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Research Article

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Lithology Determination with Well Log Measurements

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Abstract In this study, it was aimed to calculate the porosity, pollution and saturation of rocks by using sonic, density, neutron and g-ray logs taken in an oil well. The corrected values of these logs were calculated from the raw values of the density and neutron log. Using these corrected calculated values, the lithology of the rocks between 2095-2484 meters was calculated from the density neutron log values. As a result of these calculations, the lithology of the well was obtained from the well log data of the oil well.

Keywords Well Log, Lithology determination, Clayness calculation, porosity calculation

1. Introduction

Well logging application was first performed in France in 1926 by Conrad and Schlumberger. Resistivity measurements were first made on core samples and then in boreholes. In those years, logging processes first started as resistivity logs, and then these log types increased to more than 30 pieces. The well logging method is one of the most successful and most used methods in oil exploration methods. Generally, systems consisting of receiver, transmitter, cable, crane and recorder are used in well logging. In well log measurements, different measurement methods are used depending on the physical parameters of the formations to be measured (natural gamma, density, resistivity, natural potential neutron, etc.). As a result of the evaluation of well log measurements, information is obtained about the thickness, porosity, slope, temperature of the formations, and the yield and salinity of the water that may be present in the formation, by using the measured physical parameters. Developing technology and increasing consumption are in a rapid period in terms of utilizing natural resources and finding and operating underground resources. In order to investigate underground resources, well logging is the measurement and recording of various physical properties of the formations passed in drilling wells as a function of the well depth [1, 2, 3]. It is very easy to find porosity, calculate the amount of clay, and water and oil saturations in oil-yielding carbonate rocks. The porosities of carbonate rocks are found from porosity logs. The porosity and permeability of this type of rocks are generally high. The presence of porosity and saturation is important in terms of oil reserves in such lithologies. Sonic, density and neutron logs are taken as basis in determining porosity. These logs are affected by well conditions, rock porosity, physical properties of the fluid, composition of the rock and clay minerals. Therefore, these negative effects must be eliminated before starting the calculations [4, 5].

Porosity (Ø)

Porosity is one of the most important physical properties of rocks. The porosity of a porous rock is the ratio of the volume of the voids of this rock piece to the total volume.

$$F = \frac{a}{\Phi^m}$$

It is given as: Here a and m are constant values.

It is the ratio of the volume of the voids within a formation that can be filled with a fluid, filled by formation waters, to the volume of all voids. It is not possible to produce all the oil of a petroleum formation. There is always some oil left in the pores of the rock. This oil saturation, which fills a portion of the pore volume, is defined as residual oil saturation. Between resistivity and water saturation in a clean formation (without clay),

$$S_w = \left(\frac{R_0}{R_t}\right)^{1/n}$$

There is a connection. Here, S_w represents water saturation, R_o represents the resistivity of the formation that is 100% saturated with water, and R_t represents the actual resistivity of the formation containing hydrocarbons. Since $R_0 = F.R_w$, water saturation,

$$S_w = \left(\frac{FR_w}{R_t}\right)^{1/n}$$

We can write it as: In the case of a washed out region, the saturation of this region is,

$$S_{x0} = \left(\frac{F\ R_{mf}}{R_{x0}}\right)^{1/n}$$

It looks like this. Here R_{mf} indicates the resistivity of the mud water. The value of n can vary between approximately 1.7-2.5 depending on the type of formation [4].

Clayness ratio of rocks: Clay minerals present in the rocks have an effect on the raw values in log readings. Clay minerals are present in many rocks. In this regard, the clay effect must be eliminated from the raw log values. There are many methods to remove the clayey (VSH) of this rock. By choosing the one with the lowest ratio among the calculated rock clayey values, the one closest to the actual rock clayey ratio is obtained. Corrected log values are calculated using this lowest clayey value.

Gamma-Ray Method: Finding the clay percentage in the formation using the Gamma-Ray log method,

$$VSHGR = \frac{GR - GRmin}{GRmax - GRmin}$$

It is found by the relation. Here, VSHGR; GR the clay percentages calculated from the gamma-ray log; It shows the values read for each meter from the gamma-ray log, and GRmax shows the highest gamma-ray values read in the log. This GRmax value is known to occur in shale or clay. Grmax is the lowest value read in the log [4].

Netron Log Method: In this method, to find the clayey ratio of the formation,

$$VSHN = \frac{\phi N - \phi Nmin}{\phi NSH - \phi Nmin}$$

The expression is used. Here ϕNSH; The CNL reading of the clay point recognized by GR and sonic ϕN is the value read from ϕ(CNL) for each meter [4].

Sonic Log Method: Calculation of clayey ratio in the formation,

$$VSHDT = \frac{DT - DTmin}{DTSH - DTmin}$$

It is done with the relation. Here DTSH; It is the sonic reading of the clayiest point recognized by GR [4].

Resistivity Log Method: The relationshijp that gives the clayey ratio in the resistivity log method,

$$VSHR = \left(\frac{RSH}{RT}\right)^{1/2}$$

It is in the form. Here, RSH is the resistivity value at the clayiest meter known from GR and sonic log [4].

Corrected Values: It is known that porosity logs are affected by clay minerals in the rock. Knowing the rock clayey ratio is necessary for all log evaluation studies. In order to make a healthy porosity and saturation assessment, these clay effects must be eliminated. The netron porosity value read in a clayey formation with all pores saturated with water,

$$\phi_N = \phi + \mathrm{VSH}\phi\mathrm{NSH}$$

It looks like this. Here, NSH is the maximum total reading value and VSH is the rock clayiness. Here, the rock matrix is assumed to have no effect. The corrected porosity per unit volume is,

$$\phi_{Ncorr} = \frac{\phi_N - VSH\phi\mathrm{NSH}}{1.0 - VSH}$$

It is given by the relation. Here, VSH is the lowest average clayey. Density value read in a clayey formation,

$$\rho_{bcorr} = \frac{\rho_b - VSH\rho SH}{1.0 - VSH}$$

It is found as . ϕ NSH and ρSH are the maximum values read from the logs. For each point, ϕN_{corr}cor and ρ_{bcorr}corr values are found for clayey correction using these formulas.

Lithology determination by punctuation method from density and Neutron log: This method is preferred when well conditions are good. When the ρ_{bcorr} (mass density) and ϕ_{Ncorr} (neutron log) readings are punctuated in the chart given in Figure 1, the lithology of the rock can be determined, as well as its porosity and apparent matrix density.

Table 1: Well log values of oil wells.

Depth	Δt sonic	ρb density	ΦCNS NEUTRON	G.R
1900	62	2,6	12	52
1905	63	2,65	13	54
1910	63	2,59	12	47
1915	66	2,67	20	65
1920	66	2,70	14	54
1925	67	2,73	17	59
1930	66	2,54	13	45
1935	68	2,56	17	55
1940	67	2,53	17	40
1945	64	2,43	23	60
1950	63	2,57	17	40
1955	71	2,48	16	40
1960	70	2,60	13	50
1965	64	2,54	16	32
1970	65	2,66	20	63
1975	66	2,54	14	60
1980	68	2,55	30	55
1985	70	2,63	24	64
1990	71	2,44	25	58
1995	65	2,65	24	70
2000	67	2,58	12	50
2005	76	2,55	23	67
2010	80	2,56	27	55
2015	65	2,55	12	48
2020	65	2,40	18	50
2025	68	2,68	8	50
2030	63	2,30	10	55
2035	66	2,55	10	67
2040	65	2,50	20	57
2045	64	2,40	18	50
2050	64	2,62	19	47
2055	80	2,48	25	90
2060	63	2,43	17	98
2065	64	2,65	19	90
2070	63	2,55	25	60
2075	70	2,65	17	87
2080	68	2,73	19	88
2085	69	2,62	16	94
2090	69	2,60	15	30
2095	70	2,35	19	50
2100	65	2,64	10	54
2105	69	2,58	11	40
2110	64	2,66	19	50
2115	62	2,64	11	45
2120	61	2,70	12	70
2125	65	2,65	10	70
2130	63	2,60	16	35
2135	67	2,50	15	76
2140	64	2,65	11	50
2145	65	2,58	10	50
2150	64	2,58	13	50
2155	63	2,60	12	37
2160	65	2,75	17	80
2165	65	2,35	16	90
2170	63	2,50	11	60
2175	65	2,65	12	54
2180	66	2,73	18	78
2185	67	2,05	18	85
2190	67	2,65	27	67
2195	76	2,10	15	90
2200	73	2,30	21	75
2205	60	2,65	24	50
2210	73	2,25	23	74
2215	74	2,45	22	88
2220	68	2,65	9	70
2225	63	2,20	23	45
2230	71	2,67	23	75
2235	67	2,71	24	75
2240	76	2,67	22	80
2245	68	2,69	24	79
2250	71	2,67	20	80
2255	70	2,69	21	70
2260	63	2,63	10	50
2265	67	2,49	15	38
2270	65	2,40	12	54
2275	82	1,96	16	25
2280	74	1,96	14	34
2285	70	2,68	27	80
2290	58	2,63	28	57
2295	65	2,65	24	62
2300	75	2,68	27	70
2305	67	2,60	10	56
2310	68	2,53	24	70
2315	69	2,72	24	80
2320	62	2,71	18	58
2325	67	2,71	14	60
2330	70	2,73	23	80
2335	66	2,72	25	82
2340	6	2,67	18	65
2345	58	2,65	21	40
2350	63	2,40	24	66
2355	66	2,65	18	70
2360	60	2,58	24	60
2365	67	2,64	9	60
2370	64	2,70	12	63
2375	57	2,68	22	69
2380	65	2,68	22	65
2385	67	2,67	23	67
2390	65	2,69	25	74
2395	68	2,68	22	83
2400	69	2,71	26	82
2405	68	2,67	21	70
2410	67	2,70	24	70
2415	68	2,66	22	73
2420	66	2,68	21	69
2425	67	2,60	25	63
2430	66	2,71	21	73
2435	63	2,67	14	58
2440	64	2,69	8	57
2445	64	2,70	20	64
2450	66	2,68	19	70
2455	63	2,69	24	68
2460	65	2,65	18	73
2465	64	2,66	10	80
2470	56	2,68	15	54
2475	55	2,68	26	49
2485	55	2,70	15	70
2490	64	2,72	25	95
2495	60	2,68	24	83
2500	59	2,67	23	90
2505	60	2,67	22	80
2510	60	2,68	20	55
2515	64	2,69	17	75
2520	66	2,70	25	80
2525	64	2,64	17	79
2530	60	2,68	26	90
2535	64	2,65	24	100
2540	63	2,60	14	92
2545	59	2,60	11	83
2550	60	2,58	10	90
2555	64	2,42	16	100
2560	66	2,45	16	98
2565	64	2,44	14	96
2570	62	2,55	9	89
2575	63	2,66	16	80
2580	60	2,63	10	54
2585	57	2,65	15	60
2590	55	2,67	24	75
2595	64	2,65	17	100
2600	55	2,65	9	48
2605	56	2,67	26	52
2610	65	2,68	21	82
2615	64	2,72	21	80
2620	56	2,65	14	64
2625	61	2,68	24	72
2630	63	2,70	22	73
2635	66	2,68	21	73
2640	64	2,61	16	78
2645	64	2,59	15	88

Application

Finding the Clay Percentage Using the Gamma-Ray Log Method

Table 2: For example, if GR reading is made for 1945m

Depth (m)	Δt sonic	ρb density	Φ CNS NEUTRON	G.R
1900	62	2,6	12	52
1905	63	2,65	13	54
1910	63	2,59	12	47
1915	66	2,67	20	65
1920	66	2,70	14	54
1925	67	2,73	17	59
1930	66	2,54	13	45
1935	68	2,56	17	55
1940	67	2,53	17	40
1945	64	2,43	23	60
1950	63	2,57	17	40
1955	71	2,48	16	40
1960	70	2,60	13	50
1965	64	2,54	16	32
1970	65	2,66	20	63
1975	66	2,54	14	60
1980	68	2,55	30	55
1985	70	2,63	24	64
1990	71	2,44	25	58
1995	65	2,65	24	70
2000	67	2,58	12	50
2005	76	2,55	23	67
2010	80	2,56	27	55
2015	65	2,55	12	48
2020	65	2,40	18	50
2025	68	2,68	8	50
2030	63	2,30	10	55
2035	66	2,55	10	67
2040	65	2,50	20	57
2045	64	2,40	18	50
2050	64	2,62	19	47
2055	80	2,48	25	90
2060	63	2,43	17	98
2065	64	2,65	19	90
2070	63	2,55	25	60
2075	70	2,65	17	87
2080	68	2,73	19	88
2085	69	2,62	16	94
2090	69	2,60	15	30

Depth (m)	Δt sonic	ρb density	ΦCNS Neutron	G.R
1945	64	2.43	23	60

The GR value at a depth of 1945 meters appears to be 60.

$VSHGR = \frac{GR-GRmin}{GRmax-GRmin}\ \frac{60-25}{100-25} =\ 004666$ available as

Pb=2.43, QCNL=23

The point on the Density-neutron clustering chart where the values overlap is found. From this point it is drawn parallel to the porosity line. The porosity value is read from this point that intersects the porosity line. Ø DN=20.1

The distances of the parallel drawn on the point to both sides of the points are read. For this example, the distance to Limestone was found to be 17mm and to Dolomite was 15mm. Assuming this distance as 100, the inverse ratio gives lithology values of 46.88% Limestone and 53.12% Dolomite.

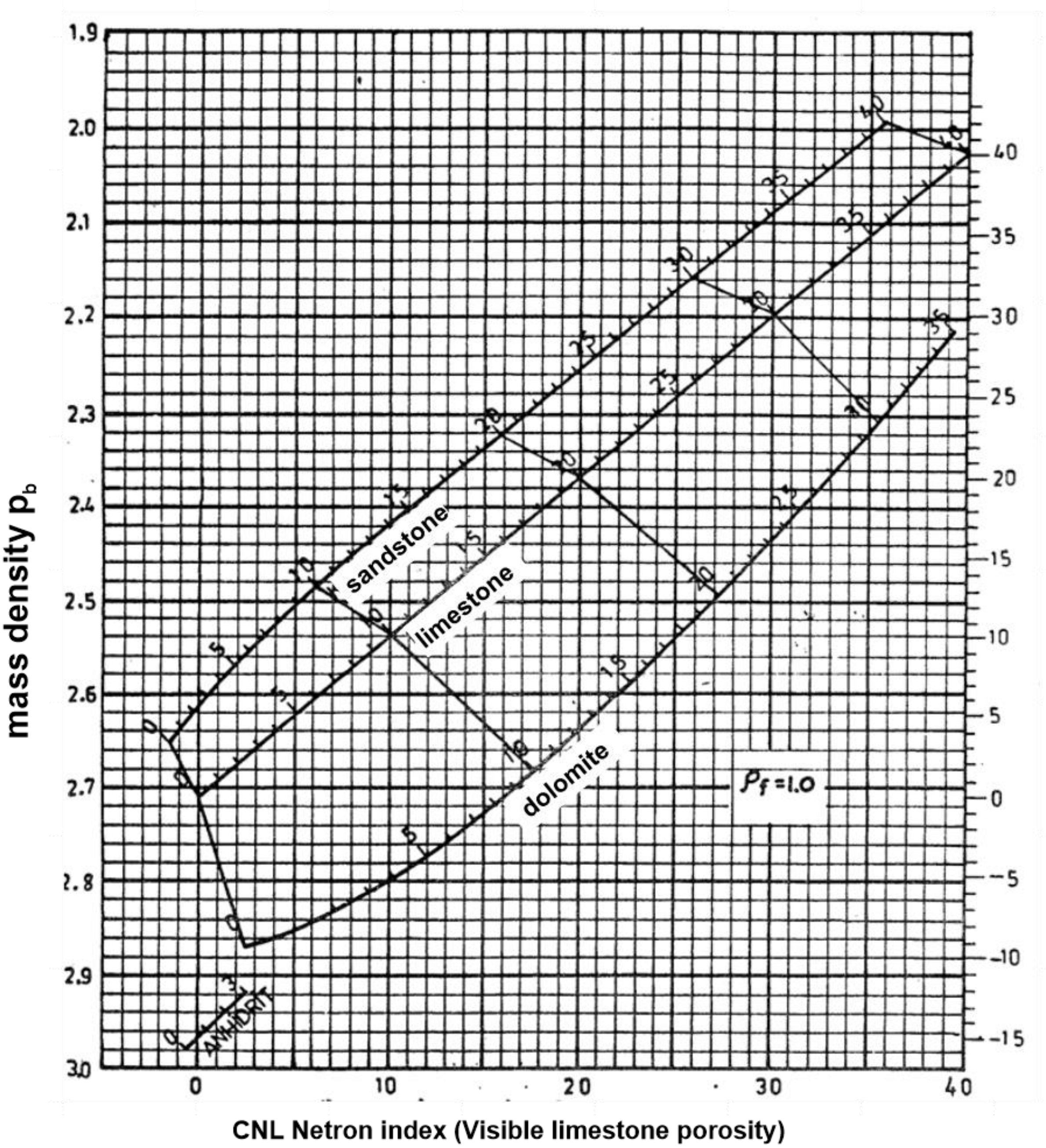

Figure 1: Porosity and lithology determination from density and netron log.

Result

When these operations are done for each point, Total amount of limestone: 2868.31; Total amount of sandstone: 2837.67; Total amount of dolomite: 8089.99; Total ØDN: 3599.04

The average lithology and effective porosity value is found by dividing the total values by the number of points read. % Limestone: 20.81407%; %Sandstone: 20.56282%; %dolomite: 58.62311%; %ØDN : 26.08% values are reached.

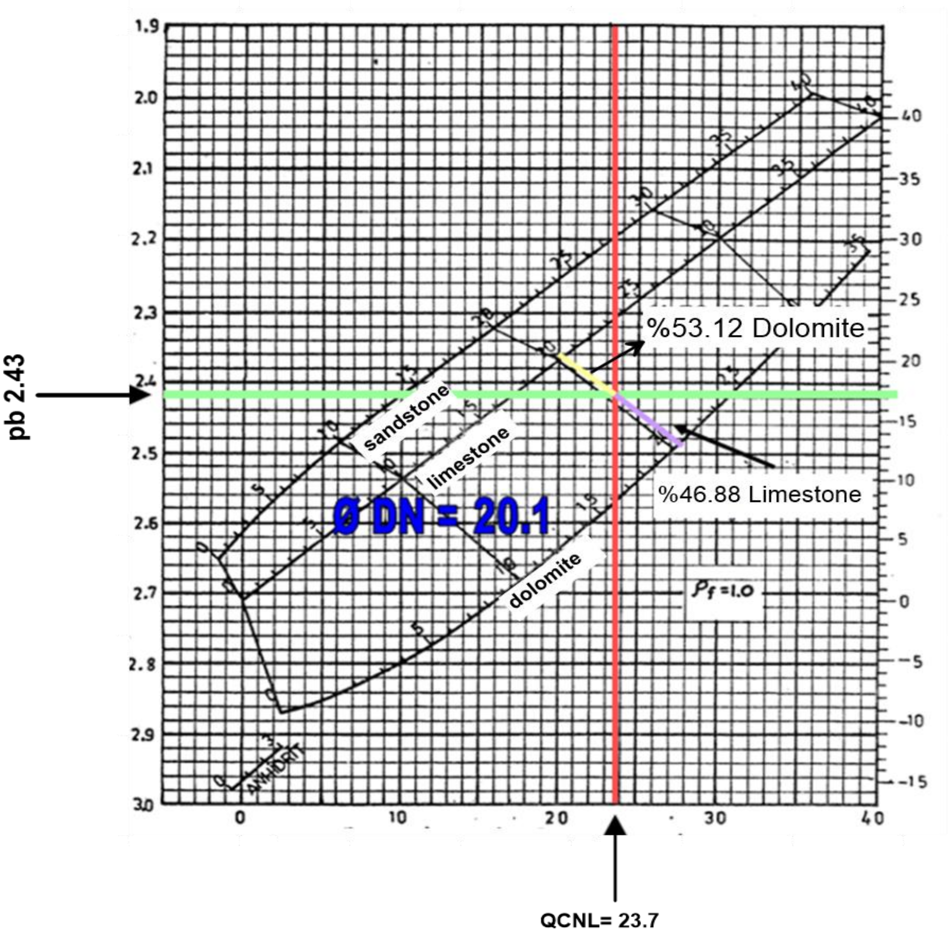

Figure 2: Lithology determination made for a depth of 1945 meters.

Table 3: Well lithology values obtained using density and netron log

Derinlik (m)	ΦDN	%KALKER	%DİĞERLERİ	Derinlik (m)	ΦDN	%KALKER	%DİĞERLERİ
1900	19,5	62,5	37,5 K	2095	-	-	-
1905	16,1	63,4	36,6 D	2100	15	100	-
1910	20,1	53,3	46,67 K	2105	20	-	100 K
1915	20,6	-	100 D	2110	20,1	-	100 D
1920	14	9,1	90,9 D	2115	15,1	100	-
1925	14,15	-	100 D	2120	12,9	29,41	70,59 D
1930	24,7	-	100 K	2125	14	88,24	11,76 D
1935	26	68,75	31,25 K	2130	22	74,42	22,58 D
1940	28	31,25	68,75 K	2135	29,2	-	100 K
1945	20,1	46,88	53,12 D	2140	14,9	84,85	15,15 D
1950	24,5	89,66	10,34 D	2145	19	-	100 K
1955	32,1	-	100 K	2150	21,5	46,66	53,34 K
1960	19,5	81,25	18,75 K	2155	19,5	66,66	33,34 K
1965	26,5	37,5	62,5 K	2160	13	-	100 D
1970	21,1	-	100 D	2165	-	-	-
1975	25,2	-	100 K	2170	26,8	-	100 K
1980	-	-	-	2175	16	69,7	30,30 D
1985	16,3	-	100 D	2180	15,2	-	100 D
1990	40	33,34	66,66 K	2185	-	-	-
1995	25	-	100 D	2190	26,9	-	100 D
2000	21	33,34	66,66 K	2195	-	-	-
2005	30,5	40	60 D	2200	-	-	-
2010	33,9	-	100 D	2205	25,1	-	100 D
2015	23,4	-	100 K	2210	-	-	-
2020	40	-	100 K	2215	36	-	100 K
2025	23,6	-	100 D	2220	14	100	-
2030	-	-	-	2225	-	-	-
2035	26,5	100	-	2230	22,8	-	100 D
2040	25	-	100 K	2235	20,9	-	100 D
2045	35,8	-	100 K	2240	22,1	-	100 D
2050	16,1	62,5	37,5 K	2245	22,1	-	100 D
2055	34	-	100 K	2250	20,6	-	100 D
2060	32,5	-	100 K	2255	19,6	-	100 D
2065	21	-	100 D	2260	15,5	80	20 K
2070	32,5	2	98 D	2265	30,9	-	100 K
2075	19,5	21,87	73,13 D	2270	32,2	-	100 K
2080	23,9	-	100 D	2275	-	-	-
2085	20,5	54,84	45,16 D	2280	-	-	-
2090	21,1	87,1	12,9 D	2285	25,5	-	100 D

Derinlik (m)	ΦDN	%KALKER	%DİĞERLERİ
2290	-	-	-
2295	25,2	-	100 D
2300	25,2	-	100 D
2305	18,2	18,75	81,25 K
2310	34	41,66	58,34 D
2315	20,2	-	100 D
2320	16,7	-	100 D
2325	13	-	100 D
2330	18,8	-	100 D
2335	20,9	-	100 D
2340	19	-	100 D
2345	22,3	-	100 D
2350	-	-	-
2355	20,5	-	100 D
2360	29	-	100 D
2365	14,1	68,75	32,25 K
2370	12,5	29,41	70,59 D
2375	21,5	-	100 D
2380	21,5	-	100 D
2385	23	-	100 D
2390	22,5	-	100 D
2395	21,5	-	100 D
2400	22,3	-	100 D
2405	21	-	100 D
2410	21,7	-	100 D
2415	23	-	100 D
2420	20,7	-	100 D
2425	29,3	-	100 D
2430	18,3	-	100 D
2435	15,3	34	66 D
2440	10	76	24 D
2445	18,8	-	100 D
2450	19,1	-	100 D
2455	22	-	100 D
2460	20,2	6	94 D
2465	13,9	81,82	18,18 D
2470	15,5	21,22	78,78 D
2475	24,9	-	100 D
2480	18,9	-	100 D

Derinlik (m)	ΦDN	%KALKER	%DİĞERLERİ
2485	14,5	-	100 D
2490	20,8	-	100 D
2495	23	-	100 D
2500	22,7	-	100 D
2505	22	-	100 D
2510	20,1	-	100 D
2515	16,5	-	100 D
2520	22	-	100 D
2525	20	31,25	68,75
2530	24,7	-	100 D
2535	25	-	100D
2540	20	100	-
2545	17,9	37,5	62,5 K
2550	18	-	100 K
2555	37	-	100 K
2560	35,2	-	100 K
2565	34,2	-	100 K
2570	21,7	-	100 K
2575	18,1	21,88	78,72 D
2580	15,7	81,25	18,75 K
2585	17,8	43,75	56,25 D
2590	23,7	-	100 D
2595	19,3	21,88	78,72 D
2600	18,5	100	-
2605	25	-	100 D
2610	20,6	-	100 D
2615	17,9	-	100 D
2620	17,1	48,49	51,51 D
2625	23	-	100 D
2630	20,2	-	100 D
2635	20,6	-	100 D
2640	21,1	61,3	38,70 D
2645	22	100	-
2650	16,5	21,88	78,12 D

Clayness values can be calculated by using gamma-ray and sonic logs from well log data. Using the lowest average clayey values obtained from Gamma-ray, corrected values of the log of netron and formation density are found. According to the calculated corrected values, lithology determination was made between 1900-2650 meters using the punctuation method of these logs. In the examination, percentages of limestone, sandstone and dolomite were measured every 5 meters. In this case, it was determined at which meters the hydrocarbon-containing rock was located.

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