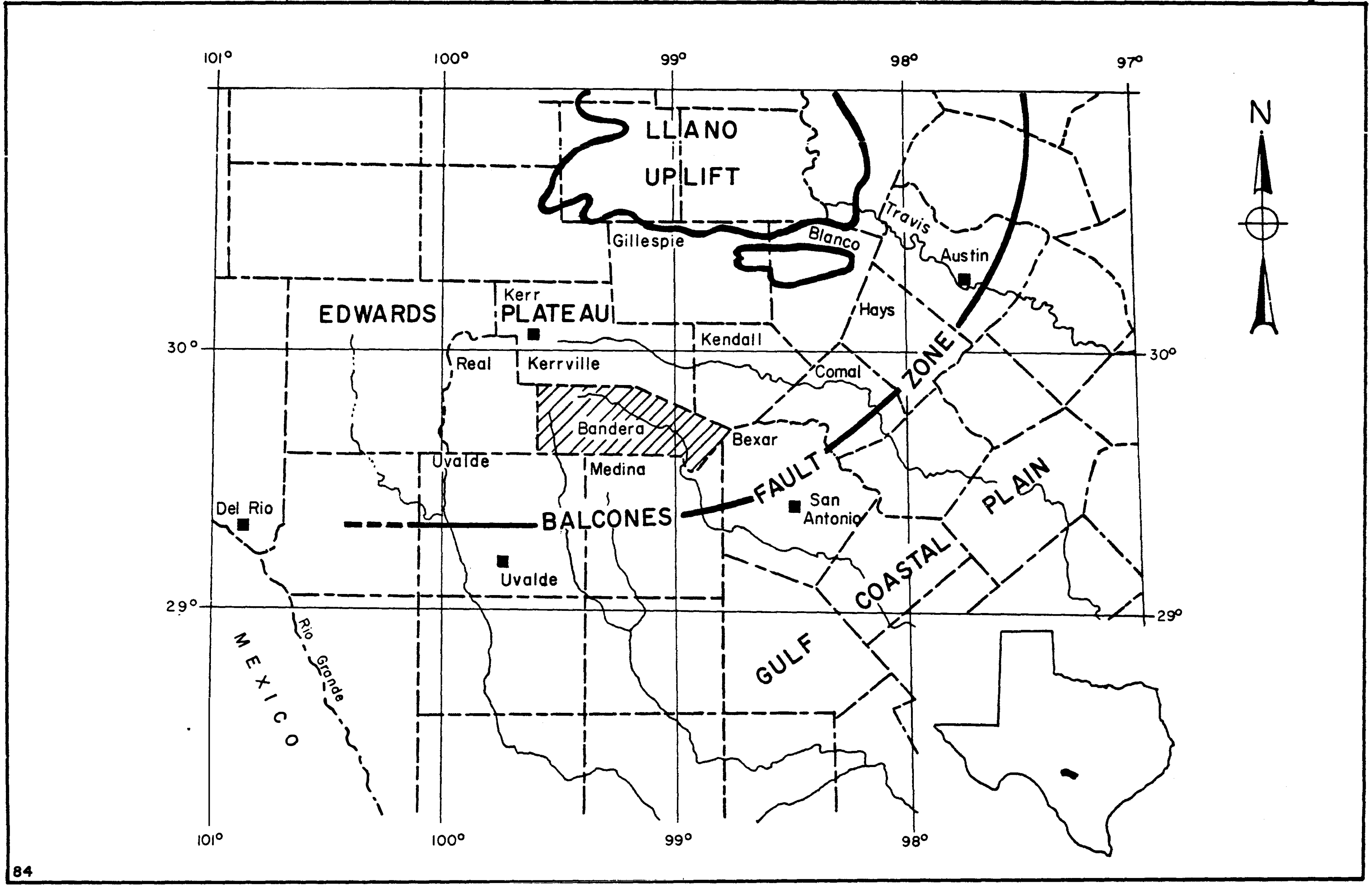

FIGURE 1.- Map of central Texas showing physiographic provinces and location of Bandera County

Acknowledgments

The writers are indebted to the many farmers, ranchers, well drillers and city and county officials who willingly supplied information and aided in the collection of field data. The authors express their appreciation to Messrs. F. L. Stricklin, Jr., and Frank Lozo of the Shell Development Co. for the loan of instruments, electric logs, and well cuttings which were used in the preparation of this report.

GEOGRAPHY

Surface Features

Bandera County is a dissected portion of the Edwards Plateau, lying along the Plateau's south edge, adjacent to the Balcones fault zone (Figure 1). The extensive dissection of the plateau has produced high hills of generally uniform altitude separated by valleys incised into materials less resistant than those forming the caprock. The summits consist of weathered surfaces of limestone, locally covered by rich black or brown soil supporting grass, shin oak, and cedar. In places the soil contains numberous pebbles and cobbles of flint. The valley walls and hillsides, in which bedrock crops out or is covered by detritus, support a sparse cover of grass, live oak, and cedar. Along some of the streams luxuriant growths of elm, sycamore, walnut, live oak, pecan, and cypress are concentrated in narrow belts upon the soils of alluvial terraces and flood plains.

The land surface ranges in altitude from about 1,000 feet above sea level in the bed of the Medina River in the extreme southeastern part of the county to about 2,300 feet in the northwestern part.

Drainage

Most of the northern and eastern parts of Bandera County are drained by the Medina River. The south-central part of the county is drained by Verde and Hondo Creeks and the western part by Turkey Creek, Seco Creek, and the Sabinal River. The Medina and Sabinal Rivers and Hondo Creek are essentially perennial in their lower reaches, although they may cease flowing at times during droughts; the rest of the streams are intermittent.

The upper reaches of the Sabinal and Medina Rivers consist of shallow draws on limestone outcrops which carry water only during times of torrential rainfall. Here most of the drainage is beneath the surface through porous or cavernous zones in the limestone. Most of this water is later released by gravity springs where the contact of the porous limestones and underlying less permeable beds has been exposed by erosion. Stream gradients in the upper reaches are steep, and the watercourses are confined between steep canyon walls.

In the lower reaches of the streams the gradients are gentler, and the streams have an interrupted flow through gravel deposits and over scoured bedrock. Locally the streams have developed broad meander patterns and extensive terraces along wide, flat-bottomed valleys. Courses of the streams are generally concordant with the regional dip of the underlying rocks, and long reaches have been developed at nearly the same gradient as the dip of the beds.

Some of the thin limestone strata contain porous zones which absorb rainfall and transmit the water laterally along interfaces of less pervious beds, releasing it to wells and gravity springs downdip. However, the small recharge (outcrop) area of these thin zones makes the springs very sensitive to rainfall fluctuation, so that many of them are intermittent. A few perennial springs issuing along faults contribute minor flow to the streams. Rather than serving as sources of new flow, these fissure springs generally serve as conduits returning flow that has been recharged to the limestone through permeable zones updip.

Climate

Bandera County has a semiarid to subhumid climate. The average annual precipitation at the town of Tarpley in the south-central part of the county was 27.76 inches during the period 1939-59. The precipitation generally is sufficient for the production of feed and grain crops except during periods of drought. The months of heaviest rainfall are May, June, September, and October (Figure 2).

The average annual temperature in Bandera County is 67°F. The summers are hot, the daily maximum temperatures being above 90°F most of the time; however, 100°F temperatures are rare. Southerly breezes generally cause a rapid drop in temperature after sunset, and the nights are comfortable. The winters are mild; north winds periodically drive the temperature below freezing, but the freezes do not last long.

STRATIGRAPHY AND WATER-BEARING PROPERTIES OF ROCK UNITS

The rocks exposed in Bandera County range in age from Early Cretaceous to Recent. The sedimentary rocks consist of limestone, dolomite, conglomerate, sand, silt, clay, and caliche. A few small bodies of intrusive basalt crop out in the southern part of the county; however, because of their small extent they are not shown on the geologic map (Plate 1).

Rock units supplying ground water (aquifers) in Bandera County include, from oldest to youngest: the Hosston, Sligo, and Pearsall formations, the Glen Rose limestone, the Comanche Peak, Edwards, and Georgetown limestones (collectively referred to as limestones of the Fredericksburg and Washita groups), and alluvial deposits. The lithologic and water-supply properties of the units are summarized in Table 1.

The areas of outcrop of the geologic formations, exclusive of the igneous rocks and the alluvium, are shown on Plate 1. The Glen Rose limestone, the oldest exposed formation, crops out in approximately three-fifths of the land surface of Bandera County. Exposures of the limestones of the Fredericksburg and Washita groups are limited to the high plateau surface in the northwestern part of the county and to interstream hills and ridges in the rest of the county.

Pre-Cretaceous Rocks

Rocks of pre-Cretaceous age are not exposed in Bandera County. They form a basement complex probably representing different systems of the Paleozoic era in different parts of the county. Little is known concerning the lithology of the pre-Cretaceous rocks in the county; however, logs of oil tests in nearby counties indicate that they consist at least in part of hard black noncalcareous shale, sandstone, and limestone.

No fresh water has been reported in the pre-Cretaceous rocks in Bandera County.

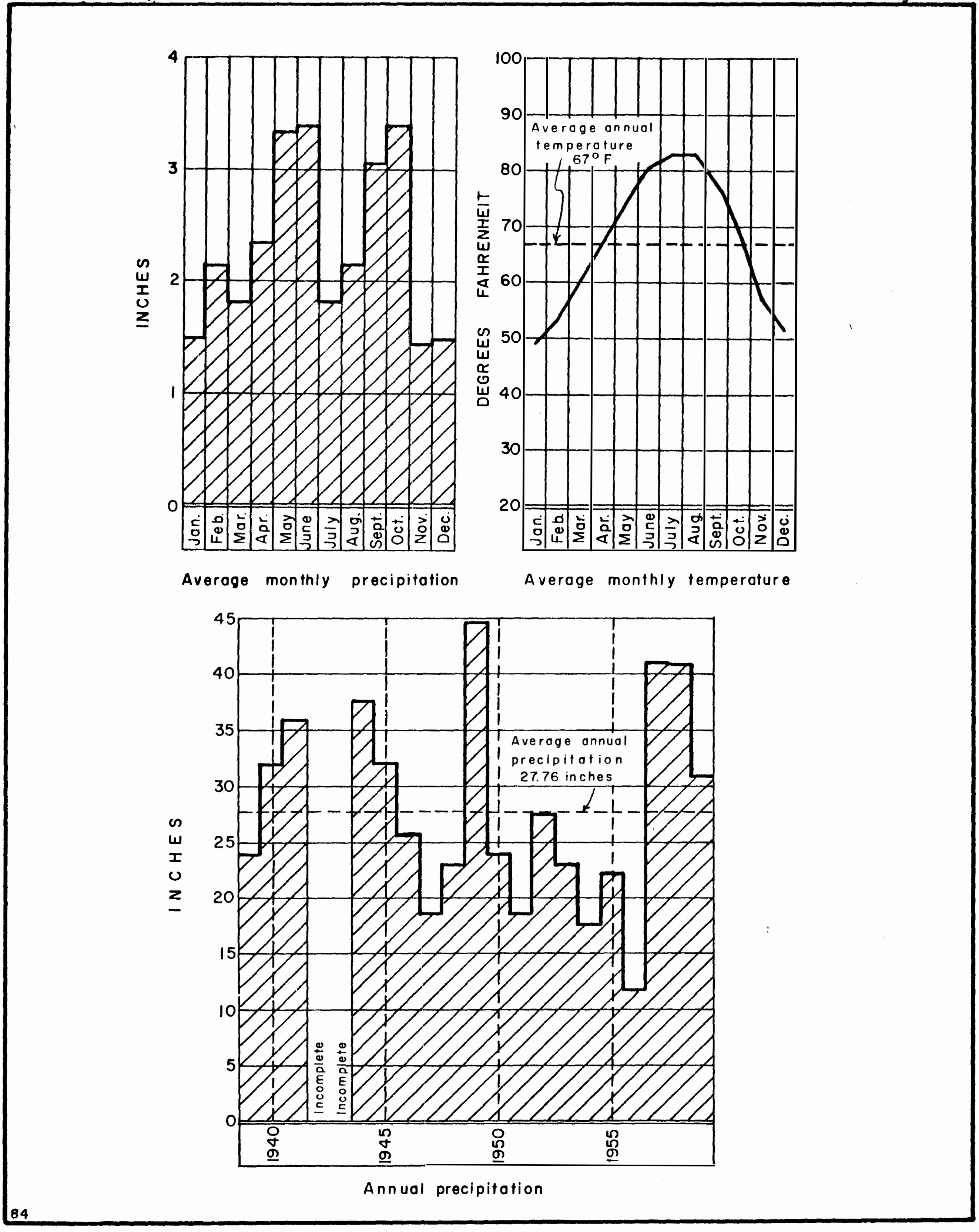

FIGURE 2.- Precipitation and temperature at Tarpley, Bandera County, Texas, 1939-59

(From records of U.S. Weather Bureau)

Table 1.--Geologic formations in Bandera County

System	Series	Group	Stratigraphic unit		Maximum observed thickness (feet)	Character of material	Water-supply properties
Quaternary and Tertiary(?)	Recent, Pleistocene and Pliocene(?)		Alluvium		50	Clay, silt, sand, and gravel.	Yields small supplies of water in valleys.
Cretaceous	Comanche	Washita and Fredericksburg groups	Georgetown and Edwards limestones	Zone C	230	Hard massive cherty limestone, bluff forming.	Yields small to moderate supplies of water.
				Zone B	170	Dark soft cavernous cherty and dolomitic limestone, flaggy to thin bedded.	
				Zone A	125	Hard massive gray limestone containing chert nodules, bluff forming.	
				Comanche Peak limestone	60	Nodular, marly limestone.	
				Walnut clay	5	Marly clay and shell aggregate.	Yields no water to wells in Bandera County.
		Trinity group	Glen Rose limestone	Upper member	440	Marl and shale alternating with thin, resistant beds of limestone and dolomite.	Yields are generally small, and much of the water is saline.
				Lower member	380	Massive limestone and marl.	Yields small supplies of water.
			Pearsall formation	Hensell shale member	150	Conglomerate, sandstone, clay, shale, and sandy dolomite.	Yields moderate to large supplies of water in northern part of county. Yields decrease and water becomes saline in southern part.
				Cow Creek limestone member	60	White to gray or brown sandy limestone and dolomite.	Yields small to moderate supplies of water in most parts of Bandera County.
				Pine Island shale member	70	Sandy dark blue to gray shale; some dolomitic limestone.	Yields no water to wells in Bandera County.
	Pre-Comanche	Nuevo Leon and Durango groups of Mexico	Sligo and Hosston formations		335	Limestone, dolomite, clay, sandstone, and conglomerate.	Yields small to large supplies of water.
Pre-Cretaceous	?	?	?		?	Hard black noncalcareous shale, sandstone and limestone.	Not tapped by wells in Bandera County.

Cretaceous System

Pre-Comanche Rocks

The Cretaceous rocks of south Texas have been divided by Imlay (1945, p. 1427) into the Coahuila series in Mexico, Comanche series, and Gulf series. The oldest rocks of Cretaceous age have been classified as the Hosston and Sligo formations and correlated with rocks of the Durango and Nuevo Leon groups of the Coahuila series in Mexico.

Hosston and Sligo Formations

In Bandera County the Hosston formation consists of conglomerate and sandstone interbedded with red and green clay and dolomite. The Hosston grades upward into dolomitic limestone and sandy dolomite of the Sligo formation. Near the southern border of the county the Hosston consists chiefly of sandy dolomite, dolomitic sandstone, and shale. The Sligo in the southern part of the county is predominately hard spherulitic limestone and dense sandy dolomite.

The formations form a wedge between the underlying Paleozoic rocks and the overlying Pearsall formation, the wedge thinning generally northward from at least 335 feet in well N-3 to about 260 feet in well D-2 (Figure 3). The rate of thinning is not uniform, however, because of a considerable amount of relief on the basement surface of Paleozoic age.

The Hosston and Sligo formations have been penetrated by only a few water wells in Bandera County because shallower aquifers provide adequate water supplies for most purposes. Wells H-43, H-45, and J-62, probably obtaining most of their supply from the Hosston, have reported yields in excess of 1,200 gpm (gallons per minute); however, all these wells have been acidized to increase their production. In contrast, the yields of wells H-57, H-61, M-11, and N-3 range from 16 to 350 gpm. Of these only well N-3, the 350-gpm well, was acidized.

In general, small to large quantities of water can be expected from the Hosston and Sligo formations in most of Bandera County. The meager data available indicate that the water is of good chemical quality and suitable for most purposes. One of the major factors that might limit the development is the comparatively great depth to the formations. This is especially true in the southern part of the county, where it would be necessary to drill more than 1,000 feet in order to penetrate enough of the formations to obtain sufficient water for irrigation, industrial, or municipal use.

Comanche Series

Trinity Group

Pearsall Formation

Imlay (1945, p. 1441) assigned the rocks above the Sligo formation and below the Glen Rose limestone to the Pearsall formation in the subsurface of south Texas, the type section being at a well in Frio County. The Pearsall formation includes the Pine Island shale, Cow Creek limestone, and Hensell shale members, a lithic sequence similar to that of the members of the Travis Peak formation as described by Hill (1901, p. 141). Imlay suggested that the Pearsall and Travis Peak formations occupy the same stratigraphic position, but that the name Travis Peak be restricted to the formation where it is exposed. The formation does not crop out in Bandera county; therefore the name Pearsall is used in this report.

Pine Island Shale Member

The Pine Island shale member, the lowest member of the Pearsall formation, overlies the Sligo formation. In southern Bandera County the Pine Island consists of sandy fossiliferous dark-blue to gray shale containing thin interbedded layers of dolomitic limestone. Northward the member becomes increasingly sandy. The thickness of the Pine Island ranges from about 70 feet in the southern part of the county to about 45 feet in the northern part (Figure 3).

The Pine Island shale member yields no water to wells in Bandera County.

Cow Creek Limestone Member

The Cow Creek limestone member of the Pearsall formation consists chiefly of white to gray or brown sandy fossiliferous limestone and dolomite. The lower and upper beds are generally dense and coquinoid, consisting of poorly cemented, worn shell fragments. Lignite is present locally. The Cow Creek limestone member maintains a fairly uniform thickness of 50 to 60 feet throughout the county (Figure 3).

The Cow Creek generally yields small to moderate quantities of water to wells in most parts of Bandera County. The yields of practically all the wells tapping the Cow Creek were greater than 5 gpm, and the average yield probably was about 15 gpm. Well N-4, which probably obtains most of its water from the Cow Creek, had a reported yield of 723 gpm with a drawdown of 61 feet after acidization.

Hensell Shale Member

The Hensell shale member of the Pearsall formation does not crop out in Bandera County. The Hensell consists of poorly cemented conglomerate, sandstone, and ferruginous clay in the northern part of the county, changing to sandstone, shale, and sandy dolomite in the southern part. The wedge of clastic materials forming the Hensell in the northern part thins southward and probably intertongues with strata of the overlying Glen Rose limestone. The member thins from 150 feet in well D-2 to 20 feet in well N-4 (Figure 3).

Because of the facies change from coarse-grained material in the northern part to fine-grained material in the southern part, the Hensell member is an important aquifer only in the northern part of Bandera County. Yields as large as 500 gpm have been reported (well C-5), and many wells in the northern part of the county are capable of producing as much as 200 gpm, although few large wells have been developed because of lack of demand. In the southern part of the county, only stray sand lenses and granular dolomite of the Hensell member yield water to wells; consequently, the yields are small. Most wells in this area are drilled to the underlying, more permeable limestone beds of the Cow Creek limestone member. Most of the wells that draw from the Hensell in the northern part of the county yield water that is of good chemical quality except that it is hard. In the southern part of the county the water becomes saline, an increase in the sulfate content being particularly noticeable.

Texas Water Commission in cooperation with the U.S. Geological Survey and the city of San Antonio — Figure 3

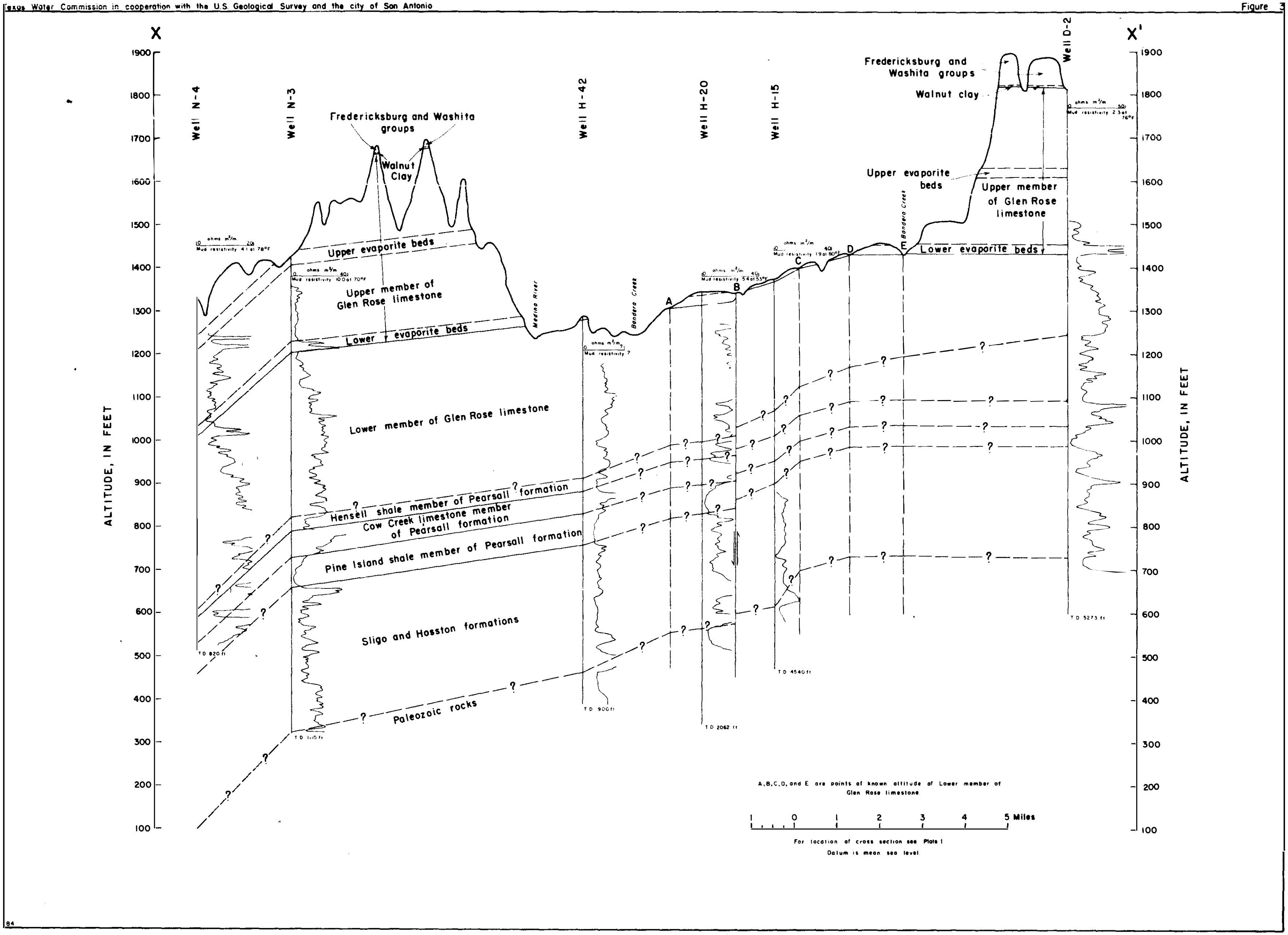

FIGURE 3.- Geologic section X-X', Bandera County, Texas

Glen Rose Limestone

Most of the land surface of Bandera County has been developed upon the alternating limestone and marl beds of the Glen Rose limestone. Differential erosion of the alternating hard and soft beds has created a characteristic terrace or stairstep topography.

The Glen Rose limestone is predominantly calcareous, containing clay and sand as accessory materials. The calcareous strata range from thick reefy, massive beds of limestone in the lower part of the formation to thin granular coquina, calcarenite, and soft granular dolomite in the upper part. Throughout Bandera County and across adjacent counties, the thickness and lithology of individual beds is remarkably uniform; many of the units are identifiable for 60 miles or more.

In Comal County, George (1952, p. 17-18) divided the Glen Rose limestone into lower and upper members. The top of a thin limestone forming the uppermost part of a prominent fossiliferous zone (*Salenia texana* zone) was arbitrarily selected as the boundary. The limestone, the uppermost part of which is formed by a layer of shells of the fossil *Corbula texana* Whitney, is overlain by porous evaporite beds of dolomite and anhydrite of the upper member. The limestone and the overlying evaporite beds form an important mapping datum which is traceable on the outcrop from Bandera County at least to Travis County. The evaporite beds, which are recognizable in well cuttings and are indicated by a strong resistivity peak on electric logs, are useful in subsurface correlation. A second evaporite zone of almost identical characteristics lies approximately in the middle of the upper member. In this report the zones are referred to as the lower and upper evaporite beds.

The separation of the Hensell shale member of the Pearsall formation and the Glen Rose limestone in Bandera County is made arbitrarily because of the gradational nature of the contact. As identified in electric logs and well cuttings, the contact is placed at the base of the lowest well-developed limestone beds of the Glen Rose.

Lower Member

The lower member of the Glen Rose limestone in Bandera County consists of massive rudistid limestone and thin beds of marl containing *Orbitolina texana* (Roemer), grading upward into thin beds of fragmental limestone and marl. Shallow-water features such as ripple marks, filled borings, finely ground shell material, solution channels, mud cracks, lignite, dinosaur tracks, and crossbedding characterize many of the thin beds in the upper 50 feet of the member. The upper 20 feet of the member, the *Salenia texana* zone, is a nodular limy marl containing many fossils of *Orbitolina texana* (Roemer), *Hemiaster* sp., crab claws, *Porocystis* sp., *Trigonia* sp., *Salenia texana* (Credner), and *Douvilleiceras* sp. As stated above, this limestone containing abundant fossils of *Corbula texana* Whitney at the top of the marl marks the upper limit of the lower member of the Glen Rose.

Exposures of the lower member are limited to areas along the Medina River and its tributaries southeast of Medina, along Hondo, Williams, Thomas, and Commissioners Creeks near Tarpley, and along the Sabinal River and its tributaries south of Vanderpool. The best exposures form cliffs along the Medina River and Red Bluff Creek southeast of Bandera. Elsewhere the exposures are poor or are mantled by alluvium which forms broad terraced flats along the streams.

Although individual beds of the lower member of the Glen Rose maintain uniform thickness along strike, the member as a whole thickens from north to south. The thickness in the northern part of the county is about 190 feet and in the southern part, about 380 feet (Figure 3).

The lower member of the Glen Rose limestone generally yields small quantities of water, most of which is of fairly good chemical quality. The yields of most of the wells range from 2 or 3 to 15 gpm, the yields varying with the size of the openings penetrated; one well (G-23) has been reported to yield 700 gpm.

Upper Member

The upper member of the Glen Rose limestone consists predominantly of blue to yellowish-brown shale, marl, and thin fossiliferous limestone. Dolomitic beds are common throughout the formation, and an oyster- and rudistid-bearing limestone occurs about 150 feet above the base of the member.

The upper member may be divided into the following sequences as observed in the northern part of the county: (1) lower evaporite beds and overlying marl, 45 to 50 feet thick and only sparsely fossiliferous; (2) marl containing abundant fossils of Orbitolina minuta Douglass and fragmental coquina which grades upward into an oyster- and rudistid-bearing limestone; total thickness 100 to 105 feet; (3) calcareous marl 30 to 40 feet thick; (4) anhydritic marl and dolomite (upper evaporite beds), 12 to 30 feet thick; and (5) upper marl and calcarenite grading upward into sugary-textured argillaceous dolomite, 160 feet thick. The overall thickness of the member ranges from about 385 feet in the northern part of the county to about 440 feet in the southern part.

The two evaporite beds form important marker horizons identifiable in both the outcrop and the subsurface. Where exposed the evaporite beds are weathered and occur as brown ferruginous dolomitic clay, weathering having removed most of the anhydrite. Sinks, collapse structures, seeps and springs, and distorted bedding are characteristic of the outcrop. In the subsurface where they are not weathered, the evaporite beds are readily identified by their caving tendencies during drilling, by the presence of anhydrite and lack of Orbitolina in well cuttings, and by a pronounced resistivity peak on electric logs (Figure 3).

The upper member of the Glen Rose limestone yields small quantities of water to wells, much of the water being saline. The most productive beds of the upper member are the evaporite beds. The anhydrite layers have been highly leached and weathered, especially in and near the outcrop, forming a highly permeable, cavernous, honeycombed mass. Unfortunately the water in these evaporite beds characteristically has a high sulfate content which makes the water unfit for most uses. Particular care should be taken in drilling wells into the Glen Rose to make sure that the evaporite beds are cased off or cemented.

Fredericksburg and Washita Groups

The Fredericksburg group in Bandera County includes the Walnut clay, the Comanche Peak limestone, and the Edwards limestone. The Kiamichi formation, the uppermost formation of the Fredericksburg group, was not recognized in the county. The only formation of the Washita group in Bandera County is the Georgetown limestone. The Fredericksburg and Washita groups have been mapped as a single unit (Plate 1). The three limestones form a single hydrologic unit.

The walnut clay, the oldest formation of the Fredericksburg group in Bandera County, consists of a thin bed of marly clay and shell aggregrate ranging in thickness from 6 inches to 5 feet. Because of its thinness it is not differentiated on the geologic map (Plate 1). The Walnut weathers to a steep slope or undercut beneath the more resistant Comanche Peak limestone. Locally a rounded bench is formed at the base of the Walnut clay on the underlying Glen Rose limestone. Echinoids (Loriolia sp., Holectypus sp.), pelecypods, gastropods, Engonoceras sp., Dictyoconus sp., Porocystis globularis (Giebel), and a profusion of Exogyra texana (Roemer) mark the horizon.

The Walnut clay is not an aquifer in Bandera County.

The Comanche Peak limestone in Bandera County is a marly nodular limestone ranging from 25 to 60 feet in thickness. The lower contact appears to be gradational with the Walnut clay; the upper contact is distinct but conformable. The nodular appearance of the outcrop is believed to have resulted from extensive boring by marine organisms. Fossils found in abundance in the Comanche Peak include Exogyra texana (Roemer), Protocardia sp., Lunatia sp., Engonoceras sp., and small, high-spired gastropods. Masses of secondary calcite are common.

A pronounced break in vegetation marks the top of the Glen Rose limestone. Live-oak trees form a band at the top of the Glen Rose limestone extending upward onto the outcrop of the Comanche Peak. The overlying resistant beds of the Edwards limestone are generally cliff-forming and support a dense growth of cedar on the tops of the cliffs.

The uppermost approximately 500 feet of the Fredericksburg and Washita groups contains the Edwards and Georgetown limestones; however, the two formations have not been recognized as such. The sequence can be divided into three zones; (A) A lower massive cavernous hard limestone, light gray in color, contains chert layers and minor beds of soft dolomitic limestone. The zone ranges in thickness from 100 to 125 feet. (B) The middle zone consists predominantly of dolomitic limestone which is softer and more thinly bedded than the limestone of the lower zone. Chert nodules, calcite masses, siliceous geodes, and solution caverns are characteristic of the zone. In general, these softer beds are contrastingly darker in color, are less resistant to erosion, and support more vegetation than the lower beds. The zone is about 170 feet thick. (C) The upper zone, 230 feet thick, consists of massive hard white bluff-forming highly fossiliferous limestone. Some of the beds are composed almost entirely of fossils containing abundant Caprina, Toucasia, Monopleura, Radiolites, Pecten, and gastropods. Kingena wacoensis (Roemer) is common near the top of the zone. Chert beds and nodules are abundant in most of the zone but disappear in the upper part where the limestones become fine grained and thin bedded.

Wells in limestones of the Fredericksburg and Washita groups in Bandera County provide small to moderate supplies of water used only for domestic and stock purposes. Hence, data pertaining to the yield of the unit are limited to a few bailing tests recorded by well drillers. The wells have a great diversity of yield according to the size and degree of interconnection of the joints or solution channels from which the water is derived. One well may enter large water-bearing channels, whereas a well only a short distance away may be practically dry because it penetrates only small water-bearing openings. The largest yield as reported by the driller of well A-6 during a bailing test was about 50 gpm with no appreciable drawdown. The water in the unit is of good chemical quality except that it is hard.

Tertiary(?) and Quaternary Systems

Pliocene(?), Pleistocene, and Recent Alluvial Deposits

Alluvial deposits in Bandera County occur as small remnants on hilltops, as terraces and fills of old meander channels of streams, and as flood-plain deposits along present streams. The deposits range in age from Pliocene(?) to Recent. Maximum thicknesses of these sediments are found in the major stream valleys where the deposits form broad valley flats. The alluvium ranges in thickness from a knife edge to about 50 feet and consists principally of limestone detritus which forms lenticular beds of gravel, sand, silt, and clay. Locally the beds are red where iron-stained materials are concentrated.

A prominent terrace occurs in many places about 25 to 40 feet above the present stream channels, but where stream gradients are low the terrace merges with Recent flood-plain deposits. The most extensive deposits of alluvium in Bandera County lie along the Medina River from Bandera northward to Medina, along Hondo Creek from the Medina County line to Tarpley, and along the Sabinal River from the Uvalde County line to Vanderpool.

The alluvial deposits in Bandera County are, for the most part, highly permeable; however, because of their thinness, small areal extent, and topographic position, they are not important as aquifers. The deposits yield only small quantities of water to a few wells along some of the streams.

Igneous Rocks

Igneous rocks occur in a few places in Bandera County as small, isolated masses. Dikes consisting largely of basalt were described by Dawson, Hanna, and Kirby (1927) at localities west and southwest of Bandera. Several other exposures of basaltic rocks were found in the county during the present investigation, including a small plug and dike about 4 miles northeast of Tarpley, and a dike on the Dean Ranch 3 miles north of Tarpley.

The igneous rocks yield no water to wells in Bandera County. Because of their small areal extent and lack of hydrologic significance, they are not shown on the geologic map (Plate 1).

GEOLOGIC STRUCTURE

The principal geologic structure of Bandera County is a southward- or southeastward-dipping monocline crossed by discontinuous northeastward-trending faults and folds roughly paralleling the Balcones fault zone of the counties to the south. In contrast to the major northeastward-striking structural trend, a minor system of synclines and anticlines strikes generally north-south across the county, their axes gently plunging southward nearly at right angles to the Balcones fault zone.

The regional structure of the county is shown on Figure 4, which shows the altitude of the top of the lower member of the Glen Rose limestone. The figure shows that the dip in much of the central and western parts of the county ranges from 10 to 20 feet per mile toward the southeast or south. In the southeastern part of the county the dip steepens to about 100 feet per mile and is chiefly toward the south.

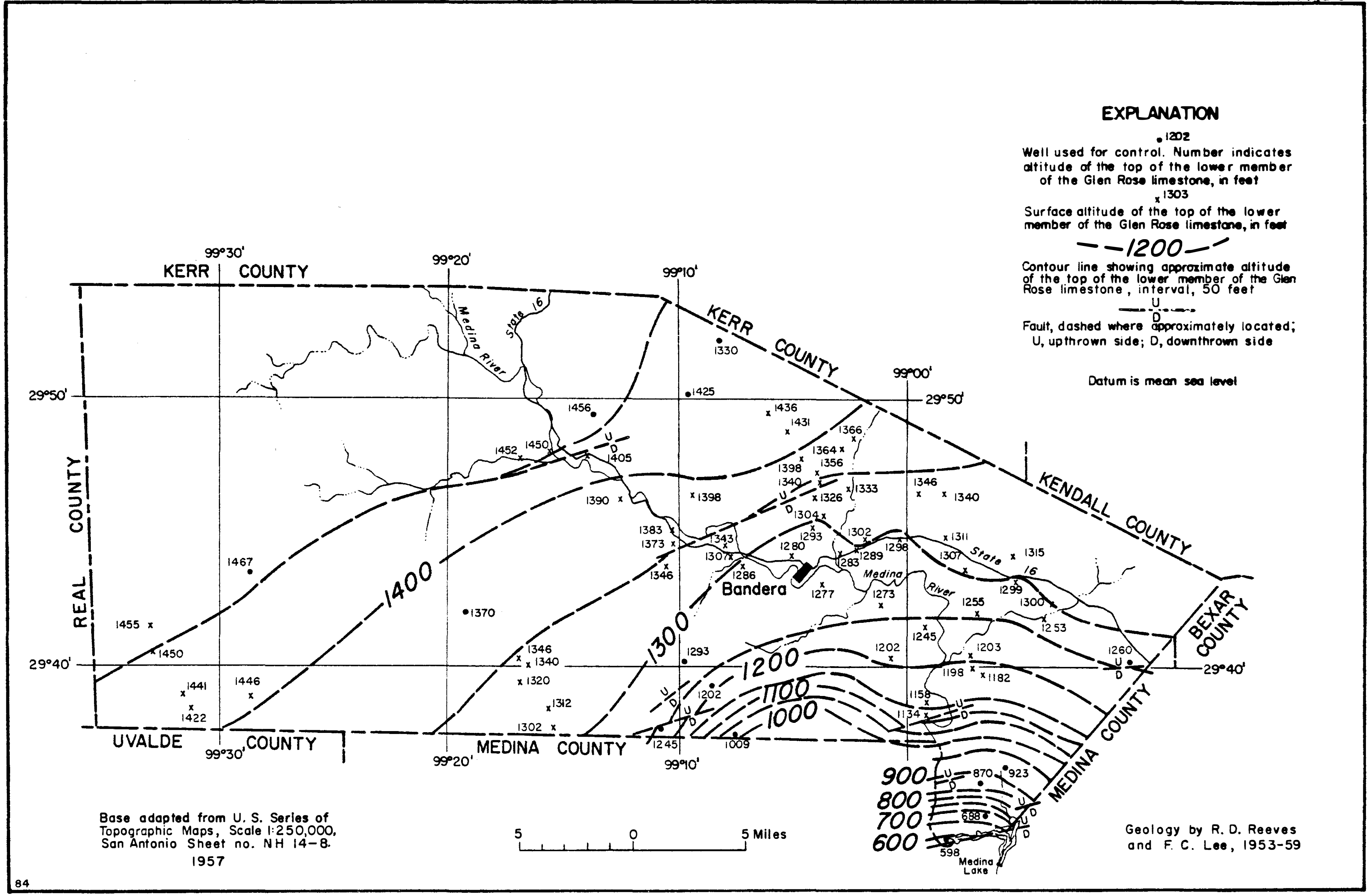

FIGURE 4.–Map showing the altitude of the top of the lower member of the Glen Rose limestone, Bandera County, Texas

Most of the faults in Bandera County strike northeastward and are not continuous for long distances. The faults roughly parallel those of the Balcones fault zone to the south. The faulting is normal and the fault planes dip steeply to the southeast at angles of 65° to 78°. The faults are generally downthrown to the south, the maximum displacement on a single fault being about 100 feet.

Folding in Bandera County occurs in two trends which with associated faulting have influenced the development of the drainage system of the county. The major trend is characterized by gentle flexures which are roughly parallel with and are probably associated with the Balcones fault zone. The strikes are northeastward, creating beltlike flattening and steepening of the beds across the southward dipping regional structure. This flattening and steepening has created temporary base levels to stream erosion, resulting in development of broad valleys having extensive meander patterns along the stream courses. Rejuvenation has caused incisement into the old valley floors, which remain as broad terraces adjacent to the present stream channels. The minor trend of folding is characterized by broad, low northward- to northwestward-striking folds which plunge slightly toward the south where they are truncated by faults of the Balcones zone.

GROUND WATER

Occurrence and Movement

Ground water in Bandera County occurs in two types of aquifers: (1) coarse- to fine-grained detrital rocks, consisting chiefly of sandstone, in which the water occurs in the spaces between the sand grains, and (2) limestone and dolomite, in which the water occurs in joints, other fracture openings, and solution channels. In either type of aquifer, the water may occur under water-table or artesian conditions. Under water-table conditions the water is unconfined and does not rise in wells above the level at which it is encountered in the formation. Under artesian conditions the water is confined under pressure between relatively impermeable layers, and the water will rise above the level at which it is encountered.

With the exception of the alluvial deposits along the streams which are thin and relatively unimportant, the detrital aquifers are found in the Hosston and Sligo formations and the Hensell shale member of the Pearsall formation and are artesian. The aquifers are charged from precipitation and streamflow on the outcrops in areas to the north of Bandera County. Most of the precipitation on the outcrop areas is lost to flood runoff. A part is consumed by evaporation and transpiration by plants; a small part percolates downward to the water table, then moves down the hydraulic gradient of the aquifers toward areas of discharge. Data are not available to map accurately the direction of ground-water movement in the aquifers in Bandera County; however, the general direction of movement in the sandstone aquifers is probably down the dip of the formations toward the south or southeast. Natural discharge from the sandstone aquifers occurs chiefly by slow upward movement into the overlying less permeable formations.

The limestone and dolomite aquifers in Bandera County consist of the Cow Creek limestone member of the Pearsall formation, the Glen Rose limestone, and the limestones of the Fredericksburg and Washita groups. As stated above, the ground water in these aquifers occurs in joints, other fracture openings, and solution channels. Piper (1932, p. 71) states that solution openings in limestone and dolomite are developed under conditions where natural waters may percolate considerable distances before they reach chemical equilibrium with the surrounding rock; and that openings along bedding planes, primary pore spaces, and fractures are converted by these percolating waters from small openings to larger crevices and caverns. The rate of this conversion is dependent upon factors of composition, texture, and primary permeability of the rocks, rate of circulation and temperature and pressure of the water, amount and seasonal distribution of rainfall, and nature of the soil and vegetal cover. Thus, rainwater containing carbon dioxide dissolved from the air and the soil, which increases the solvent power of the water toward limestone, percolates through limestone beds developing small channels which are controlled by pre-existing joint patterns or bedding planes. As solution continues, larger conduits may develop which may erase all vestiges of this primary control, and the resultant channels may transect earlier patterns.

Recharge to the Cow Creek limestone member of the Pearsall formation probably occurs chiefly from rainfall and streamflow on the outcrop areas to the north of Bandera County. A smaller amount of recharge to the Cow Creek limestone member probably occurs by seepage from overlying or underlying aquifers. Natural discharge from the Cow Creek occurs chiefly by upward seepage into overlying formations.

The Glen Rose limestone is recharged by direct infiltration of precipitation and streamflow upon exposed surfaces through fissures, or through an overlying mantle of alluvium. The streams may serve as both recharge and discharge facilities for the Glen Rose. Water may enter porous or fractured zones upstream and discharge from them downstream where the stream intersects the water table. A small amount of recharge may occur by vertical upward seepage from underlying beds where water in them is confined under higher artesian pressure.

Most of the ground water in the Glen Rose limestone occurs under artesian pressure because of the presence of shale beds which act as confining layers for the beds of limestone. In the thin-bedded limestone the solution channels are tubular and well developed parallel with the bedding planes. In the thick-bedded limestone the vertical continuity of the solution channels is greater. The channels are best developed in the most competent beds or in the dolomitic limestone and anhydrite beds of the evaporite zones.

The Comanche Peak, Edwards, and Georgetown limestones are recharged by precipitation on the outcrops, which are extensively eroded and generally honeycombed or porous. The thick beds of limestone contain fracture systems, which have been enlarged by solution, forming conduits that permit relatively free downward and lateral movement of ground water. In addition to these largely vertical conduits, sheet solution channels have been developed parallel to the bedding planes. Because of the resultant high permeability of the limestone, water entering the unit moves rapidly downward to the lower part, and thence laterally toward discharge areas along the stream valleys. The water discharges through seeps and springs at the exposed contact between the limestones of the Fredericksburg and Washita groups and the underlying Glen Rose limestone. The springs provide most of the perennial flow of the major streams in Bandera County and a part of the recharge to the Glen Rose.

Development

The total use of ground water in Bandera County as of 1958 is estimated to be about 800,000 gpd (gallons per day), or about 900 acre-feet per year. The most widespread use of water is for domestic and stock purposes in the rural areas. There is no recorded use of wells for industrial purposes in the county, and the only municipal use is that at Bandera. A small quantity of water is used for supplementary irrigation, primarily of pasture and small plots of feed crops, mostly along the river valleys.

The domestic and stock wells generally yield only a few gallons per minute and are pumped by windmills or small power pumps equipped with electric or gasoline motors. The wells are designed to produce only sufficient water for domestic or stock use, and larger yields could be obtained in many places if necessary.

Large-capacity municipal wells at Bandera and irrigation wells have yields as great as about 1,300 gpm. These wells are equipped with turbine pumps, some of them powered by electric motors and some by gasoline or diesel engines.

Although data are not available for quantitative evaluation of the ground-water resources of the county, the present development is undoubtedly only a small percentage of the potential. Large quantities of water await development in the Hosston and Sligo formations and in the northern part of the county in the Hensell shale member of the Pearsall formation. The Glen Rose limestone will yield at least small quantities of water practically anywhere in the county, but the quality of much of the water is poor. The limestones of the Fredericksburg and Washita groups will yield small to moderate quantities of water in the northwestern part of the county.

Quality of Water

Water samples from 81 wells and 4 springs in Bandera County were collected during the investigation; most of the samples were analyzed in the laboratory of the U.S. Geological Survey at Austin, Texas. The wells and springs sampled are indicated on Plate 1 by a bar above the location numbers. The results of the analyses are given in Table 4.

Standards set by the U.S. Public Health Service (1946, p. 371-384) for drinking water used on interstate carriers are often used in evaluating water for domestic and public supplies. In most instances a greater concentration of mineral constituents can be tolerated, and the use of water that does not meet the suggested standards is common in Bandera County. The suggested limits for some of the important dissolved minerals are given below:

Iron (Fe) and manganese (Mn) together should not exceed 0.3 ppm (parts per million).

Magnesium (Mg) should not exceed 125 ppm.

Chloride (Cl) should not exceed 250 ppm.

Sulfate (SO_4) should not exceed 250 ppm.

Fluoride (F) must not exceed 1.5 ppm.

Dissolved solids should not exceed 500 ppm for a water of good chemical quality. However, if such water is not available, a dissolved-solids content of 1,000 ppm may be permitted.

The nitrate content of water in limestone commonly varies considerably because surface water, which may have a high organic content, has ready access to the aquifers through solution channels and fractures. Lohr and Love (1952, p. 10) state that "more than several parts per million of nitrate may indicate previous contamination by sewage or other organic matter." However, a high nitrate content is not, of itself, an indication of pollution. Water having a high nitrate content should be tested for bacterial contamination. Most of the samples collected in Bandera County had low concentrations of nitrate; however, water from wells A-5, G-34, H-63, and J-30 had concentrations of 28, 16, 25, and 54 ppm, respectively, indicating possible contamination.

Hardness of water is caused principally by dissolved calcium and magnesium. Hardness equivalent to the carbonate and bicarbonate is called carbonate hardness; the remainder of the hardness is called noncarbonate hardness. The selection of proper methods for softening is based largely on the type and degree of hardness. Water having a hardness of 120 to 200 ppm is classified as hard; water having a hardness of more than 200 ppm is classified as very hard. The analyses show that all samples, except those from wells H-55, H-73, and M-11, which produce from the Hosston and Sligo formations, may be classified as very hard.

Fluoride in many of the water samples analyzed for that constituent was in excess of the concentration permissible for drinking water according to the U.S. Public Health Service drinking-water standards. Fluoride in excess of 1.5 ppm may cause the mottling of the tooth enamel of children, the degree or severity of mottling varying directly with the increase in concentration and ingestion of fluoride (Dean, Dixon, and Cohen, 1935, p. 424-442).

The amount and type of dissolved minerals in ground waters depend on the solubility and type of rock through which the water moves and on the length of time the water is in contact with the rock, as well as on the temperature and pressure. As a general rule, the dissolved-solids content of the water in Bandera County increases down the dip of the formations.

Most of the wells in Bandera County yield mixed waters from several formations; therefore, it is difficult to draw reliable conclusions regarding the character of the water supplied by different aquifers for the county as a whole.

The analyses from 4 wells that draw from the Hosston and Sligo formations (H-45, H-55, H-73, and M-11) in the southeastern part of the county showed a range in dissolved solids from 464 to 561 ppm and a range in hardness from 166 to 261 ppm. Available data are too meager to permit a general statement regarding the quality of the water in the Hosston and Sligo throughout the county; however, the few samples taken indicate that the water, though hard, is suitable for most purposes.

Most wells that draw from the Pearsall formation in Bandera County are cased only to the top of the massive limestone beds of the lower member of the Glen Rose limestone; consequently, most of the wells produce a mixture of waters from both formations. Analyses of samples from 4 wells (E-18, H-39, K-3, and N-4), which produce from the Pearsall formation only, show dissolved-solids contents ranging from 549 to 1,400 ppm. Sulfate appears to be the most objectionable constituent, ranging from 146 to 810 ppm in the 4 samples.

Water samples were collected from 6 wells that draw from only the lower member of the Glen Rose limestone. The dissolved-solids content of the 6 samples ranged from 310 to 601 ppm and the sulfate content ranged from 16 to 198 ppm. The most objectionable characteristic of the water is its hardness; all the samples would be classed as very hard.

The water from the upper member of the Glen Rose limestone varies widely in quality. Many of the wells yield saline water which is particularly high in sulfate content. The observed range of dissolved-solids content in 14 samples was from 283 to 4,140 ppm, and the sulfate content ranged from 10 to 2,910 ppm. All the water was very hard. The water of poor quality seems to be associated with the evaporite beds. The anhydrite dissolves fairly readily in the percolating ground water, thus contributing large amounts of sulfate to the water. Where the evaporite beds lie at shallow depth, particularly in the vicinity of streams, they may be highly leached and the contained water may be of relatively good quality.

The water from the limestones of the Fredericksburg and Washita groups in Bandera County is hard but otherwise of excellent quality. The dissolved-solids content of samples from 5 wells and 1 spring ranged from 224 to 322 ppm, and the sulfate content was low.

SUMMARY

Aquifers in Bandera County include the Hosston and Sligo formations, the Cow Creek limestone and Hensell shale members of the Pearsall formation, the Glen Rose limestone, and limestones of the Fredericksburg and Washita groups. The Hosston and Sligo formations make up the oldest and, consequently, the deepest aquifer in the county. The unit consists of limestone, dolomite, shale, sandstone, and conglomerate, the water occurring chiefly in the sandstone and conglomerate. The Hosston and Sligo unit yields small to large quantities of water to a few wells in the county, and it is believed that similar yields could be obtained in most places. The unit occurs at relatively great depth; however, the water is under artesian pressure and will rise nearly to the surface in wells.

Two members of the Pearsall formation--the Cow Creek limestone member and the Hensell shale member--form aquifers in the county. The older of the two, the Cow Creek, consists of limestone and dolomite which yield small to moderate quantities of water in most parts of the county. The overlying Hensell member consists of conglomerate, sandstone, shale, and sandy dolomite. The Hensell yields moderate to large supplies of water, chiefly in the northern part of the county. In the southern part the Hensell becomes increasingly shaly and dolomitic; the yields of wells decrease and the water becomes saline.

The Glen Rose limestone consists of a lower member composed of massive limestone and interbedded thin layers of marl, and an upper member consisting of alternating thin beds of limestone and marl. The lower member rather consistently yields small supplies of water in most parts of the county. The upper member yields only small quantities of water, and much of the water is saline. The high salinity of the water from the upper member is caused by the presence of anhydrite beds at two levels in the member. The anhydrite is rather easily dissolved by the percolating ground waters and contributes a high sulfate content to the water.

The Fredericksburg and Washita groups in Bandera County consist of four geologic formations--the Walnut clay, the Comanche Peak limestone, the Edwards limestone, and the Georgetown limestone, the three limestones forming a single hydrologic unit. The Comanche Peak limestone can be distinguished both on the surface and in logs of wells; however, the Georgetown and Edwards have not been differentiated in the county. The Comanche Peak consists of nodular marly limestone, whereas the upper two units consist predominantly of thick, massive beds of hard limestone and some dolomite. The limestones of the Fredericksburg and Washita groups crop out extensively at the surface in the western and northwestern parts of the county. Elsewhere the limestone unit forms a cap on high hills and interstream areas. The unit yields small to moderate supplies of water in much of the western part of Bandera County. The water is of excellent quality except that it is hard.

The total use of ground water in Bandera County is about 800,000 gallons per day, the principal use being for domestic and stock purposes in the rural areas. The only municipal use is at the city of Bandera, and there is no industrial use in the county. A small quantity of water is used for supplementary irrigation, primarily for pasture and small plots of feed crops along the river valleys. Although data are not available for a quantitative evaluation of the potential of undeveloped ground-water resources of Bandera County, it is believed that the present use is only a small percentage of the total potential.

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*Name of agency changed to Texas Water Commission January 30, 1962.

Table 3.--Drillers' logs of wells in Bandera County

(Formation and fossil names added by authors)

Well B-1

Owner: J. F. Camp. Driller: King Stokes.

	Thickness (feet)	Depth (feet)
Topsoil---------------	2	2
Lime, hard, and flint-	33	35
Lime------------------	7	42
Lime crevice (lost water)--------------	13	55
Lime (Edwards); struck water at 115 to 120 and at 140 feet-----	85	140
Lime (Edwards)-------	80	220
Lime, blue-----------	103	323
Shale and limestone (Glen Rose)--------	42	365
Lime, blue-----------	68	433
Shale, green, and lime---------------	23	456

Well B-3

Owner: J. F. Camp. Driller: A. Smith.

	Thickness (feet)	Depth (feet)
Limestone, white, hard	107	107
Clay and limestone----	38	145
Limestone and clay, blue----------------	100	245
Clay and limestone, shelly--------------	60	305
Gypsum----------------	30	335
Limestone and clay, blue----------------	45	380
Limestone and shells, white---------------	10	390
Clay, blue, and limestone; contains <u>Orbitolina texana (Roemer)</u>------------	110	500
Gypsum---------------	20	520
Clay, blue, shelly---	35	555
Limestone, white-----	20	575
Shale, blue----------	10	585
Limestone, white and blue---------------	115	700
Shale, red, and sand-	40	740
Sand, yellow---------	20	760
Shale and red sand---	30	790
Sand and gravel------	25	815
limestone, yellow, and sand-----------	10	825

Well B-9

Owner: C. H. Heimsath. Driller: King Stokes.

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Clay and limestone-----	70	70	Limestone, gray, shaly	90	380
Dolomite, gray, hard, and gypsum-----------	10	80	Limestone, white, shaly, sugary texture; abundant Orbitolina texana (Roemer)------------	45	425
Shale, gray, dolomitic, fossiliferous--------	50	130	Dolomite, brown; abundant lignite and sand------------	15	440
Limestone, white, dolomitic, and some sand; abundant shells------	5	135	Shale, sandy, lignitic	10	450
Shale, gray, limy; Orbitolina texana (Roemer) abundant----	110	245	Sandstone, shaly, glauconitic, and dolomite------------	30	480
Gypsum and brown, sandy dolomite; contains Corbula texana Whitney in lower part--------	20	265	Sand, medium to coarse; some glauconite and sandy dolomite------	78	558
Shale, gray, sandy; contains Orbitolina texana (Roemer)------	25	290			

Well D-7

Owner: F. M. Montague. Driller: A. Smith.

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Shale, yellow----------	45	45	Shale, blue-----------	35	280
Lime, blue-------------	65	110	Shale, gray-----------	50	330
Shale, gray------------	110	220	Lime, blue and gray---	70	400
Gypsum-----------------	20	240	Lime, brown-----------	40	440
Lime, blue-------------	5	245			

Well E-1

Owner: J. F. Camp. Driller: King Stokes.

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Topsoil----------------	4	4	Flint boulders--------	4	8

(Continued on next page)

Table 3.--Drillers' logs of wells in Bandera County--Continued

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Well E-1--Continued					
Lime and flint-------	25	33	Lime, soft---------	13	253
Lime----------------	137	170	Lime---------------	13	266
Lime and flint crevices; water at 170 to 175 feet--------	40	210	Lime and soft lime--	59	325
			Lime, honeycombed---	25	350
Lime and flint-------	30	240	Lime---------------	30	380

Well F-18, partial log

Owner: R. D. Garrison. Driller: Plateau Oil Co.

Lime, broken---------	20	20	Shale--------------	20	400
Shale, gray----------	30	50	Lime---------------	50	450
Lime-----------------	10	60	Shale, gray---------	5	455
Shale, blue----------	55	115	Lime---------------	15	470
Lime-----------------	5	120	Shale, white, soft--	5	475
Shale----------------	5	125	Lime, broken--------	21	496
Shale, blue----------	5	130	Lime---------------	157	653
Lime-----------------	25	155	Lime, hard in spots-	57	710
Shale, light---------	27	182	Lime---------------	40	750
Sand (little water)--	3	185	Shale--------------	5	755
Lime, broken---------	80	265	Sand (hole full of water)-----------	10	765
Shale, gray----------	15	280	Lime---------------	10	775
Lime, broken---------	20	300			
Shale, sticky--------	50	350	Sand (hole full of water)-----------	5	780
Lime, hard-----------	10	360	Lime---------------	15	795
Lime, broken---------	10	370	Shale, blue---------	5	800
Lime-----------------	10	380	Shale--------------	40	840

(Continued on next page)

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Well F-18, partial log--Continued					
Lime----------------	10	850	Rock, red------------	60	1,035
Mud, blue, sticky----	10	860	Rock, red, and lime (hole full of water)	23	1,058
Shale, blue----------	20	880	Sand, soft-----------	7	1,065
Lime, sandy----------	5	885	Lime, sandy----------	30	1,095
Shale, blue----------	5	890	Lime and shale-------	35	1,130
Shale----------------	5	895	Lime, broken---------	5	1,135
Lime-----------------	5	900	Lime, hard-----------	5	1,140
Shale----------------	14	914	Lime and red rock----	25	1,165
Lime, sandy----------	6	920	Sand, red; hard streaks------------	30	1,195
Shale, blue----------	5	925	Shale, red, sandy----	15	1,210
Lime-----------------	20	945	Rock-----------------	3	1,213
Rock, red------------	5	950	Slate and black shale	8	1,221
Lime-----------------	4	954	Shale and lime streaks------------	6	1,227
Rock, red------------	6	960	Total depth----------		5,365
Lime, sandy----------	10	970			
Sand-----------------	5	975			

Well G-1

Owner: H. H. Null. Driller: A. Smith.

Clay, yellow---------	35	35	Lime, blue-----------	15	195
Lime, blue-----------	5	40	Shale, gray----------	5	200
Lime and shale, blue-	40	80	Gypsum---------------	25	225
Lime, white----------	70	150	Lime, gray-----------	55	280
Shale, gray----------	30	180	Shale, blue----------	10	290

(Continued on next page)

Well G-1--Continued

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Lime, gray-------------	50	340	Sand and lime--------	20	460
Lime, blue-------------	25	365	Sand-----------------	15	475
Shale, red-------------	10	375	Lime, gray-----------	25	500
Lime and shale, gray---	65	440			

Well G-12

Owner: Pauline Crawford. Driller: King Stokes.

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
No record--------------	70	70	Limestone, white, hard, dense; abundant calcite crystals; fossils and dolomite in lower part---------	40	245
Shale, light-gray; contains dark-gray pellets and fossils; Orbitolina texana (Roemer)-------------	10	80	Dolomite, gray to brown, finely crystalline; contains sparkling dolomitic crystals; grades into dolomitic limestone in lower part; fine sand increases toward base--------	20	265
Limestone, light-gray, shaly, soft, contains dark fossils and pellets----------------	60	140	Limestone, white, sugary; abundant dark sand grains---	20	285
Limestone, white, sugary, fossiliferous, abundant foraminifera at top; gastropods, ostracods. Orbitolina texana (Roemer) and calcite veins in lower part----------------	20	160	Sand, fine to medium, in places cemented by sugary limestone and dolomite; scattered gray, sandy shale--------------	63	348
Limestone, light-gray, shaly; contains small dark fossils; overlies light-gray, sugary dolomite------	30	190			
Shale, gray and brown, calcareous, indurated, blocky--------------	15	205			

Well H-42

Owner: Bandera County Water Control and Improvement Dist. No. 1.
Driller: J. R. Johnson.

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
No record-------------	50	50	Limestone, cream to gray, dense, very porous; grades into crystalline drusy dolomite and dolomitic limestone in lower part---------	45	450
Limestone, light- to medium-gray, finely crystalline; in places speckled with dark fossil fillings; in places shell fragments abundant-------	115	165	Limestone, greenish-white to cream, dense to finely crystalline--------	10	460
Limestone, cream to gray, oölitic, sugary; abundant dolomitic crystals; fossiliferous----------------	110	275	Shale, green to gray, calcareous, soft; red to gray crystalline dolomite in lower part------	75	535
No record--------------	15	290	Limestone, cream to gray, dense, fine to medium quartz crystals abundant------	10	545
Dolomite, green to gray, sugary, indurated----	20	310	Dolomite, dense; contains some green slightly indurated shale--------------	55	600
Limestone, gray, dolomitic, speckled with dark fossils; dolomitic crystals abundant-----------------	25	335	Sandstone, cream to white, dolomitic, and some soft pink shale at top--------	50	650
Limestone, medium-gray, dense; contains well-sorted quartz grains; lowermost occurrence of abundant Orbitolina texana (Roemer) at 345 feet----------	40	375	Shale, calcareous, soft, variegated; scattered cream, dense, sandy dolomite----------------	90	740
Dolomite, green to gray, finely crystalline; very sandy in lower part-----------------	30	405			

(Continued on next page)

Well H-42--Continued

	Thickness (feet)	Depth (feet)
Dolomite, hard, crystalline and sandy; dense in places------	30	770
Dolomite, white, sugary, soft, and some gray and maroon soft shale	10	780
Dolomite, cream to buff, varies from soft to hard, grades into crystalline dolomite in lower part; abundant chert fragments and rounded quartz grains at base-------	50	830
Shale, buff, noncalcareous, moderately indurated----	45	875
Shale, gray to white, hard, noncalcareous	25	900

Well J-62

Owner: W. W. Walton. Driller: --Rossman.

	Thickness (feet)	Depth (feet)
Limestone, broken, and brown shale----------	35	35
Limestone, tan to white, hard, and earthy dolomite	80	115
Clay, yellow, and coquinal limestone---	60	175
Limestone, chalky, and tan clay------------	20	195
Dolomite and gypsum, gray, and blue clay--	17	212
Clay and shell, blue; contains *Orbitolina texana* (Roemer)------	18	230
Limestone, coquinal, and earthy dolomite--	45	275
Limestone, gray, hard, fossiliferous, and some porous, white, crystalline dolomite	85	360
Clay, blue; contains *Orbitolina texana* (Roemer)-------------	15	375
Limestone, white and light-blue, coquinal	85	460
Limestone, white to pink, coquinal, sandy, hard streaks contain crystalline dolomite-------------	115	575

(Continued on next page)

Well J-62--Continued

	Thickness (feet)	Depth (feet)
Dolomite, gray, crystalline, porous, and glauconitic shale	25	600
Limestone, sandy, hard; some dolomite at base	25	625
Limestone and dolomite, white; dolomite increases toward base	75	700
Shale, gray, sticky; dark nodules; some white limestone and dolomite; shell fragments	60	760
Limestone, light-gray, nodular, porous	40	800
Dolomite, light-gray, earthy	60	860
Dolomite, sandy, white and some pink, sandstone, and green shale	70	930
Sandstone and shale, pink and white, some dolomitic limestone, and green shale	110	1,040
Limestone, tan, and green and red shale; chert and limestone fragments	71	1,111
No record	9	1,120

Well K-3

Owner: T. J. Haby. Driller: C. Walker.

	Thickness (feet)	Depth (feet)
Gravel, silty	35	35
Shale and limestone, blue	40	75
Limestone, blue	35	110
Shale, blue	15	125
Limestone, brown	30	155
Limestone, gray and blue	75	230
Shale, gray	50	280
Limestone, gray, soft	30	310
Shale and limestone, brown	25	335
Limestone, white, sandy	40	375
Limestone, black	5	380
Limestone, brown, gritty	35	415
Sand and shale, brown	25	440
Shell and sand, black	10	450
Shale, gray and black, sticky	10	460
Shale and brown sand	10	470

(Continued on next page)

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)

Well K-3--Continued

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Sand and coal-------	10	480	Sand and white limestone---------	10	490

Well M-11

Owner: J. F. Merrick. Driller: J. R. Johnson.

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
No record-----------	130	130	Dolomite, light-gray, shaly, lignitic, and brown and grayish-white, sandy limestone; dark pellets and small shells------------	35	535
Limestone, creamy white and light-gray, sugary, fossiliferous; some soft, gray shale; shell fragments; _Orbitolina texana_ (Roemer)-----	50	180	Limestone, cream to brown, fossiliferous, shaly, sandy; dolomite in middle; ostracods and miliolids abundant-----	30	565
Shale, gray and light-gray, calcareous, indurated; fossiliferous, shaly sugary limestone-----------	40	220	Limestone, cream to gray, shaly in upper part, sandy, dolomitic, and slightly glauconitic in lower part; fossiliferous-----------	30	595
No record-------------	80	300	Dolomite, light-gray, crystalline, sandy, glauconitic; fossiliferous limestone in middle; small fossils in upper part-----	25	620
Limestone and dolomite, light-gray to brown, crystalline, sugary, fossiliferous; abundant small fossils-------------	50	350	Limestone, light-gray to brown; speckled with dark and cream-colored fossils; shaly in lower part; large shell fragments abundant in places------------	35	655
Limestone, white, sugary, fossiliferous; dolomite in middle-----------	60	410			
Limestone, creamy gray and brown, fossiliferous; dolomite in middle and at base; some lignite, gypsum, and fine crystals in sugary matrix-------	90	500			

(Continued on next page)

Well M-11--Continued

	Thickness (feet)	Depth (feet)
Dolomite, light-brown, shaly; abundant quartz sand; some lignite; calcareous, gray shale in lower part----------------	20	675
Limestone, light-brown, fossiliferous, sandy, glauconitic; sandy dolomite in middle part; large shell fragments in lower part----------------	40	715
Dolomite, white to light-gray and brown; glauconitic and sandy in upper part; shaly in lower part; abundant oyster shells--	45	760
Shale, gray; limy in upper part; soft in lower part; abundant oyster shells-------	50	810
Limestone, sugary to dense, fossiliferous; interbedded shale and sandy dolomite in lower part----------	55	865
Dolomite, light-brown and white, fossiliferous; sandy in upper part; shaly glauconitic, and lignitic in middle; poorly sorted sand in lower part; large shells at base-----	70	935
Shale, gray and brown, calcareous, indurated; and sandy, glauconitic limestone----------	50	985
Dolomite, pink and white, soft, sugary, sandy, glauconitic; and grayish-green shale--------------	65	1,050
No record------------	87	1,137

Well P-25

Owner: R. Morgan. Driller: G. Heinen

	Thickness (feet)	Depth (feet)
Limestone, light-gray, shelly, hard---------	40	40
Limestone, hard, and blue shale-----------	60	100
Limestone, light-gray, earthy---------------	90	190
Shale and limestone, light-gray---------	85	275
Dolomite and gypsum, tan, sugary; some gray shale---------	35	310
Shale, blue----------	25	335

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	Thickness (feet)	Depth (feet)
Well P-25--Continued		
Limestone, gray, shelly, hard	40	375
Shale and gray limestone; abundant *Orbitolina texana* (Roemer)	132	507
Dolomite and gypsum, dark, and some gray shale; *Corbula texana* Whitney in lower part	23	530
Shale, blue, sticky; some *Orbitolina texana* (Roemer)	20	550
Limestone, gray to white, shelly, hard	30	580
Limestone, white, shelly, sugary, porous	45	625

Table 4.--Analyses of water from wells and springs in Bandera County
(Analyses by U. S. Geological Survey, Austin, Texas. Chemical constituents in parts per million)

Water-bearing unit: A, alluvium; E, limestones of the Fredericksburg and Washita groups; Gu, Glen Rose limestone, upper member; Gl, Glen Rose limestone, lower member; G, Glen Rose limestone, undifferentiated; Ph, Pearsall formation, Hensell shale member; Pc, Pearsall formation, Cow Creek limestone member; P, Pearsall formation, undifferentiated; S, Sligo formation; H, Hosston formation.

Well	Owner	Depth of well (ft.)	Date of collection	Water-bearing unit	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na + K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Percent sodium	Sodium-adsorption ratio (SAR)	Specific conductance (micromhos at 25°C)	pH
A-2	A. S. Kelley	301	Feb. 12, 1957	E	13	-	72	22	10	326	3.4	12	-	5.6	-	298	270	3	8	0.3	513	7.3
A-5	J. Short	200	do	E	13	-	87	16	6.6 1.3	304	4.6	16	-	28	-	322	283	0	5	.2	569	7.3
B-5	J. F. Camp	250	Feb. 10, 1957	E	9.8	-	89	13	12	345	2.6	10	-	2.0	-	308	276	0	8	.3	529	7.4
B-10	C. H. Heimsath	445	May 6, 1954	Gu	9.2	-	516	421	124	274	2,910	25	-	.0	-	4,140	3,020	2,790	8	1.0	4,220	7.7
B-11	J. N. Rayzor	450	Aug. 6, 1955	Gl & Ph	12	a0.00	101	70	57	325	327	40	-	1.5	-	818	540	274	17	1.0	1,170	7.4
B-17	Mrs. E. B. Stephens	465	do	Gl & Ph	12	.01	96	64	49	340	267	37	-	.5	-	735	502	224	17	1.0	1,080	7.4
C-4	Medina Childrens Home	285	Feb. --, 1952	G	13	-	98	71	27	351	242	34	2.8	.5	-	712	536	249	10	.5	1,050	7.3
C-5	do	520	Feb. --, 1952	Gl & Ph	13	.00	86	64	34 9.2	351	190	34	2.8	1.0	0.53	635	478	190	13	.7	982	7.8
C-8	E. Hund	150	Aug. 24, 1955	G	12	b .01	554	263	48	267	2,210	34	-	.5	-	3,250	2,460	2,240	4	.4	3,430	7.2
C-9	E. W. Brown, Jr.	Spring	Feb. 13, 1957	E	9.8	-	68	21	5.0 .6	296	4.2	12	-	3.0	-	270	256	14	4	.1	474	7.3
C-10	do	630	do	Gl & Ph	5.4	-	54	49	49	338	129	22	-	.0	-	485	336	59	24	1.2	772	7.8
D-6	Albee Storms	380	Aug. 20, 1953	G	12	.00	-	-	49	358	902	31	-	.2	.59	-	1,170	876	8	.6	1,960	7.8
E-5	Paul Harbin	20	Feb. 12, 1957	Gu & A	8.4	-	46	20	13	226	19	14	-	.0	-	231	197	12	12	.4	406	7.5
E-8	N. L. Coffee	Spring	Aug. 11, 1947	Gu & A	-	-	-	-	-	288	10	14	-	-	-	-	c 264	28	-	-	510	-
E-11	G. W. Henri	60	June 1, 1952	Gu	-	-	-	-	-	511	-	18	-	-	-	-	283	0	-	-	1,340	7.6
E-12	do	22	Aug. 10, 1947	Gu	-	-	-	-	-	260	10	12	-	-	-	-	c 216	3	-	-	464	-

See footnotes at end of table.

Table 4.--Analyses of water from wells and springs in Bandera County--Continued

Well	Owner	Depth of well (ft.)	Date of collection	Water-bearing unit	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na + K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids	Hardness as $CaCO_3$ Calcium, magnesium	Hardness as $CaCO_3$ Non-carbonate	Percent sodium	Sodium-adsorption ratio (SAR)	Specific conductance (micromhos at 25°C)	pH
E-13	G. W. Henri	Spring	Aug. 10, 1947	Gu	-	-	-	-	-	256	10	16	-	-	-	-	c 246	36	-	-	543	-
E-18	W. F. Stelzer	872	Feb. 12, 1957	Pc	11	-	121	83	91	331	482	41	3.6	0.2	-	996	644	372	23	1.6	1,400	7.6
E-21	R. G. Thompson	84	do	Gu	15	-	124	33	20	349	160	24	.2	1.4	-	561	445	159	9	.4	840	7.4
F-3	A. C. Allsup	232	Feb. 8, 1957	E	12	-	71	21	6.0 -	311	4.0	12	-	5.5	-	284	264	8	5	.2	497	7.3
F-5	B. H. LeStourgeon	160	Feb. 7, 1957	E	8.2	-	58	16	3.8 -	246	3.4	9.5	-	4.6	-	224	210	9	4	.1	397	7.5
F-11	A. A. Keese	69	Feb. --, 1957	Gu	8.4	-	70	19	10	288	15	13	-	5.3	-	283	252	16	8	.3	493	7.2
F-15	P. L. Garrison	487	Aug. 25, 1955	Gl & Ph	13	d0.01	83	55	57	337	215	39	-	1.0	-	651	433	157	22	1.2	1,010	7.4
F-21	L. R. Dukes	73	Feb. 12, 1957	Gu	13	-	546	216	37	266	2,000	15	3.6	.2	-	2,960	2,250	2,030	3	.3	3,050	7.3
F-22	I. K. Reavis	190	do	G	11	-	163	87	27	303	525	17	1.8	.0	-	981	764	516	7	.4	1,310	7.5
G-5	G. D. Sears	317	Aug. 6, 1955	Gl & Ph	12	.01	88	62	46	351	221	40	-	.5	-	678	474	187	17	.9	1,030	7.4
G-7	L. O. Reatherford	340	Aug. 29, 1955	Gl & Ph	12	e .02	97	52	43	354	196	38	-	.0	-	643	455	165	17	.9	988	7.4
G-18	S. W. Stevens	61	May 18, 1954	Gu	15	-	628	64	15	293	1,540	14	-	.0	-	2,420	1,830	1,590	2	.2	2,600	7.2
G-20	T-4 Ranch	Spring	May 15, 1954	Gu	12	-	607	71	12	291	1,510	16	-	.0	-	2,370	1,810	1,570	1	.1	2,570	7.5
G-25	Tex Anderson	455	May 16, 1954	G & P	11	-	476	209	28	292	1,770	18	-	.0	-	2,660	2,050	1,910	3	.3	2,850	7.4
G-27	C. R. Frederick	520	Aug. 29, 1955	G & P	12	f .00	580	76	31	220	1,560	16	-	.5	-	2,380	1,760	1,580	4	.3	2,560	7.3
G-29	B. L. Light	580	Aug. 6, 1955	G & P	12	.01	396	163	70	324	1,440	31	-	4.0	-	2,280	1,660	1,390	8	.7	2,610	7.1
G-33	Gilbert Wendt	330	June 17, 1954	Gl & P	12	-	71	50	54	363	147	35	-	1.0	-	550	382	85	24	1.2	920	7.7
G-34	R. M. Kendrick	100	Feb. 7, 1957	Gu	12	-	142	31	7.0 2.3	348	175	15	.6	16	-	572	482	197	3	.1	866	7.2

See footnotes at end of table.

Table 4.--Analyses of water from wells and springs in Bandera County--Continued

Well	Owner	Depth of well (ft.)	Date of collection	Water-bearing unit	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na + K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Non-carbonate	Percent sodium	Sodium-adsorption ratio (SAR)	Specific conductance (micromhos at 25°C)	pH
G-35	R. M. Kendrick	143	Feb. 7, 1957	Gl	12	-	98	38	25	363	131	13	-	2.5	-	504	401	104	12	0.5	749	8.0
G-38	J. W. Halley	570	Jan. 17, 1957	G & P	11	-	522	330	61	346	2,360	27	5.2	.8	-	3,490	2,660	2,380	5	.5	3,570	7.3
G-42	G. A. Cooper	650	Feb. 12, 1957	Gl & P	11	-	54	42	8.2 -	285	67	12	-	.2	-	334	307	74	6	.2	596	7.2
H-9	J. Garrett	309	May 13, 1954	Gl & Ph	14	-	105	37	15	368	87	28	-	18	-	500	414	112	7	.3	809	7.9
H-11	J. A. Barnett	400	June 14, 1954	Gl & Ph	12	-	122	92	38	351	410	36	-	1.5	-	957	683	396	11	.6	1,320	7.8
H-12	L. R. Vaughn	403	Aug. 9, 1955	P & G	12	0.01	106	83	39	361	333	33	-	1.0	-	853	606	310	12	.7	1,190	7.4
H-13	J. D. Fly	390	Jan. 16, 1957	P & G	12	-	133	110	44	363	500	35	4.4	.5	-	1,020	784	487	11	.7	1,410	7.4
H-17	W. C. Ramsey	135	do	Gu	11	-	149	121	46	375	577	36	4.4	.0	-	1,130	870	562	10	.7	1,520	7.4
H-23	Hugo Bausch	425	May 30, 1954	Gl & P	17	-	104	71	51	428	187	82	-	1.0	-	757	552	201	17	.9	1,200	7.3
H-28	Howard G. Hay	400	Jan. 17, 1957	Gl	12	-	74	55	51	372	156	33	2.6	.2	-	569	410	106	21	1.1	898	7.5
H-30	F. M. Montague	425	May 16, 1954	Ph, Pc & Gl	11	-	80	53	41	390	142	28	-	.0	-	558	418	98	18	.9	915	7.6
H-35	B. Tilghman	520	Jan. 16, 1957	Ph, Pc & Gl	12	-	84	66	63	367	248	36	3.4	.2	-	701	482	181	22	1.3	1,060	7.6
H-37	Mrs. L. Rainey	130	do	Gl	13	-	82	15	11	283	36	13	.4	.8	-	310	265	33	8	.3	516	7.4
H-39	Raymond Hicks	460	Aug. 16, 1955	P	13	.00	72	52	46	362	146	32	-	1.0	-	549	394	97	20	1.0	899	7.6
H-44	Bandera County Water Control & Improvement District No. 1	435	Nov. 2, 1945	Gl & P	14	g .20	73	51	38 21	362	139	37	2.8	0	-	560	392	85	16	.8	933	7.2
*H-45	do	896	Mar. 22, 1950	S & H	11	1.6	50	33	-	372	68	57	2.2	.4	-	492	261	0	-	-	-	-
H-46	do	467	Nov. 2, 1945	Gl & P	13	.06	86	62	39 20	358	220	36	2.4	0	-	682	464	176	15	.8	1,070	6.9

See footnotes at end of table.

Table 4.--Analyses of water from wells and springs in Bandera County--Continued

Well	Owner	Depth of well (ft.)	Date of collection	Water-bearing unit	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na + K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids	Hardness as $CaCO_3$ Calcium, magnesium	Hardness as $CaCO_3$ Non-carbonate	Percent sodium	Sodium adsorption ratio (SAR)	Specific conductance (micromhos at 25°C)	pH
H-54	Purple Sage Ranch	400	May 20, 1954	Gl & P	8.8	-	76	87	47	377	279	35	-	0.0	-	751	547	238	16	0.9	1,130	7.7
H-55	do	780	do	S & H	13	-	38	25	106	378	46	50	-	.0	-	464	198	0	54	3.3	824	7.7
H-60	J. P. Heinen	463	July 2, 1954	Gl & P	14	-	76	45	30	378	89	27	-	.0	-	476	374	265	15	.7	797	7.8
H-63	B. Parker	454	Aug. 18, 1955	Gl & P	18	0.00	80	28	24	377	14	16	-	25	-	390	314	6	14	.6	670	8.0
H-65	L. D. Fisher	420	June 14, 1954	Gl & P	13	-	73	55	49	355	167	35	-	1.5	-	573	408	117	21	1.1	954	8.0
H-68	W. M. Ratcliffe	165	Aug. 24, 1955	Gl	15	.01	97	69	12	397	198	14	-	1.0	-	601	526	200	5	.2	947	7.4
H-70	M. L. Stoner	528	Aug. 16, 1955	G & P	14	.01	332	195	30	336	1,330	24	-	2.0	-	2,090	1,630	1,360	4	.3	2,420	7.3
H-73	D. H. Crowell	1,085	Jan. --, 1957	S & H	13	-	32	21	134	360	51	73	2.8	.0	-	504	166	0	64	4.5	858	7.6
J-3	Emory Brown	413	Jan. 10, 1957	G & P	12	-	132	147	47	381	628	40	5.6	.8	-	1,200	934	622	10	.7	1,630	7.4
J-9	Mrs. P. G. Northrup	740	Jan. 5, 1957	G & P	10	-	242	166	79	320	1,080	43	4.0	.0	-	1,780	1,290	1,020	12	1.0	2,180	7.5
J-15	A. Kronkosky	651	do	Gl & P	12	-	86	60	29	301	234	18	2.6	.4	-	605	461	214	12	.6	883	7.7
J-21	W. F. Bush	60	Jan. --, 1957	G	13	-	137	101	21	296	507	20	1.6	.0	-	947	758	515	6	.3	1,290	7.4
J-22	E. H. Frerich	475	Jan. 5, 1957	Gl & P	12	-	65	62	22	336	140	24	3.6	.2	-	499	417	142	10	.5	807	7.5
J-30	Jim Edwards	120	Jan. 9, 1957	Gl	20	-	133	10	13	380	16	21	.4	54	-	454	374	62	7	.3	728	7.4
J-33	J. W. & Milton Lewis	480	Jan. 14, 1957	Gl & P	13	-	158	117	59	361	621	36	3.4	1.5	-	1,190	875	579	13	.9	1,590	7.3
J-41	E. D. Du Frechoru	387	do	Gl & P	16	-	104	32	29	398	79	24	1.4	9.7	-	491	391	65	14	.6	816	7.2
J-50	C. D. Lovelace	420	Aug. 19, 1955	Gl & P	20	.01	92	17	22	339	15	37	-	1.0	-	393	300	22	14	.6	662	7.4
J-55	A. R. Heisler	420	July 2, 1954	Gl & P	13	-	64	57	66	356	189	35	-	.0	-	611	394	102	27	1.4	977	7.9

See footnotes at end of table.

Table 4.--Analyses of water from wells and springs in Bandera County--Continued

Well	Owner	Depth of well (ft.)	Date of collection	Water-bearing unit	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na + K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids	Hardness as $CaCO_3$ Calcium, magnesium	Hardness as $CaCO_3$ Noncarbonate	Percent sodium	Sodium-adsorption ratio (SAR)	Specific conductance (micromhos at 25°C)	pH
J-62	W. W. Walton	1,120	Dec. 21, 1956	Gl, P, S, & H	13	-	304	180	46	316	1,260	20	-	1.4	-	1,980	1,5[illegible]0	1,240	6	.5	2,270	7.4
J-63	do	500	do	G & Ph	12	-	302	194	77	356	1,340	21	-	2.0	-	2,120	1,550	1,260	10	.8	2,430	7.1
K-3	T. J. Haby	490	Feb. 12, 1957	P	12	-	194	142	45	336	810	26	3.6	1.3	-	1,400	1,070	792	8	.6	1,780	7.3
M-5	R. R. Pue	405	Aug. 1, 1953	Gl & P	15	-	166	145	21	355	692	23	2.6	4.7	-	1,240	1,010	719	4	.3	1,660	7.6
M-9	A. W. Nichols	14	Jan. 17, 1957	Gl	13	-	130	24	13	356	127	16	.6	3.8	-	512	422	130	6	.3	787	7.4
M-11	John F. Merrick	1,137	do	H	13	-	39	20	137 15	364	70	85	3.0	.0	0.8	561	180	0	60	4.4	949	7.7
N-1	Roland Britsch	30	do	Gu	14	-	264	33	11	330	500	14	.6	6.1	-	1,000	794	524	3	.2	1,300	7.2
N-4	J. S. Morris	820	Mar. 27, 1952	Pc	1.6	0.9	-	-	13	143	622	65	-	24	-	-	840	723	3	-	1,730	7.9
N-9	Gene Dunlap	84	Jan. 16, 1957	Gu	14	-	550	142	27	288	1,680	18	1.8	.0	-	2,570	1,960	1,720	3	.3	2,730	7.1
P-5	Rudolph Schott	400	Jan. 7, 1957	G	13	-	62	32	20	299	56	15	-	6.7	-	352	286	41	13	.5	585	7.3
P-13	R. D. Faurie	300	Feb. --, 1957	G	15	-	138	54	15	367	251	16	1.0	15	-	685	566	266	6	.3	1,010	7.3
P-16	A. K. Smith	480	Feb. 13, 1957	G	12	-	205	157	63	466	819	22	4.8	.7	-	1,520	1,160	758	11	.8	1,880	7.4
P-21	W. R. Walls	356	June 16, 1954	Gu	15	-	352	305	207	312	2,210	16	-	3.5	-	3,260	2,130	1,880	17	1.9	3,38[illegible]	7.0
P-22	J. E. McDonald	525	June 20, 1954	G	15	-	538	125	54	256	1,590	77	-	.0	-	2,520	1,860	1,650	6	.5	2,570	7.6
P-23	Buck Morse	320	June 17, 1953	G	7.2	h .00	472	255	10 12	283	1,930	20	2.6	.5	.38	2,850	2,230	1,990	1	.1	3,070	7.8
P-24	George Ruede	275	Feb. 7, 1957	Gu	13	-	492	92	20	243	1,370	15	1.8	.1	-	2,120	1,610	1,410	3	.2	2,330	7.2

a Total iron (Fe), 1.5 ppm.
b Total iron (Fe), 2.5 ppm.
c Hardness by soap method.
d Total iron (Fe), 1.2 ppm.
e Total iron (Fe), 3.5 ppm.
f Total iron (Fe), 4.8 ppm.
g Total iron (Fe), 1.1 ppm.
h Total iron (Fe), 2.4 ppm.
* Analysis by Texas State Department of Health