HENDERSON OIL FIELD AREA

RUSK COUNTY, TEXAS

INVESTIGATION OF GROUND-WATER CONTAMINATION

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By

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INTRODUCTION

On June 25, 1962, the Texas Water Commission received a copy of a letter dated June 22, 1962, from the Texas Railroad Commission to Mrs. Burris Dorsey, Henderson, Texas, concerning their investigation of alleged salt water contamination of the Dorsey water well. The letter stated that the Railroad Commission did not feel that there was an obvious cause of the contamination problem other than the possibility that a nearby abandoned surface pit might be the source. The Railroad Commission's letter suggested that Mrs. Dorsey contact the Texas Water Commission in the belief that a hydrologist might be able to determine the source of pollution.

On June 28, the Texas Water Commission received a letter from Mrs. Dorsey requesting assistance in locating the source of ground water contamination on her property.

METHODS OF INVESTIGATION

A field investigation of this problem was undertaken by the staff of the Waste Disposal Section of the Texas Water Commission on August 1 and 2, 1962. During this investigation water wells in the general area of the Burris Dorsey property were located, water samples for chemical analysis were obtained, and oil and gas wells and salt water disposal facilities in nearby areas were located.

Included in the report is a composite electric log showing stratigraphic relationships of geologic formations in the oil field area (Figure 1); a plat showing property ownership and location of water wells, oil and gas wells, salt water disposal facilities, and surface drainage (Plate 1); a table of records of brine production on leases investigated (Table 1); a table of chemical analyses of water samples (Table 2); and a graphic illustration of chemical quality of ground water in the area (Figure 2). Water samples were analyzed by the Texas State Department of Health.

LOCATION, ECONOMY, AND CLIMATE

The contaminated water well owned by Mrs. Burris Dorsey is in the north-central part of the Henderson Oil Field in central Rusk County. The southern edge of the field is approximately 2 miles northwest of the City of Henderson. The present oil and gas productive area of the Henderson Field covers approximately 15-20 square miles.

Much of the area is relatively densely populated. Oil and gas production, agriculture, and stock raising are the principal contributors to the local economy.

The climate of this region is sub-tropical in nature with an annual rainfall of 45.95 inches and a mean annual temperature of 66°F. The net annual evaporation rate of this region, for the period 1940-1957, ranged from +26 inches per year to -30 inches per year, with the average net rate being -2.5 inches per year. Therefore, on the average, rainfall exceeds the evaporation rate in this area.

OIL AND GAS PRODUCTION

The Henderson Oil Field discovery well was completed in the fall of 1943 by the Beacon Oil & Refining Company in conjunction with American Liberty Oil Company on the J. H. Allen Estate tract, Taylor Brown Survey. Most of the oil and gas wells were drilled during the years 1944-1957 inclusive with an additional surge of drilling activity in the years 1957 and 1958.

Oil production with limited gas production is primarily from the Pettet lime (Glen Rose). Most of the more recent gas discoveries in the northwest area of the field are from the Travis Peak reservoir, which also produces some oil in the eastern parts of the Henderson Field. Reservoir energy is the result of a combination water drive and gas expansion, with water drive apparently the dominant factor.

BRINE PRODUCTION AND DISPOSAL

Pumpage of salt water was reportedly negligible from most oil and gas wells during the early years of production; however, brine production has increased substantially on many leases during recent years. The average quality of brine produced, as shown by analyses of samples taken directly from tank batteries, exceeds 135,000 ppm (parts per million) chloride and 218,000 ppm total dissolved solids.

At the time of the current field study, all of the leases visited utilized open, unlined surface pits for brine disposal. These pits ranged in size from small, shallow excavations receiving a few barrels of brine per day to large pits covering two acres or more. Many of the large pits were constructed adjacent to surface streams.

Table 1, which compiles records of brine production and disposal on leases investigated in the Henderson Oil Field, indicates that of the leases inspected in the present study, the S. N. Scarbrough, N. R. Dorsey, and C. B. Dorsey leases operated by Beacon Oil Company; the N. R. Dorsey lease, operated by W. R. King (well now abandoned); the R. P. Yandle lease, operated by Trice Production Company; the N. R. Dorsey lease, formerly operated by Danciger Oil Company, Southern Production Company, and now operated by Sinclair (well now abandoned); and the C. C. Dorsey lease, operated by Sinclair; have been and currently are the principal producers of salt water.

OPEN, UNLINED SURFACE PITS AS A MEANS OF BRINE DISPOSAL

The following discussion was partly adapted from a paper titled "Possible Movement of Salt Water from Salt-Water Disposal Pits into Ground Water Reservoirs and Surface Streams," February, 1958, by William F. Guyton and Associates, Consulting Ground-Water Hydrologists.

Storage of produced oil field brine in open, unlined, earthen pits is at present the most widely used method of brine disposal in Texas. The water in which minerals are dissolved (primarily sodium, chloride, calcium, and magnesium ions) may be lost from a surface pit by evaporation. The dissolved minerals, however, cannot be evaporated. If the pit is constructed in relatively impermeable material such as clay or shale, and if there is no overflow, most of the minerals are held in the pit in solution or as a precipitate, depending on the net rate of evaporation of the area. Water leaving the pit by overflow or subsurface leakage, however, will carry dissolved minerals with it.

The net average annual evaporation rate from an open body of water, after adjusting for losses from evaporation and gains from precipitation, also depends upon other climatic factors such as temperature, relative humidity, and wind velocity and direction. Net evaporation is low in humid regions and high in arid regions. Studies have shown that the rate of evaporation of water containing dissolved salt (sodium chloride) is less than that of water free from salt. The evaporation rate is reduced approximately in proportion to the percentage of salt crystals which frequently form on the water surface as the saturation point is reached. Oil, which is commonly present in disposed brine, forms a surface film which also significantly retards evaporation.

Theoretically, a completely impermeable pit subjected to continuously introduced brine for an extended period of time would eventually be filled by the solid salt precipitate as a result of evaporation and concentration. This, however, seldom happens since rainfall will frequently fill the pit, resulting in dilution and overflow. In addition, although there are some relatively impermeable types of rock such as shale and clay which will not permit rapid infiltration of water, no rock type is absolutely impermeable; therefore, there will always be some leakage of brine from unlined pits.

A surface disposal pit which is receiving a continuous inflow of brine and is not overflowing, and which shows no salt deposit accumulations, or insignificant deposits with respect to the volume of brine inflow, is therefore leaking brine. If the walls of the pit are constructed above ground level, as is commonly the case, and if the brine level is raised above the ground surface as the result of heavy rain or excessive additions of brine, some leakage will commonly occur through the pit walls. Overflow or leakage of brine from the pit walls will either evaporate, reach a surface stream, or filter into the ground outside the pit. Minerals left by evaporation as a precipitate on the ground outside the pit will be re-dissolved by rainfall and are either carried into surface streams or percolate into the subsurface.

Seepage of salt water into the subsurface, either outside or inside of the surface pit, will follow the path of least resistance. The brine may either move laterally underground on top of relatively impermeable beds and emerge in surface drainage at points of lower elevation or it may percolate downward by gravity through the capillary fringe and ultimately mix with the ground water below the water table, or both. Leakage of brine from an unlined disposal pit can occur readily if the soil and rock strata between the bottom of the pit and the water table are relatively permeable (gravel, sand, sandstone, fractured and cavernous limestone) and thus capable of readily transmitting fluids. Therefore, the relative amounts of brine seeping from surface pits which directly enter the ground-water body or moves more or less laterally into surface drainage ways is dependent upon the many variables discussed above, notably porosity and permeability of the underlying material, presence or absence of semipermeable beds below the surface pit and the lateral extent of these beds.

Ground water under water-table conditions generally is in constant motion from areas of recharge to points of discharge. Generally, the slope of the water table follows that of the land surface and is controlled by the position of the master drainage in the area, that is, the water moves in the direction of lower surface elevations along surface drainage ways. The rate of movement under natural conditions is dependent upon the hydraulic gradient and the character of the aquifer and may range from a few feet per year in fine-grained material to hundreds of feet per day in fractured and cavernous limestone. Thus, ground water under water-table conditions, moving under the local hydraulic gradient through the subsurface, is either discharged naturally at the land surface or by water wells. Such natural discharge occurs in the form of seeps and springs or by direct flow into surface bodies of water where these bodies intercept the water table, as transpiration where the water table is shallow and roots of plants are able to reach it, and by evaporation where the water table is shallow enough for capillary forces to draw the water to the surface.

Brine which percolates into the water table thus ultimately mixes with the ground-water body and emerges at points of artificial or natural discharge. Numerous studies by ground-water hydrologists have led to the belief that once the pollutant enters the water table, underground mixing proceeds very slowly in contrast to relatively fast mixing that takes place in surface streams, and that movement of foreign water through ground-water aquifers is confined to rather narrow zones or belts. Thus, in a homogeneous aquifer, a "ribbon" or brine could move for hundreds or thousands of feet with only slight increase in width as it slowly mixes with the ground water.

Dissolved minerals are not discharged with transpiration and evaporation but are concentrated in the capillary fringe and in the soil, where seepage and surface runoff carry them into surface drainage.

Minerals which escape from a surface disposal pit, therefore, generally reach surface drainage, either by surface or subsurface routes. The drainage system receiving the surface runoff may, of course, be different from the system receiving subsurface flow. Usually, however, they are the same. The length of time required for contaminants from a surface pit to reach surface water in an area depends upon the path of movement and the distance of travel, and may range from a few minutes to many years. Dissolved minerals which may slowly filter into confined artesian aquifers in some areas will move down the dip of the aquifer and therefore may never enter surface drainage unless discharged through wells or springs.

GENERAL GEOLOGY AND GROUND WATER

Detailed surface geologic mapping in the area was not included in the present study. Available geologic maps indicate that the Carrizo formation and the overlying Reklaw formation of the Claiborne group are present as thin erosional outliers in the general area of study, and the underlying Wilcox group crops out in the northern part of the oil field. Unconsolidated alluvial sand and silt deposits of undetermined thickness border surface streams in the area.

The Carrizo and Reklaw sands and clays, where present, apparently yield small quantities of water to shallow wells in the area. Formations of the Wilcox group, which consists of 700 to 800 feet of interlayered sand, sandstone, claystone, and lignite, constitute the principal aquifer of this region. These water-bearing sands furnish the Henderson municipal water supply to twelve wells located within the Henderson city limits. These wells range in depth between 576 and 752 feet. Water samples analyzed in 1959 by the State Department of Health show a range in chloride concentration between 10 and 40 ppm and a range in total dissolved solids between 183 and 570 ppm.

The formations discussed above strike northeast with a regional dip to the northwest toward the East Texas embayment. Areal movement of ground water under artesian conditions in these aquifers is therefore northwest down the regional dip, except where the direction of movement may be influenced by local structural anomalies or by heavy pumping by water wells.

SURFACE DRAINAGE

Surface drainage in the Henderson oil field is through intermittent streams flowing northeast into Lake Cherokee, which furnishes the municipal water supply for the City of Longview. Major drainage ways are Cherokee Bayou, Beaver Run Bayou and their tributaries. All other major streams in this region are effluent into the Sabine River to the northeast. Land surface elevations in the general area investigated are in the approximate range between 380 feet and 475 feet above sea level.

LOCAL GROUND WATER CONDITIONS

Investigation of water wells in the immediate area of the Dorsey water well indicates that there are two separate, shallow, water-bearing zones, one occurring in the general depth interval 20-25 feet which contains water under water-table conditions, and the other between 75 and 85 feet, apparently containing water under artesian conditions. Movement of ground water under water-table conditions would be expected to follow the slope of the water table in a homogenous aquifer, which would in turn be controlled by the configuration of the land surface.

The measured static water level in the Burris Dorsey 85 foot deep well was 20 feet below ground level, whereas the static water level in a nearby 100 foot deep well on the S. N. Scarbrough property, which is apparently completed in the same sand, was 50 feet below ground level. Although no detailed topographic data are available in this area, adjustment for estimated differences in surface elevations at these two well localities strongly suggests that water in this sand is confined under artesian or semi-artesian conditions in this immediate area and that the natural direction of movement is northwest down the regional dip of the aquifer. However, two water-level measurements do not constitute sufficient data for a positive determination of the hydraulics of ground water in this particular sand. Detailed field determinations of land surface elevations and numerous water-level measurements of this aquifer would be required to determine positively whether ground water in this deeper zone is under artesian or water-table conditions and to determine the direction of movement of ground water.

Should it become apparent as a result of possible further study that water-table conditions exist in the deeper sand, then it would be expected that movement of water in the immediate area of the Dorsey well would follow the slope of the water table. The direction of movement at this locality would therefore be toward the master drainage pattern, or east-northeast. To the east of the Dorsey well, the water table would dip toward the north-northwest, and to the west of the Dorsey well, the water table would dip generally to the east-northeast.

Pumpage would have some influence upon direction and magnitude of movement in each of the water-bearing zones, although this effect is not thought to be significant in the area of study as pumps used on wells scheduled have relatively small pumping capacities.

SUMMARY OF CURRENT INVESTIGATION

Analyses of water samples from seven water wells in the area studied indicate that only the well belonging to Mrs. Burris Dorsey, and subject of the initial complaint, is producing water extremely high in dissolved mineral solids. This well is cased to total depth, gravel packed, and cemented. It is completed in a sandstone in the depth interval between 75 and 85 feet, and a sample of water obtained in the current study indicated a mineral concentration of 1,499 ppm chloride and 2,475 ppm total dissolved solids. Significant increases over normal native quality in both sodium (609 ppm) and calcium (261 ppm) concentrations in this water sample are also evident as illustrated in the graphic analyses (Figure 2). A slight increase in magnesium concentration is also thought to be significant.

The native quality of ground water in this particular water-bearing sand is on the order of 13 ppm chloride and 210 ppm total dissolved solids as shown by an analysis of the nearby 100 foot deep well on the Scarbrough property, which apparently produces water from the sand. Complete data concerning the method of completion of the Scarbrough well was not available at the time of investigation, although the well was reported to be cased to total depth and perforated in a sand occurring in the general depth interval between 80 to 90 feet.

All other wells sampled in the area produce water, which is under water-table conditions, from shallow sands in the general depth interval between 20 and 25 feet. A driller's log of the 85-foot deep contaminated well on the Burris Dorsey property reportedly indicates that the two water-bearing zones are separated in the immediate area of this well by an aquiclude of lignite and lignitic clay which is approximately 25 feet thick.

The shallow wells in this area produce water with chloride concentrations of 55 ppm or less with the exception of a well on the T. V. Bennett property which had a chloride concentration of 181 ppm. This value may indicate alteration of native water quality. It should also be pointed out that the sample from the Bennett well was obtained by bail whereas a sample obtained after pumping this well would perhaps indicate considerably higher mineral concentration of the water.

The only sources of water containing high concentrations of chloride, calcium, sodium, and magnesium in this region are oil field brine disposal pits; however, the possibility exists for brine leakage from deep salt water-bearing zones in oil and gas wells which may be improperly cased, cemented, or plugged. The first zone productive of brine which is encountered in drilling in this area is the Nacatoch formation which occurs in the general depth interval 2050-2250 feet (see Figure 1). Because of the high porosity and permeability of both the sandy soils and shallow subsurface formations in the area, the rate of seepage loss of brine from surface pits approaches the rate of brine disposal into the pits. There can be no doubt that much of this brine contributes directly to stored ground water by vertical infiltration into the aquifers. However, a part of the brine lost by seepage from these surface pits constitutes a major part of the base flow of streams investigated. Analyses of stream samples, locations of which are shown on the accompanying plat, show surface drainage in this area to have chloride concentrations ranging from 4,072 to 72,685 ppm and a total dissolved solid range from 6,609 to 116,880. These effluent brine streams become influent locally and therefore also contribute brine to ground-water aquifers in this region.

An abnormally high nitrate concentration in water samples from both wells on the Burris Dorsey property (see Table 2) strongly suggest some organic source of nitrogen in addition to the salt water contamination problem. The fact that the nitrate concentration decreased markedly after five hours of pumping whereas chlorides increased approximately 500 ppm would indicate a very local concentration of nitrate, possibly the result of leakage from a subsurface sewage septic tank located about thirty feet east of the water wells or perhaps from the use of fertilizers on the soil.

CONCLUSIONS

(1) A salt water pollution problem, general to the area of investigation, resulting from the use of unlined surface pits as a means of oil field brine storage has definitely been established by the current investigation. Since precipitation exceeds the evaporation rate in this area, thereby ruling out evaporation as having any effect in the removal of brine from surface pits, and the high porosity and permeability of the underlying strata allows a fast rate of leakage of

brine from these surface pits, brine is therefore entering the shallow subsurface in this area.

Some of the pits, such as those on the S. N. Scarbrough lease, have been in existence since the early years of oil production and have therefore contributed substantially larger quantities of brine by seepage into subsurface ground water than other pits receiving smaller amounts of brine or having been put into use more recently.

(2) Because of the number of surface pits in the area and variations in volume of disposed brine discharged into these pits, and because of the many factors which influence ground-water hydraulics, it is not possible, using currently available data, to determine the exact source of contaminants of the well owned by Mrs. Burris Dorsey.

(3) A comprehensive test drilling program, including numerous water level measurements and sampling of individual water-bearing sands, in conjunction with aquifer tests using tracer techniques, would be required to outline areas and direction of movement of present ground-water contamination.

RECOMMENDATIONS

(1) As an initial step in preventing further salt water contamination of ground and surface water in this area, the immediate cessation of use of unlined surface pits as a means of brine disposal is recommended. Similar geologic and ground-water conditions are present throughout the oil field. Therefore, elimination of surface pits should include not only leases pointed out in this report as being major contributors to salt water pollution but also all leases in the Henderson oil field where unlined surface disposal pits are maintained.

abandon surface pits in area

(2) Continuing observation of water levels and especially chemical quality of ground and surface water should be made over a long period of time following termination of surface disposal to determine whether additional measures to detect possible subsurface leakage from oil well bores are required. Considerable time, perhaps several years, will be required for dilution and ultimate removal of these contaminants which have been entering the subsurface for many years in this area. Should contamination of ground and surface water still be apparent following cessation of surface disposal, testing of oil and gas wells in the area should be conducted to determine if contamination by leakage of salt water in well bores is occurring.

Set up observation program in area

(3) The septic tank on the Dorsey property should be investigated as a possible source of high nitrate concentrations in the two water wells, and bacterial tests of samples of these two wells should be made. Sample bottles for use in such analyses have been forwarded to Mrs. Dorsey by the State Department of Health.

check for high nitrates the Dorsey septic tank

Table 1.--Records of brine production and disposal facilities of leases investigated in the Henderson Oil Field

Operator	Lease	Wells	Salt Water Prod. (bbls/day)	Salt Water Disposal	Remarks
Sinclair	C. C. Dorsey	2 (producing)	Unknown	Surface pit	
Do	N. R. Dorsey	1 (abandoned, 1959)	85 (rept. 1956)	Surface pit (abandoned & covered in 1960)	Originally operated by Southern Production Company. Used for annular salt water disposal below 1000' for five months in 1959. Sinclair anticipates use for salt water disposal at some future date. Present seepage of brine from subsurface into surface drainage on lease apparently result of old surface pit. All casing reportedly remains in well.
Beacon	N. R. Dorsey	1 (producing)	100-125 (estimated)	Surface pit (2)	
Do	C. B. Dorsey	2 (producing)	50-75 (estimated)	Surface pit	
Do	T. V. Bennett	2 (one abandoned, one producing)	Unknown	None located	Evidence of past surface disposal near well No. 2.
Do	S. N. Scarbrough	1 (producing)	125 (rept. 1956)	Surface pit (2) (Abandoned June, 1962) (Salt water apparently now hauled away)	
Do	Burris Dorsey	1 (producing)	5 (estimated)	Surface pit	
W. R. King	N. R. Dorsey	1 (abandoned August, 1962)	60 (rept. 1961)	Surface pit & stream	Salt water formerly discharged directly to surface stream prior to construction of surface pit in late 1961.
Trice Production Company	R. P. Yandle	1 (producing). Well #2 drilled as dry hole in 1958	90 (rept. 1962)	Surface pit	Seepage of brine into adjacent stream indicates gross seepage from surface pit.
Paul McBride	S. D. Loyd	1 (producing)	Unknown	Surface pit	
J. Simmons	J. T. Allen	1 (producing)	Apparently very little salt water production.	Surface pit	

Table 2.--Analyses of ground water samples

(ANALYSES GIVEN ARE IN PARTS PER MILLION EXCEPT SPECIFIC CONDUCTANCE, pH, PERCENT SODIUM.

Well	Owner	Depth of Well (ft)	Date of Collection	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Nitrogen (N)	Dissolved Solids	Total Hardness as $CaCO_3$	Specific Conductance (Micromhos)	pH
1 1/	Burris Dorsey	85	8-1-62	20	192	58	420	26	8	1,009	0.3	137	30.9	1,870	720	3,300	6.5
1 2/	do	do	do	18	261	46	609	7	15	1,499	0.2	20.4	4.6	2,475	840	4,430	5.6
2	do	25	do	28	82	37	22	185	5	62	0.6	204	47.1	625	355	816	7.8
	S. N. Scarbrough	100	8-2-62	24	32	4	13	85	5	13	0.1	34	7.7	210	97	255	7.2
	J. S. Smith	?	do	18	10	5	17	12	3	38	0.1	16	3.6	119	45	198	6.2
	J. W. Dorsey	25	do	14	16	7	39	27	5	55	0.3	71	16.1	234	71	350	6.7
	J. S. Dorsey	80	do	13	36	4	4	117	5	5	0.1	4.4	0.9	188	104	220	7.2
	T. V. Bennett	20	do	22	15	16	75	12	4	181	0.2	<0.4	0.1	325	-	630	6.0
Tank Battery	Sinclair C. C. Dorsey lease		8-2-62	-	19,440	2920	61,100	34	266	137,700	2.5	<0.4		221,460	60,500	> 12,000	5.6
do	Trice Prod. Co. R. P. Yandle lease		8-1-62	-	19,240	2311	60,550	20	255	135,650	2.0	<0.4		218,000	57,500	> 12,000	5.7
Stream site (1)	Burris Dorsey		8-1-62	21	2	1	5	2	14	5	0.1	<0.4		50	10	62	5.4
Stream site (2)	N. R. Dorsey		8-1-62	-	10,220	2190	31,775	9	-	72,685	0.1	<0.4		116,880	34,500	> 12,000	3.4
Stream site (3)	R. P. Yandle		8-2-62	17	565	85	1,940	-	5	4,072	0.1	<0.4		6,684	1,760	10,510	3.5
Stream site (4)	do		8-1-62	-	549	85	1,870	-	5	4,100	0.1	<0.4		6,609	1,720	10,120	3.8

1/ Sampled after pumping 1 minute

2/ Sampled after pumping 5 hours

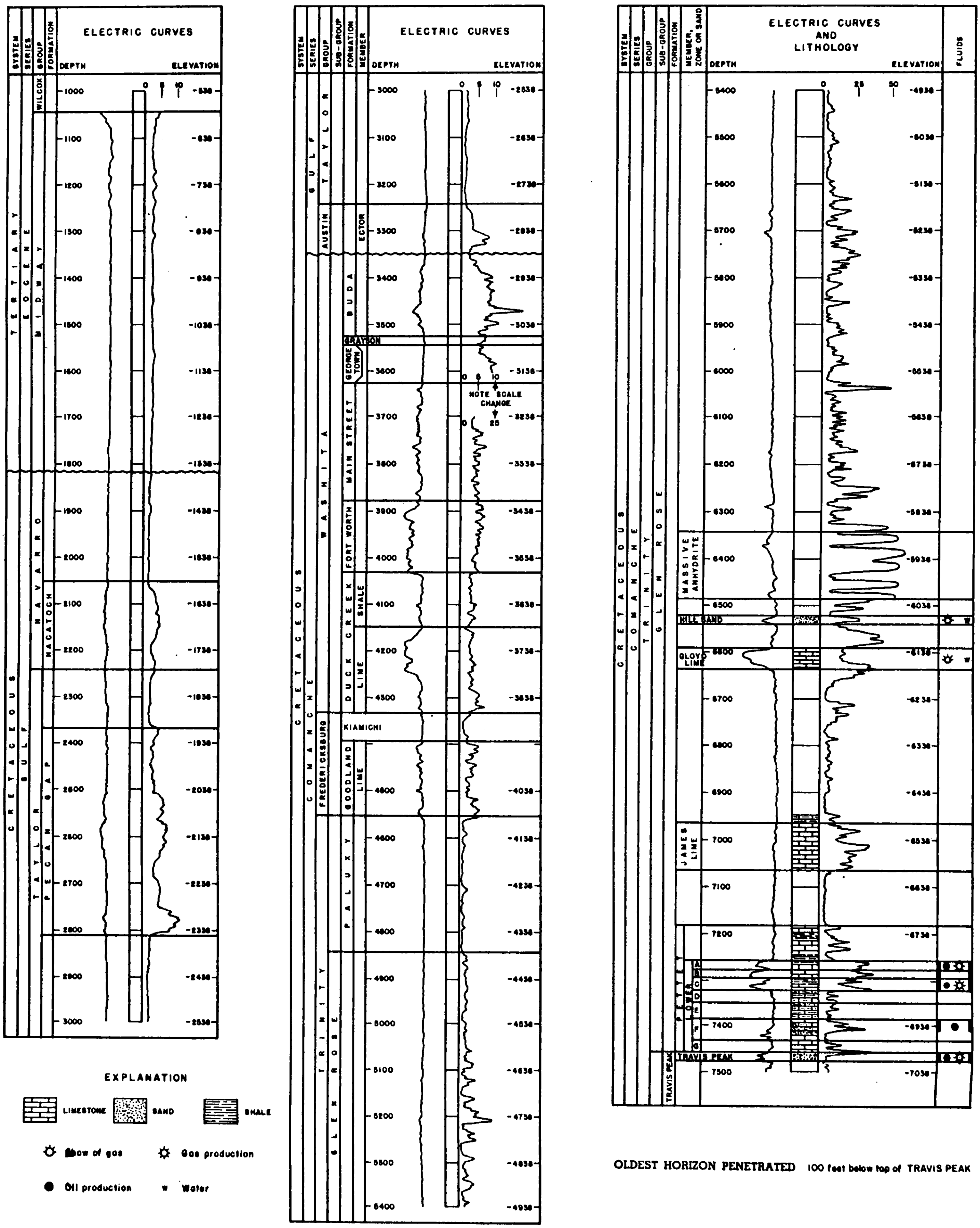
Figure 1

HENDERSON FIELD, Rusk County, Texas

TYPE SECTION OF ROCKS PENETRATED

SURFACE FORMATIONS: WILCOX and REKLAW

ELEVATION OF SURFACE: 410 to 525 feet



OLDEST HORIZON PENETRATED 100 feet below top of TRAVIS PEAK

Figure 2

Graphic representation of analyses of ground water samples, Henderson Oil Field area