SUMMARY
AND
CONCLUSIONS

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The Bahariya Formation is counted among the most important hydrocarbon reservoirs in the Western Desert of Egypt. It was formed at the beginning of the Cenomanian transgression and consists of sediments deposited under fluvio-marine to shallow marine conditions. The samples of the Bahariya Formation investigated in the presented study can be divided into two types of samples. a) laminated samples and b) non-laminated samples. The petrophysical parameters are determined for both types of samples (laminated and non-laminated) and for both orientations of the samples (horizontal and vertical). The lamination is considered to be the main source of anisotropic behaviour. Petrophysical laboratory investigation has been carried out to determine different petrophysical parameters such as density, porosity, internal surface and magnetic susceptibility as scalar parameters. The petrophysical investigation of directional parameters has confirmed that in general the laminated samples show a distinct anisotropy. The degree of anisotropy was determined for electrical resistivity, gas permeability, p-wave velocity and thermal conductivity. The coefficients of anisotropy of electrical and hydraulic conductivity have been defined in a way that they become comparable. Fractures in the direction of the lamination cause an increased horizontal permeability and consequently a considerable anisotropy. The anisotropy of p-wave velocity is less sensitive to the lamination.

Scalar parameters

1- Density:

The grain density measurements show that the laminated and non-laminated samples cannot be differentiated by their average values. The laminated and non-laminated values differ from each other only by 0.003 g/cm^3. The average grain density for horizontal and vertical samples differs from each other only by 0.002 g/cm^3. The grain density does not separate clearly between laminated and non-laminated samples.

Bulk density which includes the pore space filling fluid (saturated with tap water) only reflects the changes in porosity. The increasing bulk density is caused by reduced porosity. There is only a slight difference in bulk density values between laminated and non-laminated samples.

2-Porosity:

The rock porosity of the Bahariya samples varies from 3.6 % to 17.0% with a mean porosity value of 10.8%. For laminated samples, the pore space filling clay minerals cause a gradual decrease in porosity while the porosity for non-laminated samples increases. For laminated samples, porosity spreads over a relatively wide interval but this interval becomes narrower for non-laminated samples.

3-Internal surface:

The pore volume related specifc surface area S_{por} of the Bahariya samples varies from 1.4 μm^{-1} to 113 μm^{-1} with a mean value17.2 μm^{-1}. The mean specifc surface area for non-laminated samples is lower with 4.7 μm^{-1} while the mean specifc surface area value for laminated samples is higher with 25.6 μm^{-1}. Though the average values indicate a remarkable difference, the surface ranges broadly overlap. It can be observed that the laminated samples are characterized by higher internal surface than the non-laminated samples. Generally, the internal surface decreases with increasing porosity and permeability for laminated and non-laminated samples.

4- Magnetic susceptibility:

The magnetic susceptibility of the Bahariya samples varies from $23*10^{-6}$ SI to $595*10^{-6}$ SI with a mean susceptibility value of $112*10^{-6}$ SI. There is a broad overlapping interval between the susceptibility value of laminated and non-laminated samples. The mean susceptibility value for non-laminated samples is lower with $59*10^{-6}$ SI while the mean susceptibility value for laminated samples is higher with $147*10^{-6}$ SI. It can be observed that the laminated samples show a higher magnetic susceptibility than the non-laminated ones. Though no difference in grain density has been observed, the changes in the mineral content of the strongly laminated samples obviously cause an increase in magnetic susceptibility.

Directional parameters

1-Electrical resistivity:

The average resistivity of the vertical samples is slightly higher than the average horizontal resistivity values. The comparison between laminated samples and non-laminated samples without any reference to orientation shows that the average resistivity for laminated samples is higher than the average value for the non-laminated samples. It can be noticed that the laminated and vertical samples are more resistive than the non-laminated and horizontal samples. Generally, the resistivity values range from 213 Ωm to 914 Ωm with a mean values 439 Ωm. The coefficients of anisotropy of resistivity for all investigated pairs of samples range from 0.95 to 1.67 with a mean value of 1.14. Generally, the anisotropy of resistivity for the laminated samples is larger than the anisotropy of the non-laminated samples.

2-Gas permeability:

The investigated sandstone samples of the Bahariya Formation show a large variation in gas permeability ranging from 0.01 mD (non-permeable) to 69 mD (permeable) with a geometric mean permeability value of 0.47 mD. The comparison between laminated and non-laminated samples shows that the laminated samples are less permeable than non-laminated samples. The geometric mean value of the vertical samples is slightly lower than the geometric mean value for the horizontal samples. As expected, the horizontal samples show higher permeability values than the vertical samples. The coefficients of anisotropy of permeability for all investigated pairs of samples range from 0.95 to 2.00 with a mean value of 1.31. Since for most pairs of samples the coefficient of anisotropy of permeability is larger than one it was verified that the permeability in horizontal direction exceeds the permeability in vertical direction. As expected, the anisotropy of the laminated samples is higher than that of the non-laminated samples which show a smaller but non-vanishing degree of anisotropy that is caused by the sedimentation process.

3-P-wave velocity:

The seismic p-wave velocity has been determined on dry samples under ambient conditions. The average velocity value for laminated samples is higher than that of non-laminated samples. The average velocity value for horizontal samples is higher than the average velocity of the vertical samples. It is interesting to note that the average velocity for laminated and horizontal samples is similar and the average velocity for non-laminated samples approaches the average value of the vertical samples. The p-wave velocity anisotropy ratio ranges for all investigated pairs of samples from

0.98 to 1.35 with a resulting mean value of 1.15. For laminated samples, the coefficient of anisotropy is slightly higher than the non-laminated samples. Generally, the anisotropy of p-wave velocity is less sensitive to the lamination structures. The average seismic anisotropy ratio only slightly increases for the laminated samples.

4-Thermal conductivity:

The average thermal conductivity value for dry samples is 3.07 $Wm^{-1}K^{-1}$. For the water saturated samples, an increased average thermal conductivity value of 4.14 $Wm^{-1}K^{-1}$ has been determined. Considering the thermal conductivity determined along the core mantle of eight pairs of dry samples, an average coefficient of anisotropy has been determined to be 1.35. For the saturated samples, the average coefficient of anisotropy decreases to 1.18.

Petrophysical relationships

Relationships between different petrophysical parameters have been investigated. A variety of parameters shows a significant correlation to porosity or permeability. Because of the low variation in grain density bulk density becomes strongly related to porosity.

The sample lamination shows a strong influence on most petrophysical parameters. It causes higher internal surface (S_{por}), higher electrical resistivity, increased p-wave velocity and a reduction in both porosity and permeability. A special feature of the Bahariya samples is that magnetic susceptibility becomes related to porosity. The pore filling material causing the lamination results in increased magnetic susceptibility and decreased porosity. Consequently, the samples with higher magnetic susceptibility are characterized by lower porosity. Porosity and magnetic susceptibility have proven to be appropriate parameters for a rough classification in laminated and non-laminated samples.

The correlations of different parameters with permeability are of great interest for reservoir evaluation. The porosity – permeability (or poro-perm) relation shows the general trend of increasing permeability with increasing porosity. The large scatter in the relevant cross plot shows that a permeability prediction only considering porosity will fail. Further investigations have shown that several other parameters show a distinct relation to permeability. The permeability – formation resistivity factor relation reflects the effect of porosity changes as indicated by Archie's law.

The pore volume related internal surface shows an inverse relation to permeability. Since it is known that S_{por} is related to the inverse to the effective pore radius it is clear that an increase of S_{por} will result in a decrease of permeability. In general, an increase of S_{por} will result in an increase of the imaginary part of conductivity. Though the Bahariya data show only a slight influence of S_{por} on the imaginary part of conductivity the positive correlation between imaginary part of conductivity and permeability is surprising. It seems to be a special effect of the Bahariya sandstone samples. This effect becomes stronger for the laminated samples.

The well-known Archie's law between formation resistivity factor and porosity is confirmed by our data set. The relation becomes more reliable if only non-laminated samples are considered. The determination of the true resistivity formation factor considering the interface conductivity as additional term has proven to be a suitable extension. The interface conductivity has been determined from the imaginary part of conductivity.

In agreement with data of other authors, it was confirmed that $A_K > A_\rho > A_V$. Fractures in direction of lamination were identified to be the reason of the increased permeability in horizontal direction. The laminated Bahariya samples show higher degree of anisotropy and non-laminated samples showing lower degree of anisotropy.

P-wave velocity decreases in general with increasing porosity. The p-wave velocity for horizontal samples is larger than that in vertical direction. Moreover, the data points of the vertical direction are highly scattered more than that in horizontal direction. It was shown that both Wyllie and Raymer equations fail to provide a reliable prediction of p-wave velocity for dry and saturated samples from porosity data. Compressional wave velocity increases with increasing saturation but shear wave velocity decreases. The Poisson's ratio increases with increasing saturation. The modeling of saturation dependent p- and s-wave velocities is the basis for the determination of a saturation dependent Poisson's ratio. Compressional and shear wave velocities at different saturation levels can be interpolated from dry and fully saturated state. The discrimination between fluid and gas filling is based on a reliable prediction of the Poisson's ratio. The calculated Poisson's ratio values determined from appropriately interpolated compressional and shear wave velocities are in good agreement with the values obtained from measured data.

Several formulas have been developed to predict permeability from other parameters. Considering the equations with a single independent parameter, the porosity and the formation resistivity factor prove to be the most relevant parameters resulting in the highest coefficient of determination and the lowest average deviation at logarithmic scale. It is known that at least two parameters are necessary to provide a good permeability prediction. One parameter should characterize the pore volume. Porosity or formation resistivity factor seem to be appropriate parameters. The other parameter should characterize the pore size. Since a direct measurement of pore size distribution becomes difficult, indirect measurements of pore size distribution are of interest. S_{por} or the imaginary part of conductivity seems to be appropriate parameters that are related to an effective pore size. It could be confirmed by our data that a combination of two parameters, one characterizing the pore volume (Φ or F) and the other the pore size (S_{por} or ρ'') results in an improved quality of permeability prediction. The multivariate correlation yields the best fitting equation. Since the logarithm is used for all parameters a general power law equation is given. The equation based on F and S_{por} yields the most reliable results. An extension of the equation using all four quantities (Φ, F, S_{por} and ρ'') enables an even improved permeability prediction with the highest coefficient of determination (0.84) and then lowest average deviation (0.37).

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APPENDIXES

APPENDIX 1

Table 2-1 The scalar parameters of petrophysical measurements for all studied samples of the Bahariya Formation.

Samples Number	depth [m]	dry d_b [g/cm³]	wet d_b [g/cm³]	d_g [g/cm³]	Φ [%]	S_{por} [µm⁻¹]	κ [10^{-6} SI]
1V	3512.0	2.30	2.42	2.61	11.76	1.48	27.28
2H							
3H	3513.6	2.29	2.41	2.65	12.29	12.10	134.36
3V	3513.6	2.25	2.39	2.64	12.42	9.49	100.51
4H	3513.8	2.28	2.40	2.63	12.12	9.09	84.00
4V	3513.8	2.26	2.39	2.64	12.78	9.63	75.58
5H	3514.6	2.29	2.41	2.64	11.85	1.98	106.53
5V	3514.6	2.27	2.38	2.63	11.29	16.47	110.12
6H	3514.7	2.37	2.46	2.61	9.24	23.03	148.64
6V	3514.7						
7H	3515.2	2.40	2.48	2.65	8.00	34.53	135.82
7V	3515.2	2.39	2.47	2.65	8.34	2.11	110.68
8H							
8V							
9H	3515.6	2.45	2.51	2.65	5.92	32.76	103.12
9V	3515.6	2.45	2.52	2.65	7.00	3.84	112.08
10H							
10V							
11V							
12H	3517.1	2.26	2.40	2.62	13.66	6.50	75.12
12V	3517.1	2.25	2.39	2.61	13.38	6.14	68.36
13H	3517.2	2.22	2.37	2.65	15.29		39.76
13V	3517.2	2.22	2.37	2.65	15.52	3.48	40.45
14H	3517.4	2.37	2.48	2.69	11.39	4.43	131.44
14V	3517.4	2.21	2.31	2.69	11.71	4.95	148.23
15H	3518.1	2.22	2.37		13.10	2.97	34.72
15V	3518.1	2.16	2.32	2.65	15.40	1.95	53.55
16H	3518.2	2.28	2.42	2.62	13.41	1.35	139.76
16V	3518.2	2.28	2.42	2.64	13.62	2.13	163.84
21H	3519.5	2.47	2.53	2.57	5.51	9.21	90.51
21V	3519.5	2.46	2.52	2.59	5.25	17.16	98.56
22H	3519.7						
22V	3519.7						
24H	3520.0	2.37	2.46	2.63	8.75	23.78	88.88
24V	3520.0	2.36	2.47	2.63	10.32	20.87	94.04
25H	3520.9		2.46	2.64	7.99	23.02	84.36
25V	3520.9	2.40	2.47	2.64	7.18	31.67	93.97
26H	3521.0						
26V	3521.0						
27H	3521.3	2.37	2.45	2.59	8.96		119.12
27V	3521.3	2.38	2.46	2.56	7.68	14.00	101.16
28H	3521.6	2.29	2.39	2.63	10.59	10.55	75.29
28V	3521.6	2.27	2.38	2.62	12.04	11.09	92.69
29H	3521.9	2.34	2.44	2.64	9.46	3.78	23.17
29V	3521.9	2.34	2.45	2.65	10.41		44.50
30H	3522.5	2.30	2.42	2.59	11.53	4.16	72.75
30V	3522.5	2.31	2.43	2.60	11.35	4.88	115.54
31H	3522.7	2.48	2.53	2.64	4.95		76.51
31V	3522.7	2.45	2.51	2.64	5.25	47.38	139.95
39H	3525.4						
40H	3526.3	2.57	2.58	2.66	3.56	33.42	158.12
40V	3526.3	2.57	2.61	2.63	3.74	17.66	168.98
41H	3526.4	2.33	2.44	2.61	10.53	9.03	70.12
41V	3526.4	2.34	2.44	2.61	10.21	8.49	70.46
42H	3527.3	2.22	2.37	2.65	15.00	4.73	38.91
42V	3527.3	2.22	2.37	2.65	15.40	4.78	47.89
43H	3527.5	2.38	2.45	2.60	6.80		327.22
43V	3527.5	2.34	2.41	2.61	7.48	25.33	234.18

Table 2-1 (Continued), the scalar parameters of petrophysical measurements for all studied samples of the Bahariya Formation.

Samples Number	depth (MD) [m]	dry d_b [g/cm³]	wet d_b [g/cm³]	d_g [g/cm³]	Φ [%]	S_{por} [µm⁻¹]	κ [10^{-6} SI]
44H	3528.2	2.24	2.39	2.62	14.73	4.83	90.99
44V	3528.2	2.23	2.38	2.61	14.47	3.14	33.18
46H	3528.5	2.24	2.38	2.66	14.76		44.62
46V	3528.5	2.22	2.37	2.66	14.83		32.56
47H	3528.7	2.51	2.56	2.66	4.92	30.13	146.99
47V	3528.7	2.35	2.44	2.67	9.27	23.31	133.56
48H	3529.1	2.23	2.38	2.61	14.42	10.75	86.07
48V	3529.1	2.25	2.39	2.60	13.80	9.70	89.17
49H	3529.3	2.21	2.36	2.65	15.78	3.26	30.31
49V	3529.3	2.20	2.36	2.65	16.30	3.54	31.82
50H	3529.4	2.23	2.37	2.65	14.90	4.60	32.87
50V	3529.4	2.23	2.39	2.65	16.16	4.30	33.63
51H	3530.0	2.20	2.36	2.62	16.28	2.60	38.14
51V	3530.0	2.17	2.34	2.61	17.03	2.87	34.47
52H	3530.1	2.31	2.42	2.66	11.50		120.69
52V	3530.1	2.32	2.43	2.66	11.06	24.29	305.49
53H	3530.3	2.36	2.46	2.67	10.08		138.41
53V	3530.3	2.38	2.48	2.69	10.03		223.31
54H	3531.1	2.32	2.44	2.65	12.17		64.96
54V	3531.1	2.30	2.41	2.65	11.31		64.82
55H	3531.2	2.20	2.36	2.65	15.33	9.36	82.30
55V	3531.2	2.21	2.35	2.65	15.10	10.40	82.58
56H	3531.6	2.24	2.38	2.65	13.71		112.78
56V	3531.6	2.17	2.30	2.65	13.32		159.50
57H	3531.8	2.41	2.48	2.65	7.63		159.29
57V	3531.8	2.41	2.50	2.67	8.46		139.94
58H	3532.4	2.31	2.41	2.62	9.38	19.62	117.16
58V	3532.4			2.63	4.17	9.73	
59H	3533.0	2.37	2.47	2.60	10.04	10.79	172.85
59V	3533.0	2.33	2.45	2.63	11.66	12.06	115.73
60H	3533.1						
60V	3533.1						
61H	3533.3						
62H	3533.7	2.23	2.38	2.65	15.81		28.89
62V	3533.7	2.22	2.38	2.66	16.17		41.79
63H	3534.8	2.29	2.42	2.61	12.85	2.33	40.48
63V	3534.8	2.26	2.40	2.62	14.17	10.87	77.37
64H	3536.3						
64V	3536.3						
65H	3536.8	2.27	2.41	2.64	13.67	4.08	38.44
65V	3536.8	2.26	2.39	2.65	13.46	4.95	35.98
71H	3543.4	2.36	2.45	2.66	9.21	5.82	37.84
71V	3543.4	2.38	2.47	2.66	9.04	9.67	45.68
73H	3543.9	2.47	2.54	2.66	7.40	32.68	250.47
73V	3543.9	2.47	2.56	2.69	8.47	53.13	301.86
74H	3544.7	2.56	2.65	2.84	8.41	86.69	594.92
74V	3544.7	2.48	2.55	2.72	7.13	76.05	234.19
75H	3544.9	2.41	2.49	2.66	7.73	56.45	104.07
75V	3544.9	2.40	2.48	2.66	7.75	55.74	99.67
76H	3545.5						
76V	3545.5						
77H	3545.7						
77V	3545.7						
78H	3546.4	2.46	2.53	2.68	6.55	113.02	197.62
78V	3546.4	2.47	2.54	2.68	6.50	16.80	164.00
79H	3546.6	2.49	2.51	2.65	5.80		184.83
79V	3546.6	2.35	2.44	2.55	9.26	50.29	152.08
80H	3547.4	2.28	2.49	2.67	7.04		189.71
80V	3547.4	2.27	2.48	2.68	7.03		208.93

Table 2-2 The scalar parameters of petrophysical measurements for laminated studied samples of the Bahariya Formation.

Samples Number	depth (MD) [m]	dry d_b [g/cm³]	wet d_b [g/cm³]	d_g [g/cm³]	Φ [%]	S_{por} [μm⁻¹]	κ [10⁻⁶ SI]
1V	3512.0	2.30	2.42	2.61	11.76	1.48	27.28
3H	3513.6	2.29	2.41	2.65	12.29	12.10	134.36
3V	3513.6	2.25	2.39	2.64	12.42	9.49	100.51
4H	3513.8	2.28	2.40	2.63	12.12	9.09	84.00
4V	3513.8	2.26	2.39	2.64	12.78	9.63	75.58
5H	3514.6	2.29	2.41	2.64	11.85	1.98	106.53
5V	3514.6	2.27	2.38	2.63	11.29	16.47	110.12
6H	3514.7	2.37	2.46	2.61	9.24	23.03	148.64
6V	3514.7						
7H	3515.2	2.40	2.48	2.65	8.00	34.53	135.82
7V	3515.2	2.39	2.47	2.65	8.34	2.11	110.68
9H	3515.6	2.45	2.51	2.65	5.92	32.76	103.12
9V	3515.6	2.45	2.52	2.65	7.00	3.84	112.08
21H	3519.5	2.47	2.53	2.57	5.51	9.21	90.51
21V	3519.5	2.46	2.52	2.59	5.25	17.16	98.56
24H	3520.0	2.37	2.46	2.63	8.75	23.78	88.88
24V	3520.0	2.36	2.47	2.63	10.32	20.87	94.04
25H	3520.9		2.46	2.64	7.99	23.02	84.36
25V	3520.9	2.40	2.47	2.64	7.18	31.67	93.97
27H	3521.3	2.37	2.45	2.59	8.96		119.12
27V	3521.3	2.38	2.46	2.56	7.68	14.00	101.16
28H	3521.6	2.29	2.39	2.63	10.59	10.55	75.29
28V	3521.6	2.27	2.38	2.62	12.04	11.09	92.69
31H	3522.7	2.48	2.53	2.64	4.95		76.51
31V	3522.7	2.45	2.51	2.64	5.25	47.38	139.95
40H	3526.3	2.57	2.58	2.66	3.56	33.42	158.12
40V	3526.3	2.57	2.61	2.63	3.74	17.66	168.98
43H	3527.5	2.38	2.45	2.60	6.80		327.22
43V	3527.5	2.34	2.41	2.61	7.48	25.33	234.18
47H	3528.7	2.51	2.56	2.66	4.92	30.13	146.99
47V	3528.7	2.35	2.44	2.67	9.27	23.31	133.56
48H	3529.1	2.23	2.38	2.61	14.42	10.75	86.07
48V	3529.1	2.25	2.39	2.60	13.80	9.70	89.17
52H	3530.1	2.31	2.42	2.66	11.50		120.69
52V	3530.1	2.32	2.43	2.66	11.06	24.29	305.49
53H	3530.3	2.36	2.46	2.67	10.08		138.41
53V	3530.3	2.38	2.48	2.69	10.03		223.31
55H	3531.2	2.20	2.36	2.65	15.33	9.36	82.30
55V	3531.2	2.21	2.35	2.65	15.10	10.40	82.58
56H	3531.6	2.24	2.38	2.65	13.71		112.78
56V	3531.6	2.17	2.30	2.65	13.32		159.50
57H	3531.8	2.41	2.48	2.65	7.63		159.29
57V	3531.8	2.41	2.50	2.67	8.46		139.94
58H	3532.4	2.31	2.41	2.62	9.38	19.62	117.16
58V	3532.4			2.63	4.17	9.73	
59H	3533.0	2.37	2.47	2.60	10.04	10.79	172.85
59V	3533.0	2.33	2.45	2.63	11.66	12.06	115.73
73H	3543.9	2.47	2.54	2.66	7.40	32.68	250.47
73V	3543.9	2.47	2.56	2.69	8.47	53.13	301.86
74H	3544.7	2.56	2.65	2.84	8.41	86.69	594.92
74V	3544.7	2.48	2.55	2.72	7.13	76.05	234.19
75H	3544.9	2.41	2.49	2.66	7.73	56.45	104.07
75V	3544.9	2.40	2.48	2.66	7.75	55.74	99.67
78H	3546.4	2.46	2.53	2.68	6.55	113.02	197.62
78V	3546.4	2.47	2.54	2.68	6.50	16.80	164.00
79H	3546.6	2.49	2.51	2.65	5.80		184.83
79V	3546.6	2.35	2.44	2.55	9.26	50.29	152.08
80H	3547.4	2.28	2.49	2.67	7.04		189.71
80V	3547.4	2.27	2.48	2.68	7.03		208.93

Table 2-3 The scalar parameters of petrophysical measurements for non-laminated studied samples of the Bahariya Formation.

Samples Number	depth (MD) [m]	dry d_b [g/cm³]	wet d_b	d_g [g/cm³]	Φ [%]	S_{por} [μm^{-1}]	κ [10^{-6} SI]
12H	3517.1	2.26	2.40	2.62	13.66	6.50	75.12
12V	3517.1	2.25	2.39	2.61	13.38	6.14	68.36
13H	3517.2	2.22	2.37	2.65	15.29		39.76
13V	3517.2	2.22	2.37	2.65	15.52	3.48	40.45
14H	3517.4	2.37	2.48	2.69	11.39	4.43	131.44
14V	3517.4	2.21	2.31	2.69	11.71	4.95	148.23
15H	3518.1	2.22	2.37		13.10	2.97	34.72
15V	3518.1	2.16	2.32	2.65	15.40	1.95	53.55
16H	3518.2	2.28	2.42	2.62	13.41	1.35	139.76
16V	3518.2	2.28	2.42	2.64	13.62	2.13	163.84
29H	3521.9	2.34	2.44	2.64	9.46	3.78	23.17
29V	3521.9	2.34	2.45	2.65	10.41		44.50
30H	3522.5	2.30	2.42	2.59	11.53	4.16	72.75
30V	3522.5	2.31	2.43	2.60	11.35	4.88	115.54
41H	3526.4	2.33	2.44	2.61	10.53	9.03	70.12
41V	3526.4	2.34	2.44	2.61	10.21	8.49	70.46
42H	3527.3	2.22	2.37	2.65	15.00	4.73	38.91
42V	3527.3	2.22	2.37	2.65	15.40	4.78	47.89
44H	3528.2	2.24	2.39	2.62	14.73	4.83	90.99
44V	3528.2	2.23	2.38	2.61	14.47	3.14	33.18
46H	3528.5	2.24	2.38	2.66	14.76		44.62
46V	3528.5	2.22	2.37	2.66	14.83		32.56
49H	3529.3	2.21	2.36	2.65	15.78	3.26	30.31
49V	3529.3	2.20	2.36	2.65	16.30	3.54	31.82
50H	3529.4	2.23	2.37	2.65	14.90	4.60	32.87
50V	3529.4	2.23	2.39	2.65	16.16	4.30	33.63
51H	3530.0	2.20	2.36	2.62	16.28	2.60	38.14
51V	3530.0	2.17	2.34	2.61	17.03	2.87	34.47
54H	3531.1	2.32	2.44	2.65	12.17		64.96
54V	3531.1	2.30	2.41	2.65	11.31		64.82
62H	3533.7	2.23	2.38	2.65	15.81		28.89
62V	3533.7	2.22	2.38	2.66	16.17		41.79
63H	3534.8	2.29	2.42	2.61	12.85	2.33	40.48
63V	3534.8	2.26	2.40	2.62	14.17	10.87	77.37
65H	3536.8	2.27	2.41	2.64	13.67	4.08	38.44
65V	3536.8	2.26	2.39	2.65	13.46	4.95	35.98
71H	3543.4	2.36	2.45	2.66	9.21	5.82	37.84
71V	3543.4	2.38	2.47	2.66	9.04	9.67	45.68

APPENDIX 2

Table 3-1 The directional parameters of petrophysical measurements for all studied samples of the Bahariya Formation.

Samples Number	depth (MD) [m]	Permeability k (mD)	rho_0 ρ [Ωm]	*Vp* [m/s]	apparent *F'*	True *F*	ρ'' [mS/m] @1.4 Hz
1V	3512.0	28.28		3103			
2H		1.040					
3H	3513.6	6.39	375.22	3385	37.53	45.14	0.04
3V	3513.6	0.45	531.55	2990	53.17	67.06	0.04
4H	3513.8	1.19	370.72	3410	33.58	42.01	0.05
4V	3513.8	0.98	425.35	2830	38.16	45.79	0.04
5H	3514.6	0.140		3380			
5V	3514.6	0.090		2790			
6H	3514.7	0.290		3503			
6V	3514.7						
7H	3515.2	0.24	472.36	3480	47.25	63.95	0.06
7V	3515.2	0.03	691.63	2780	69.18	85.27	0.03
8H		0.060					
8V		0.020					
9H	3515.6	0.020	593.03	3760	53.50	66.49	0.03
9V	3515.6	0.010	826.68		74.74	91.97	0.02
10H		0.130					
10V		0.020					
11V		6.520					
12H	3517.1	1.54	213.59	3102	21.36	23.42	0.04
12V	3517.1	1.31	260.64	2763	26.06	28.32	0.03
13H	3517.2	15.69		2705			
13V	3517.2	6.52		2610			
14H	3517.4	13.52	371.00	3483	37.10	39.38	0.02
14V	3517.4	14.06	382.50	3385	38.25	40.05	0.01
15H	3518.1	23.310		3130			
15V	3518.1	18.94		3050			
16H	3518.2	15.09	332.84	3588	33.29	36.32	0.03
16V	3518.2	13.80	334.10	3053	33.41	36.15	0.02
21H	3519.5	0.320		4330			
21V	3519.5	0.040		3330			
22H	3519.7	0.680					
22V	3519.7	0.140					
24H	3520.0	0.054	534.73	3250	48.00	62.51	0.04
24V	3520.0	0.017	651.61	2950	58.94	72.20	0.03
25H	3520.9						
25V	3520.9	0.020		2800			
26H	3521.0	0.110					
26V	3521.0	0.020					
27H	3521.3	0.480		3340			
27V	3521.3	0.070		2475			
28H	3521.6	0.420		3432			
28V	3521.6	0.260					
29H	3521.9	0.800		3852			
29V	3521.9	0.930		3282			
30H	3522.5	3.690	458.78	3062	45.88	50.80	0.02
30V	3522.5	2.270	570.16	3122	57.02	63.64	0.02
31H	3522.7	0.120		4324			
31V	3522.7	0.020	808.54	3564	80.87	100.93	0.02
39H	3525.4	0.230					
40H	3526.3	0.140		4354			
40V	3526.3	0.030					
41H	3526.4	0.26	405.88	3555	40.59	45.05	0.02
41V	3526.4	0.18	452.59	2904	45.26	52.09	0.03
42H	3527.3	27.56	230.45	2670	23.05	24.42	0.02
42V	3527.3	22.70	255.52	2315	25.55	27.22	0.02
43H	3527.5	1.740		3860			
43V	3527.5	0.010					

Table 3-1 (Continued), the directional parameters of petrophysical measurements for all studied samples of the Bahariya Formation.

Samples Number	depth (MD) [m]	Permeability k (mD)	rho_0 ρ [Ωm]	*Vp* [m/s]	apparent *F'*	True *F*	ρ'' [mS/m] @1.4 Hz
44H	3528.2	19.42	222.68	2875	22.27	24.00	0.03
44V	3528.2	23.77	281.91	2860	28.19	30.70	0.03
46H	3528.5	13.250		2912			
46V	3528.5	4.550		2818			
47H	3528.7	0.43	527.63	4425	52.77	62.81	0.03
47V	3528.7	0.06	914.45	3315	91.46	115.17	0.02
48H	3529.1	3.737	247.74	2860	24.78	29.18	0.06
48V	3529.1	1.16	312.67	2425	31.27	37.55	0.05
49H	3529.3	68.525	259.95	3299	23.46	25.41	0.03
49V	3529.3	47.475	276.68	2925	25.07	27.27	0.03
50H	3529.4	38.55	245.99	2960	24.60	26.40	0.03
50V	3529.4	24.75	300.76	2630	30.08	32.47	0.02
51H	3530.0	54.58	213.35	3258	19.81	21.75	0.05
51V	3530.0	55.93	228.44	2493	20.83	22.38	0.03
52H	3530.1	0.460					
52V	3530.1	0.160		3140			
53H	3530.3	0.050		3410			
53V	3530.3	0.020		3417			
54H	3531.1	0.180		3368			
54V	3531.1	0.130		2950			
55H	3531.2	5.58	254.99	3360	25.50	29.62	0.05
55V	3531.2	1.25	346.56	2535	34.66	39.83	0.04
56H	3531.6			3575			
56V	3531.6	0.070					
57H	3531.8	0.070		3715			
57V	3531.8	0.020		3235			
58H	3532.4			3655			
58V	3532.4						
59H	3533.0	0.09	402.81	3885	54.79	70.11	0.04
59V	3533.0	0.11	493.39	3110	49.35	60.65	0.04
60H	3533.1	0.320					
60V	3533.1	0.160					
61H	3533.3	4.290					
62H	3533.7	21.920		2890			
62V	3533.7	9.240		2565			
63H	3534.8	15.04	333.30	3498	33.33	37.11	0.03
63V	3534.8	6.48	299.64	3268	29.97	35.10	0.05
64H	3536.3	0.100					
64V	3536.3	0.020					
65H	3536.8	14.35	368.05	3310	36.81	41.04	0.03
65V	3536.8	11.96	440.86	2885	44.09	48.64	0.02
71H	3543.4	3.39	674.98	3395	67.50	72.82	0.01
71V	3543.4	1.27	827.29	2980	82.73	89.49	0.01
73H	3543.9	0.09	381.26	3320	38.13	46.20	0.05
73V	3543.9	0.04	442.56	2940	44.26	52.49	0.04
74H	3544.7	0.05	378.41	3835	37.85	44.46	0.04
74V	3544.7	0.01	763.17	3365	76.33	91.27	0.02
75H	3544.9	0.230	421.81	3450	42.19	52.60	0.05
75V	3544.9	0.037	721.95	3065	72.21	89.47	0.03
76H	3545.5	0.230					
76V	3545.5	0.010					
77H	3545.7	0.070					
77V	3545.7	0.010					
78H	3546.4	0.111	300.21	3870	30.03	36.44	0.06
78V	3546.4	0.007	837.79		83.80	106.31	0.03
79H	3546.6	0.090					
79V	3546.6	0.010					
80H	3547.4	0.010		3820			
80V	3547.4	0.010					

Table 3-2 The directional parameters of petrophysical measurements for laminated studied samples of the Bahariya Formation.

Samples Number	depth (MD) [m]	Permeability k (mD)	rho_0 ρ [Ωm]	*Vp* [m/s]	apparent *F'*	True *F*	ρ'' [mS/m] @1.4 Hz
1V	3512.0	28.28		3103			
2H		1.040					
3H	3513.6	6.39	375.22	3385	37.53	45.14	0.04
3V	3513.6	0.45	531.55	2990	53.17	67.06	0.04
4H	3513.8	1.19	370.72	3410	33.58	42.01	0.05
4V	3513.8	0.98	425.35	2830	38.16	45.79	0.04
5H	3514.6	0.140		3380			
5V	3514.6	0.090		2790			
6H	3514.7	0.290		3503			
7H	3515.2	0.24	472.36	3480	47.25	63.95	0.06
7V	3515.2	0.03	691.63	2780	69.18	85.27	0.03
8H		0.060					
8V		0.020					
9H	3515.6	0.020	593.03	3760	53.50	66.49	0.03
9V	3515.6	0.010	826.68		74.74	91.97	0.02
10H		0.130					
10V		0.020					
11V		6.520					
21H	3519.5	0.320		4330			
21V	3519.5	0.040		3330			
22H	3519.7	0.680					
22V	3519.7	0.140					
24H	3520.0	0.054	534.73	3250	48.00	62.51	0.04
24V	3520.0	0.017	651.61	2950	58.94	72.20	0.03
25V	3520.9	0.020		2800			
26H	3521.0	0.110					
26V	3521.0	0.020					
27H	3521.3	0.480		3340			
27V	3521.3	0.070		2475			
28H	3521.6	0.420		3432			
28V	3521.6	0.260					
31H	3522.7	0.120		4324			
31V	3522.7	0.020	808.54	3564	80.87	100.93	0.02
39H	3525.4	0.230					
40H	3526.3	0.140		4354			
40V	3526.3	0.030					
43H	3527.5	1.740		3860			
43V	3527.5	0.010					

Table 3-2 (Continued), the directional parameters of petrophysical measurements for laminated studied samples of the Bahariya Formation.

Samples Number	depth (MD) [m]	Permeability k (mD)	rho_0 ρ [Ωm]	*Vp* [m/s]	apparent *F'*	True *F*	ρ'' [mS/m] @1.4 Hz
47H	3528.7	0.43	527.63	4425	52.77	62.81	0.03
47V	3528.7	0.06	914.45	3315	91.46	115.17	0.02
48H	3529.1	3.737	247.74	2860	24.78	29.18	0.06
48V	3529.1	1.16	312.67	2425	31.27	37.55	0.05
52H	3530.1	0.460					
52V	3530.1	0.160		3140			
53H	3530.3	0.050		3410			
53V	3530.3	0.020		3417			
55H	3531.2	5.58	254.99	3360	25.50	29.62	0.05
55V	3531.2	1.25	346.56	2535	34.66	39.83	0.04
56H	3531.6			3575			
56V	3531.6	0.070					
57H	3531.8	0.070		3715			
57V	3531.8	0.020		3235			
58H	3532.4			3655			
59H	3533.0	0.09	402.81	3885	54.79	70.11	0.04
59V	3533.0	0.11	493.39	3110	49.35	60.65	0.04
60H	3533.1	0.320					
60V	3533.1	0.160					
64H	3536.3	0.100					
64V	3536.3	0.020					
73H	3543.9	0.09	381.26	3320	38.13	46.20	0.05
73V	3543.9	0.04	442.56	2940	44.26	52.49	0.04
74H	3544.7	0.05	378.41	3835	37.85	44.46	0.04
74V	3544.7	0.01	763.17	3365	76.33	91.27	0.02
75H	3544.9	0.230	421.81	3450	42.19	52.60	0.05
75V	3544.9	0.037	721.95	3065	72.21	89.47	0.03
76H	3545.5	0.230					
76V	3545.5	0.010					
77H	3545.7	0.070					
77V	3545.7	0.010					
78H	3546.4	0.111	300.21	3870	30.03	36.44	0.06
78V	3546.4	0.007	837.79		83.80	106.31	0.03
79H	3546.6	0.090					
79V	3546.6	0.010					
80H	3547.4	0.010		3820			
80V	3547.4	0.010					

Table 3-3 The directional parameters of petrophysical measurements for non-laminated studied samples of the Bahariya Formation.

Samples Number	depth (MD) [m]	*k* (mD)	rho_0 ρ [Ωm]	*Vp* [m/s]	apparent *F'*	True *F*	ρ'' [mS/m] @1.4 Hz
12H	3517.1	1.54	213.59	3102	21.36	23.42	0.04
12V	3517.1	1.31	260.64	2763	26.06	28.32	0.03
13H	3517.2	15.69		2705			
13V	3517.2	6.52		2610			
14H	3517.4	13.52	371.00	3483	37.10	39.38	0.02
14V	3517.4	14.06	382.50	3385	38.25	40.05	0.01
15H	3518.1	23.310		3130			
15V	3518.1	18.94		3050			
16H	3518.2	15.09	332.84	3588	33.29	36.32	0.03
16V	3518.2	13.80	334.10	3053	33.41	36.15	0.02
29H	3521.9	0.800		3852			
29V	3521.9	0.930		3282			
30H	3522.5	3.690	458.78	3062	45.88	50.80	0.02
30V	3522.5	2.270	570.16	3122	57.02	63.64	0.02
41H	3526.4	0.26	405.88	3555	40.59	45.05	0.02
41V	3526.4	0.18	452.59	2904	45.26	52.09	0.03
42H	3527.3	27.56	230.45	2670	23.05	24.42	0.02
42V	3527.3	22.70	255.52	2315	25.55	27.22	0.02
44H	3528.2	19.42	222.68	2875	22.27	24.00	0.03
44V	3528.2	23.77	281.91	2860	28.19	30.70	0.03
46H	3528.5	13.250		2912			
46V	3528.5	4.550		2818			
49H	3529.3	68.525	259.95	3299	23.46	25.41	0.03
49V	3529.3	47.475	276.68	2925	25.07	27.27	0.03
50H	3529.4	38.55	245.99	2960	24.60	26.40	0.03
50V	3529.4	24.75	300.76	2630	30.08	32.47	0.02
51H	3530.0	54.58	213.35	3258	19.81	21.75	0.05
51V	3530.0	55.93	228.44	2493	20.83	22.38	0.03
54H	3531.1	0.180		3368			
54V	3531.1	0.130		2950			
61H	3533.3	4.290					
62H	3533.7	21.920		2890			
62V	3533.7	9.240		2565			
63H	3534.8	15.04	333.30	3498	33.33	37.11	0.03
63V	3534.8	6.48	299.64	3268	29.97	35.10	0.05
65H	3536.8	14.35	368.05	3310	36.81	41.04	0.03
65V	3536.8	11.96	440.86	2885	44.09	48.64	0.02
71H	3543.4	3.39	674.98	3395	67.50	72.82	0.01
71V	3543.4	1.27	827.29	2980	82.73	89.49	0.01

Table 3-4 The directional parameters (thermal conductivity) of petrophysical measurements for all studied samples (dry and saturated) of the Bahariya Formation.

		Dry				Saturated			
Samples Number	depth (MD) [m]	TC [W/mK] d_ct_⊥	TC [W/mK] d_ct_‖	TC [W/mK] d_cm_⊥	TC [W/mK] d_cm_‖	TC [W/mK] d_ct_⊥	TC [W/mK] d_ct_‖	TC [W/mK] d_cm_⊥	TC [W/mK] d_cm_‖
2H	3512.9	3.11	3.27	2.57	2.65	4.64	4.71	3.87	4.77
8H	3515.4	3.36	3.78	3.20	2.85	4.51	4.36	4.34	4.46
8V	3515.4	3.40	3.36	3.54	3.44	3.99	3.93	4.26	3.99
10H	3516.3	3.30	3.90	2.68	2.55	3.63	4.46	3.88	3.80
10V	3516.3	2.85	3.00	3.54	3.62	3.51	3.26	4.23	4.64
11V	3516.5	3.35	3.40	3.50	3.54	3.58	3.62	4.37	4.29
22H	3519.7	3.53	3.17	3.20	2.93	4.49	3.69	4.15	4.18
22V	3519.7	3.24	3.23	3.41	3.47	3.88	3.80	4.51	4.51
26H	3521.0	3.64	2.97	2.45	3.09	4.82	4.23	3.75	4.65
26V	3521.0	2.52	2.47	3.29	3.22	3.97	3.46	4.62	4.56
39H	3525.4	3.82	2.86	2.46	2.64	3.35	4.21	3.50	3.38
60H	3533.1	2.79	2.73	2.51	2.68	3.96	4.04	4.22	4.08
60V	3533.1	2.91	2.84	2.73	2.73	4.75	4.19	4.40	4.26
61H	3533.3	2.90	3.02	2.53	2.58	4.79	4.09	4.51	4.59
64H	3536.3	3.53	2.88	3.43	3.06	3.83	3.64	3.36	3.47
64V	3536.3	2.59	2.68	3.18	3.29	2.88	2.67	3.37	4.08
76H	3545.5	3.45	3.35	2.79	2.60	5.03	5.05	4.30	4.25
76V	3545.5	2.70	2.68	3.09	3.17	4.07	3.90	4.72	4.74
77H	3545.7	3.10	3.40	2.76	2.55	4.74	4.75	4.10	4.01
77V	3545.7	3.20	3.16	3.19	3.27	4.29	4.27	4.73	4.64

APPENDIX 3

Table 4-1 Anisotropy of resistivity, compressional wave velocity and permeability, for all studied samples of the Bahariya Formation.

Sample (all)	depth (MD) [m]	anisotropy Resistivity	anisotropy Vp	anisotropy Permeability
3H/3V	3513.6	1.19	1.13	1.94
4H/4V	3513.8	1.07	1.20	1.05
5H/5V	3514.6		1.21	1.12
6H/6V	3514.7			
7H/7V	3515.2	1.21	1.25	1.73
8H/8V	3515.4			1.32
9H/9V	3515.6	1.18		1.19
10H/10V	3516.3			1.60
12H/12V	3517.1	1.10	1.12	1.04
13H/13V	3517.2		1.04	1.25
14H/14V	3517.4	1.02	1.03	0.99
15H/15V	3518.1		1.03	1.05
16H/16V	3518.2	1.00	1.18	1.02
21H/21V	3519.5		1.30	1.68
22H/22V	3519.7			1.48
24H/24V	3520.0	1.10	1.10	1.35
25H/25V	3520.9			
26H/26V	3521.0			1.53
27H/27V	3521.3		1.35	1.62
28H/28V	3521.6			1.13
29H/29V	3521.9		1.17	0.96
30H/30V	3522.5	1.11	0.98	1.13
31H/31V	3522.7		1.21	1.57
40H/40V	3526.3			1.47
41H/41V	3526.4	1.06	1.22	1.09
42H/42V	3527.3	1.05	1.15	1.05
43H/43V	3527.5			
44H/44V	3528.2	1.13	1.01	0.95
46H/46V	3528.5		1.03	1.31
47H/47V	3528.7	1.32	1.33	1.62
48H/48V	3529.1	1.12	1.18	1.34
49H/49V	3529.3	1.03	1.13	1.10
50H/50V	3529.4	1.11	1.13	1.12
51H/51V	3530.0	1.03	1.31	0.99
52H/52V	3530.1			1.30
53H/53V	3530.3		1.00	1.26
54H/54V	3531.1		1.14	1.08
55H/55V	3531.2	1.17	1.33	1.45
56H/56V	3531.6			
57H/57V	3531.8		1.15	1.37
58H/58V	3532.4			
59H/59V	3533.0	1.11	1.25	0.96
60H/60V	3533.1			1.19
62H/62V	3533.7		1.13	1.24
63H/63V	3534.8	0.95	1.07	1.23
64H/64V	3536.3			1.50
65H/65V	3536.8	1.09	1.15	1.05
71H/71V	3543.4	1.11	1.14	1.28
73H/73V	3543.9	1.08	1.13	1.25
74H/74V	3544.7	1.42	1.14	1.48
75H/75V	3544.9	1.31	1.13	1.58
76H/76V	3545.5			
77H/77V	3545.7			1.63
78H/78V	3546.4	1.67		2.00
79H/79V	3546.6			1.73
80H/80V	3547.4			1.00

Table 4-2 Anisotropy of resistivity, compressional wave velocity and permeability, for laminated studied samples of the Bahariya Formation.

Sample pair (+Lamination)	depth (MD) [m]	anisotropy Resistivity	anisotropy Vp	anisotropy Permeability
3H/3V	3513.6	1.19	1.13	1.94
4H/4V	3513.8	1.07	1.20	1.05
5H/5V	3514.6		1.21	1.12
6H/6V	3514.7			
7H/7V	3515.2	1.21	1.25	1.73
8H/8V				1.32
9H/9V	3515.6	1.18		1.19
10H/10V				1.60
21H/21V	3519.5		1.30	1.68
22H/22V				1.48
24H/24V	3520.0	1.10	1.10	1.35
25H/25V	3520.9			
26H/26V				1.53
27H/27V	3521.3		1.35	1.62
28H/28V	3521.6			1.13
31H/31V	3522.7		1.21	1.57
40H/40V	3526.3			1.47
43H/43V	3527.5			
47H/47V	3528.7	1.32	1.33	1.62
48H/48V	3529.1	1.12	1.18	1.34
52H/52V	3530.1			1.30
53H/53V	3530.3		1.00	1.26
55H/55V	3531.2	1.17	1.33	1.45
56H/56V	3531.6			
57H/57V	3531.8		1.15	1.37
58H/58V	3532.4			
59H/59V	3533.0	1.11	1.25	0.96
60H/60V				1.19
64H/64V				1.50
73H/73V	3543.9	1.08	1.13	1.25
74H/74V	3544.7	1.42	1.14	1.48
75H/75V	3544.9	1.31	1.13	1.58
76H/76V				
77H/77V				1.63
78H/78V	3546.4	1.67		2.00
79H/79V	3546.6			1.73
80H/80V	3547.4			1.00

Table 4-3 Anisotropy of resistivity, compressional wave velocity and permeability, for non-laminated studied samples of the Bahariya Formation.

Sample pair (-Lamination)	depth (MD) [m]	anisotropy Resistivity	anisotropy Vp	anisotropy Permeability
12H/12V	3517.1	1.10	1.12	1.04
13H/13V	3517.2		1.04	1.25
14H/14V	3517.4	1.02	1.03	0.99
15H/15V	3518.1		1.03	1.05
16H/16V	3518.2	1.00	1.18	1.02
29H/29V	3521.9		1.17	0.96
30H/30V	3522.5	1.11	0.98	1.13
41H/41V	3526.4	1.06	1.22	1.09
42H/42V	3527.3	1.05	1.15	1.05
44H/44V	3528.2	1.13	1.01	0.95
46H/46V	3528.5		1.03	1.31
49H/49V	3529.3	1.03	1.13	1.10
50H/50V	3529.4	1.11	1.13	1.12
51H/51V	3530.0	1.03	1.31	0.99
54H/54V	3531.1		1.14	1.08
62H/62V	3533.7		1.13	1.24
63H/63V	3534.8	0.95	1.07	1.23
64H/64V				
65H/65V	3536.8	1.09	1.15	1.05
71H/71V	3543.4	1.11	1.14	1.28

APPENDIX 4

Table 5-1 Compressional wave velocity measured at different saturation for studied samples of the Bahariya Formation.

Samples Number	Depth (m)	V_P [m/s] at dry	V_P [m/s] at 25%	V_P [m/s] at 50%	V_P [m/s] at 75%	V_P [m/s] at 100%
1V	3512.0	3020	3090	3200	3310	3440
6H	3514.7	3300	3140	3190	3560	3850
12H	3517.1	2980	3080	3190	3300	3430
12V	3517.1	2670	2690	2820	2920	3300
16H	3518.2	3480	3480	3600	3600	3870
16V	3518.2	2920	3090	3160	3160	3360
21H	3519.5	4000	4100	4320	4430	4560
21V	3519.5	2820	2860	2860	2860	4020
27H	3521.3	3220	3240	3350	3240	3870
27V	3521.3	2310	1820	1870	2220	3430
30H	3522.5	2940	2500	3120	3360	3540
30V	3522.5	2920	3000	3480	3480	3540
41H	3526.4	3050	3100	3650	3970	3970
41V	3526.4	2950	2870	3590	3590	3670
44H	3528.2	2790	3070	3100	3150	3230
44V	3528.2	2540	2820	2900	2860	3160
48H	3529.1	2570	2860	3150	3150	3420
48V	3529.1	2380	2350	2650	2650	2930
51H	3530.0	3270	3390	3460	3390	3630
51V	3530.0	2380	2540	2690	2690	3020
59H	3533.0	3580	3700	3960	3960	4270
59V	3533.0	2900	2900	3230	3230	3650
63H	3534.8	3420	3510	3690	3730	3890
63V	3534.8	3340	3370	3440	3440	3570
73H	3543.9	3240	3050	3980	4070	4160
73V	3543.9	2900	2540	2860	3000	3730
Average		**2996**	**3006**	**3250**	**3320**	**3635**

Table 5-2 Compressional wave velocity calculates from equation 7 at different saturation for studied samples of the Bahariya Formation.

Samples Number	Depth (m)	V_P [m/s] at dry	V_P [m/s] at 25%	V_P [m/s] at 50%	V_P [m/s] at 75%	V_P [m/s] at 100%
1V	3512.0	3020	3822	5205	8156	18829
6H	3514.7	3300	4025	5160	7184	11822
12H	3517.1	2980	3924	5742	10699	78308
12V	3517.1	2670	3385	4622	7284	17178
16H	3518.2	3480	4805	7759	20147	-33778
16V	3518.2	2920	3817	5510	9903	48825
21H	3519.5	4000	4599	5410	6567	8353
21V	3519.5	2820	3091	3418	3824	4339
27H	3521.3	3220	3882	4886	6590	10121
27V	3521.3	2310	2580	2922	3369	3976
30H	3522.5	2940	3676	4904	7363	14769
30V	3522.5	2920	3631	4799	7077	13467
41H	3526.4	3050	3764	4915	7081	12655
41V	3526.4	2950	3589	4582	6333	10252
44H	3528.2	2790	3685	5424	10275	97194
44V	3528.2	2540	3244	4489	7285	19310
48H	3529.1	2570	3291	4574	7496	20763
48V	3529.1	2380	2953	3890	5697	10638
51H	3530.0	3270	4771	8821	58350	-12644
51V	3530.0	2380	3130	4569	8460	56998
59H	3533.0	3580	4545	6224	9868	23806
59V	3533.0	2900	3624	4830	7238	14434
63H	3534.8	3420	4619	7115	15472	-88564
63V	3534.8	3340	4637	7579	20736	-28169
73H	3543.9	3240	3775	4521	5636	7479
73V	3543.9	2900	3392	4086	5136	6912
Average		**2996**	**3779**	**5229**	**10509**	**13357**

Table 5-3 Compressional wave velocity calculates from equation 8 at different saturation for studied samples of the Bahariya Formation.

Samples Number	Depth (m)	V_P [m/s] at dry	V_P [m/s] at 25%	V_P [m/s] at 50%	V_P [m/s] at 75%	V_P [m/s] at 100%
1V	3512.0	1545	1792	2133	2633	3440
6H	3514.7	1853	2129	2501	3033	3850
12H	3517.1	1418	1661	2006	2532	3430
12V	3517.1	1411	1647	1977	2473	3300
16H	3518.2	1504	1776	2166	2778	3870
16V	3518.2	1408	1647	1984	2495	3360
21H	3519.5	2588	2902	3302	3831	4560
21V	3519.5	2451	2716	3046	3466	4020
27H	3521.3	1887	2164	2537	3065	3870
27V	3521.3	1908	2146	2452	2860	3430
30H	3522.5	1583	1837	2188	2704	3540
30V	3522.5	1597	1851	2201	2714	3540
41H	3526.4	1752	2036	2431	3015	3970
41V	3526.4	1718	1982	2341	2858	3670
44H	3528.2	1323	1552	1877	2374	3230
44V	3528.2	1325	1550	1867	2347	3160
48H	3529.1	1371	1612	1957	2490	3420
48V	3529.1	1317	1527	1817	2243	2930
51H	3530.0	1300	1549	1915	2507	3630
51V	3530.0	1180	1392	1697	2173	3020
59H	3533.0	1857	2163	2588	3223	4270
59V	3533.0	1594	1856	2219	2760	3650
63H	3534.8	1547	1821	2214	2822	3890
63V	3534.8	1409	1661	2021	2581	3570
73H	3543.9	2152	2447	2837	3373	4160
73V	3543.9	1906	2171	2523	3010	3730
Average		**1650**	**1907**	**2261**	**2783**	**3635**

Table 5-4 Compressional wave velocity calculates from equations 11a and 11b at different saturation for studied samples of the Bahariya Formation.

Samples Number	Depth (m)	V_P [m/s] at dry	V_P [m/s] at 25%	V_P [m/s] at 50%	V_P [m/s] at 75%	V_P [m/s] at 100%
1V	3512.0	3020	3117	3213	3323	3440
6H	3514.7	3300	3397	3610	3726	3850
12H	3517.1	2980	3100	3150	3284	3430
12V	3517.1	2670	2826	2904	3090	3300
16H	3518.2	3480	3584	3634	3749	3870
16V	3518.2	2920	3037	3087	3218	3360
21H	3519.5	4000	4059	4413	4485	4560
21V	3519.5	2820	2919	3667	3835	4020
27H	3521.3	3220	3328	3590	3725	3870
27V	3521.3	2310	2442	2956	3175	3430
30H	3522.5	2940	3069	3214	3369	3540
30V	3522.5	2920	3051	3207	3365	3540
41H	3526.4	3050	3219	3492	3716	3970
41V	3526.4	2950	3083	3314	3483	3670
44H	3528.2	2790	2916	2936	3076	3230
44V	3528.2	2540	2706	2742	2936	3160
48H	3529.1	2570	2785	2836	3101	3420
48V	3529.1	2380	2521	2576	2741	2930
51H	3530.0	3270	3388	3369	3495	3630
51V	3530.0	2380	2581	2522	2749	3020
59H	3533.0	3580	3710	3941	4099	4270
59V	3533.0	2900	3058	3230	3427	3650
63H	3534.8	3420	3538	3615	3747	3890
63V	3534.8	3340	3407	3426	3496	3570
73H	3543.9	3240	3359	3814	3980	4160
73V	3543.9	2900	3023	3377	3545	3730
Average		**2996**	**3124**	**3301**	**3459**	**3635**

Table 5-5 Shear wave velocity measured at different saturation for studied samples of the Bahariya Formation.

Samples Number	depth (m)	V_S [m/s] at dry	V_S [m/s] at 25%	V_S [m/s] at 50%	V_S [m/s] at 75%	V_S [m/s] at 100%
1V	3512.0	1940	1890	1290	1450	2160
6H	3514.7	2360	1810	1650	1710	1890
12H	3517.1	2060	1890	1620	1620	1650
12V	3517.1	1820	1510	1040	1590	1620
16H	3518.2	2520	2270	1630	1450	1110
16V	3518.2	2010	1790	1350	1250	1120
21H	3519.5	2690	1640	1320	1460	1370
21V	3519.5	1700	1640	1320	1320	1290
27H	3521.3	2340	1930	1360	1420	1440
27V	3521.3	1690	1130	1110	1130	1540
30H	3522.5	2050	1490	1110	1070	1170
30V	3522.5	2080	1740	1590	1640	1640
41H	3526.4	2200	1940	1770	1860	1830
41V	3526.4	2010	1650	1580	1470	1360
44H	3528.2	1890	1620	1520	1470	1790
44V	3528.2	1830	1120	1100	1250	1330
48H	3529.1	1830	1760	1720	1310	1290
48V	3529.1	1710	1550	1490	1390	1230
51H	3530.0	2250	1910	1570	1480	1670
51V	3530.0	1630	1580	1330	1190	1390
59H	3533.0	2310	2130	1910	1630	1630
59V	3533.0	1390	1270	1240	1240	1620
63H	3534.8	2400	1760	1720	1660	1720
63V	3534.8	2460	2020	1820	1820	1820
73H	3543.9	2290	1850	1040	1480	1580
73V	3543.9	1870	1600	1450	1230	1720
Average		**2051**	**1711**	**1448**	**1446**	**1538**

Table 5-6 Shear wave velocity calculates from equation 16 at different saturation for studied samples of the Bahariya Formation.

Samples Number	Depth (m)	V_S [m/s] at dry	V_S[m/s] at 25%	V_S [m/s] at 50%	V_S [m/s] at 75%	V_S [m/s] at 100%
1V	3512.0	1940	1928	1916	1904	1892
6H	3514.7	2360	2349	2337	2326	2315
12H	3517.1	2060	2045	2030	2015	2000
12V	3517.1	1820	1807	1794	1781	1768
16H	3518.2	2520	2502	2484	2466	2449
16V	3518.2	2010	1995	1981	1966	1952
21H	3519.5	2690	2682	2675	2667	2660
21V	3519.5	1700	1695	1691	1687	1682
27H	3521.3	2340	2329	2318	2307	2297
27V	3521.3	1690	1683	1676	1670	1663
30H	3522.5	2050	2037	2025	2012	2000
30V	3522.5	2080	2067	2055	2043	2031
41H	3526.4	2200	2188	2176	2164	2152
41V	3526.4	2010	1999	1988	1978	1968
44H	3528.2	1890	1875	1860	1845	1831
44V	3528.2	1830	1815	1801	1787	1773
48H	3529.1	1830	1815	1801	1787	1774
48V	3529.1	1710	1697	1684	1672	1660
51H	3530.0	2250	2229	2209	2190	2171
51V	3530.0	1630	1614	1599	1584	1570
59H	3533.0	2310	2298	2286	2274	2262
59V	3533.0	1390	1381	1373	1365	1356
63H	3534.8	2400	2383	2367	2351	2335
63V	3534.8	2460	2441	2422	2404	2386
73H	3543.9	2290	2281	2273	2265	2256
73V	3543.9	1870	1862	1854	1846	1839
Average		**2051**	**2038**	**2026**	**2014**	**2002**

Table 5-7 Shear wave velocity calculates from equations 17a and 17b at different saturation for studied samples of the Bahariya Formation.

Samples Number	Depth (m)	V_S [m/s] at dry	V_S[m/s] at 25%	V_S [m/s] at 50%	V_S [m/s] at 75%	V_S [m/s] at 100%
1V	3512.0	1940	2139	2179	2173	2160
6H	3514.7	2360	2028	1923	1899	1890
12H	3517.1	2060	1778	1686	1662	1650
12V	3517.1	1820	1692	1648	1632	1620
16H	3518.2	2520	1570	1192	1120	1110
16V	3518.2	2010	1394	1172	1129	1120
21H	3519.5	2690	1779	1436	1376	1370
21V	3519.5	1700	1404	1311	1294	1290
27H	3521.3	2340	1707	1488	1448	1440
27V	3521.3	1690	1589	1556	1546	1540
30H	3522.5	2050	1438	1219	1178	1170
30V	3522.5	2080	1772	1673	1650	1640
41H	3526.4	2200	1943	1861	1840	1830
41V	3526.4	2010	1551	1398	1368	1360
44H	3528.2	1890	1843	1820	1804	1790
44V	3528.2	1830	1482	1367	1341	1330
48H	3529.1	1830	1453	1328	1300	1290
48V	3529.1	1710	1375	1264	1240	1230
51H	3530.0	2250	1850	1718	1685	1670
51V	3530.0	1630	1475	1422	1403	1390
59H	3533.0	2310	1829	1671	1639	1630
59V	3533.0	1390	1590	1632	1630	1620
63H	3534.8	2400	1923	1766	1732	1720
63V	3534.8	2460	2014	1868	1834	1820
73H	3543.9	2290	1784	1617	1587	1580
73V	3543.9	1870	1771	1738	1727	1720
Average		2051	1699	1575	1548	1538

Table 5-8 Poisson's ratio measured at different saturation for studied samples of the Bahariya Formation.

Samples Number	Depth (m)	Poisson's at dry	Poisson's at 25%	Poisson's at 50%	Poisson's at 75%	Poisson's at 100%
1V	3512.0	0.15	0.20	0.40	0.38	0.17
6H	3514.7	-0.02	0.25	0.32	0.35	0.34
12H	3517.1	0.04	0.20	0.33	0.34	0.35
12V	3517.1	0.07	0.27	0.42	0.29	0.34
16H	3518.2	-0.05	0.13	0.37	0.40	0.46
16V	3518.2	0.05	0.25	0.39	0.41	0.44
21H	3519.5	0.09	0.40	0.45	0.44	0.45
21V	3519.5	0.21	0.26	0.36	0.36	0.44
27H	3521.3	-0.06	0.23	0.40	0.38	0.42
27V	3521.3	-0.08	0.19	0.23	0.33	0.37
30H	3522.5	0.03	0.22	0.43	0.44	0.44
30V	3522.5	-0.02	0.25	0.37	0.36	0.36
41H	3526.4	-0.04	0.18	0.35	0.36	0.37
41V	3526.4	0.07	0.25	0.38	0.40	0.42
44H	3528.2	0.08	0.31	0.34	0.36	0.28
44V	3528.2	-0.04	0.41	0.42	0.38	0.39
48H	3529.1	-0.01	0.20	0.29	0.40	0.42
48V	3529.1	-0.03	0.11	0.27	0.31	0.39
51H	3530.0	0.05	0.27	0.37	0.38	0.37
51V	3530.0	0.06	0.18	0.34	0.38	0.37
59H	3533.0	0.14	0.25	0.35	0.40	0.41
59V	3533.0	0.35	0.38	0.41	0.41	0.38
63H	3534.8	0.01	0.33	0.36	0.38	0.38
63V	3534.8	-0.09	0.22	0.31	0.31	0.32
73H	3543.9	0.00	0.21	0.46	0.42	0.42
73V	3543.9	0.14	0.17	0.33	0.40	0.36
Average		0.042	0.243	0.363	0.376	0.379

Table 5-9 Poisson's ratio calculated from Vp and Vs calculated equations at different saturation for studied samples of the Bahariya Formation.

Samples Number	Depth (m)	Poisson's at dry	Poisson's at 25%	Poisson's at 50%	Poisson's at 75%	Poisson's at 100%
1V	3512.0	0.149	0.055	0.075	0.126	0.175
6H	3514.7	-0.023	0.223	0.302	0.324	0.341
12H	3517.1	0.042	0.255	0.299	0.328	0.349
12V	3517.1	0.066	0.220	0.263	0.307	0.341
16H	3518.2	-0.051	0.381	0.440	0.451	0.455
16V	3518.2	0.050	0.366	0.416	0.430	0.438
21H	3519.5	0.087	0.381	0.441	0.448	0.450
21V	3519.5	0.215	0.349	0.427	0.436	0.443
27H	3521.3	-0.060	0.322	0.396	0.411	0.420
27V	3521.3	-0.076	0.133	0.308	0.345	0.374
30H	3522.5	0.027	0.359	0.416	0.430	0.439
30V	3522.5	-0.015	0.245	0.313	0.342	0.363
41H	3526.4	-0.042	0.214	0.302	0.337	0.365
41V	3526.4	0.067	0.331	0.392	0.409	0.420
44H	3528.2	0.076	0.168	0.188	0.238	0.278
44V	3528.2	-0.040	0.286	0.335	0.368	0.392
48H	3529.1	-0.014	0.313	0.360	0.393	0.417
48V	3529.1	-0.034	0.288	0.341	0.372	0.393
51H	3530.0	0.050	0.288	0.324	0.349	0.366
51V	3530.0	0.058	0.257	0.267	0.324	0.366
59H	3533.0	0.143	0.340	0.390	0.405	0.415
59V	3533.0	0.351	0.315	0.329	0.354	0.377
63H	3534.8	0.015	0.290	0.343	0.364	0.378
63V	3534.8	-0.093	0.231	0.288	0.310	0.324
73H	3543.9	0.001	0.304	0.390	0.406	0.416
73V	3543.9	0.144	0.239	0.320	0.344	0.365
Average		**0.042**	**0.275**	**0.333**	**0.360**	**0.379**

Table 5-10 Compressional wave velocity measured and calculate at saturated sample (100%) from Wyllie and Raymer equations for studied samples of the Bahariya Formation.

Sample Number	depth [m]	VP [m/s], Measured	VP [m/s], saturated Calculate from Wyllie equation	VP [m/s], saturated Calculate from Raymer equation
1V	3512.0	3440	3585	3602
6H	3514.7	3850	3733	3763
12H	3517.1	3430	3481	3485
12V	3517.1	3300	3496	3502
16H	3518.2	3870	3494	3500
16V	3518.2	3360	3483	3487
21H	3519.5	4560	3976	4011
21V	3519.5	4020	3994	4029
27H	3521.3	3870	3750	3781
27V	3521.3	3430	3831	3866
30H	3522.5	3540	3598	3617
30V	3522.5	3540	3608	3628
41H	3526.4	3970	3656	3680
41V	3526.4	3670	3674	3700
44H	3528.2	3230	3425	3420
44V	3528.2	3160	3438	3436
48H	3529.1	3420	3441	3439
48V	3529.1	2930	3473	3476
51H	3530.0	3630	3346	3328
51V	3530.0	3020	3310	3284
59H	3533.0	4270	3685	3711
59V	3533.0	3650	3591	3609
63H	3534.8	3890	3524	3535
63V	3534.8	3570	3454	3454
73H	3543.9	4160	3849	3884
73V	3543.9	3730	3781	3813

Table 5-11 Compressional wave velocity measured and calculate at dry samples from Wyllie and Raymer equations for studied samples of the Bahariya Formation.

Sample Number	depth [m]	VP [m/s], dry Measured	VP [m/s], dry Calculate from Wyllie equation	VP [m/s], dry Calculate from Raymer equation
1V	3512.0	3103	1795	3465
2H			4400	4400
3H	3513.6	3385	1749	3425
3V	3513.6	2990	1738	3416
4H	3513.8	3410	1763	3438
4V	3513.8	2830	1708	3390
5H	3514.6	3380	1788	3458
5V	3514.6	2790	1839	3500
6H	3514.7	3503	2056	3655
6V	3514.7		4400	4400
7H	3515.2	3480	2215	3750
7V	3515.2	2780	2169	3724
8H			4400	4400
8V			4400	4400
9H	3515.6	3760	2542	3914
9V	3515.6		2361	3828
10H			4400	4400
10V			4400	4400
11V			4400	4400
12H	3517.1	3102	1639	3325
12V	3517.1	2763	1660	3345
13H	3517.2	2705	1525	3208
13V	3517.2	2610	1510	3192
14H	3517.4	3483	1829	3492
14V	3517.4	3385	1800	3469
15H	3518.1	3130	1682	3366
15V	3518.1	3050	1518	3200
16H	3518.2	3588	1658	3343
16V	3518.2	3053	1642	3328
21H	3519.5	4330	2619	3946
21V	3519.5	3330	2670	3967
22H	3519.7		4400	4400
22V	3519.7		4400	4400
24H	3520.0	3250	2116	3692
24V	3520.0	2950	1936	3573
25H	3520.9		2216	3752
25V	3520.9	2800	2334	3815
26H	3521.0		4400	4400
26V	3521.0		4400	4400
27H	3521.3	3340	2090	3676
27V	3521.3	2475	2260	3776
28H	3521.6	3432	1908	3553
28V	3521.6		1770	3444
29H	3521.9	3852	2031	3638
29V	3521.9	3282	1926	3566
30H	3522.5	3062	1817	3482
30V	3522.5	3122	1834	3496
31H	3522.7	4324	2732	3991
31V	3522.7	3564	2671	3967
39H	3525.4		4400	4400
40H	3526.3	4354	3057	4104
40V	3526.3		3012	4090
41H	3526.4	3555	1914	3557
41V	3526.4	2904	1947	3581
42H	3527.3	2670	1544	3228
42V	3527.3	2315	1518	3200
43H	3527.5	3860	2394	3845
43V	3527.5		2289	3791

Table 5-11 (Continued), compressional wave velocity measured and calculate at dry samples from Wyllie and Raymer equations for studied samples of the Bahariya Formation.

Sample Number	depth [m]	VP [m/s], Measured	VP [m/s], dry Calculate from Wyllie equation	VP [m/s], dry Calculate from Raymer equation
44H	3528.2	2875	1562	3248
44V	3528.2	2860	1580	3267
46H	3528.5	2912	1560	3246
46V	3528.5	2818	1555	3240
47H	3528.7	4425	2739	3994
47V	3528.7	3315	2053	3653
48H	3529.1	2860	1583	3270
48V	3529.1	2425	1628	3315
49H	3529.3	3299	1494	3173
49V	3529.3	2925	1462	3137
50H	3529.4	2960	1551	3236
50V	3529.4	2630	1470	3146
51H	3530.0	3258	1463	3137
51V	3530.0	2493	1419	3085
52H	3530.1		1820	3484
52V	3530.1	3140	1861	3517
53H	3530.3	3410	1961	3591
53V	3530.3	3417	1967	3595
54H	3531.1	3368	1759	3434
54V	3531.1	2950	1837	3498
55H	3531.2	3360	1522	3205
55V	3531.2	2535	1538	3222
56H	3531.6	3575	1635	3322
56V	3531.6		1665	3350
57H	3531.8	3715	2267	3779
57V	3531.8	3235	2153	3715
58H	3532.4	3655	2040	3644
58V	3532.4		2906	4055
59H	3533.0	3885	1966	3594
59V	3533.0	3110	1805	3472
60H	3533.1		4400	4400
60V	3533.1		4400	4400
61H	3533.3		4400	4400
62H	3533.7	2890	1492	3171
62V	3533.7	2565	1470	3146
63H	3534.8	3498	1702	3384
63V	3534.8	3268	1601	3288
64H	3536.3		4400	4400
64V	3536.3		4400	4400
65H	3536.8	3310	1638	3324
65V	3536.8	2885	1654	3340
71H	3543.4	3395	2060	3657
71V	3543.4	2980	2080	3670
73H	3543.9	3320	2300	3797
73V	3543.9	2940	2152	3714
74H	3544.7	3835	2160	3719
74V	3544.7	3365	2341	3818
75H	3544.9	3450	2253	3772
75V	3544.9	3065	2250	3770
76H	3545.5		4400	4400
76V	3545.5		4400	4400
77H	3545.7		4400	4400
77V	3545.7		4400	4400
78H	3546.4	3870	2433	3864
78V	3546.4		2442	3868
79H	3546.6		2564	3923
79V	3546.6		2054	3653
80H	3547.4	3820	2356	3826
80V	3547.4		2356	3826

APPENDIX 5

Table 6-1 Measured and calculates permeability from bulk density, porosity, magnetic susceptibility, Spor, apparent and true formation resistivity factor for studied samples of the Bahariya Formation.

Sample Number	depth [m]	*K* [mD] Measured	*k** [mD] From (d_b)	*k** [mD] From (Φ)	*k** [mD] From (κ)	*k** [mD] From (S_{por})	*k** From (F')	*k** From (F)
1V	3512.0	28.28	0.94	1.09	17.09	25.72		
2H	3512.9	1.040						
3H	3513.6	6.39	1.28	1.51	0.21	0.51	1.47	1.24
3V	3513.6	0.45	2.69	1.63	0.46	0.80	0.26	0.18
4H	3513.8	1.19	1.50	1.36	0.76	0.87	2.57	1.76
4V	3513.8	0.98	2.05	2.04	1.02	0.78	1.35	1.15
5H	3514.6	0.140	1.23	1.15	0.39	15.02		
5V	3514.6	0.090	1.77	0.81	0.36	0.28		
6H	3514.7	0.290	0.26	0.23	0.16	0.15		
6V	3514.7							
7H	3515.2	0.24	0.15	0.10	0.20	0.07	0.46	0.23
7V	3515.2	0.03	0.18	0.13	0.35	13.26	0.07	0.06
8H	3515.4	0.060						
8V	3515.4	0.020						
9H	3515.6	0.020	0.06	0.03	0.43	0.08	0.25	0.19
9V	3515.6	0.010	0.06	0.06	0.34	4.33	0.05	0.04
10H	3516.3	0.130						
10V	3516.3	0.020						
11V	3516.5	6.520						
12H	3517.1	1.54	2.18	3.53	1.03	1.62	24.86	30.19
12V	3517.1	1.31	2.49	2.97	1.34	1.81	9.15	11.97
13H	3517.2	15.69	4.96	9.73	6.02			
13V	3517.2	6.52	5.02	11.22	5.74	5.21		
14H	3517.4	13.52	0.29	0.86	0.22	3.33	1.55	2.40
14V	3517.4	14.06	5.63	1.05	0.16	2.70	1.33	2.21
15H	3518.1	23.310	4.90	2.49	8.76	7.03		
15V	3518.1	18.94	15.11	10.42	2.64	15.43		
16H	3518.2	15.09	1.40	3.03	0.19	30.47	2.68	3.57
16V	3518.2	13.80	1.42	3.45	0.12	13.08	2.63	3.65
21H	3519.5	0.320	0.04	0.02	0.62	0.85		
21V	3519.5	0.040	0.05	0.02	0.49	0.26		
22H	3519.7	0.680						
22V	3519.7	0.140						
24H	3520.0	0.054	0.28	0.17	0.65	0.14	0.43	0.25
24V	3520.0	0.017	0.31	0.44	0.55	0.18	0.15	0.13
25H	3520.9			0.10	0.75	0.15		
25V	3520.9	0.020	0.15	0.06	0.56	0.08		
26H	3521.0	0.110						
26V	3521.0	0.020						

Table 6-1 (Continued), Measured and calculates permeability from bulk density, porosity, magnetic susceptibility, Spor, apparent and true formation resistivity factor for studied samples of the Bahariya Formation.

Sample Number	depth [m]	*K* [mD] Measured	*k** [mD] From (d_s)	*k** [mD] From (Φ)	*k** [mD] From (κ)	*k** [mD] From (S_{por})	*k** [mD] From (F')	*k** [mD] From (F)
27H	3521.3	0.480	0.30	0.19	0.29			
27V	3521.3	0.070	0.23	0.09	0.45	0.39		
28H	3521.6	0.420	1.23	0.52	1.03	0.66		
28V	3521.6	0.260	1.95	1.29	0.58	0.60		
29H	3521.9	0.800	0.46	0.26	26.86	4.46		
29V	3521.9	0.930	0.46	0.47	4.41			
30H	3522.5	3.690	0.99	0.94	1.13	3.73	0.54	0.70
30V	3522.5	2.270	0.78	0.84	0.31	2.77	0.18	0.23
31H	3522.7	0.120	0.04	0.02	0.98			
31V	3522.7	0.020	0.06	0.02	0.18	0.04	0.03	0.02
39H	3525.4	0.230						
40H	3526.3	0.140	0.01	0.01	0.13	0.08		
40V	3526.3	0.030	0.01	0.01	0.11	0.25		
41H	3526.4	0.26	0.55	0.50	1.25	0.88	0.99	1.25
41V	3526.4	0.18	0.52	0.41	1.23	0.98	0.57	0.62
42H	3527.3	27.56	4.62	8.14	6.39	2.94	16.98	24.63
42V	3527.3	22.70	4.51	10.41	3.60	2.88	10.11	14.52
43H	3527.5	1.740	0.21	0.05	0.02			
43V	3527.5	0.010	0.51	0.08	0.04	0.13		
44H	3528.2	19.42	3.31	6.87	0.61	2.82	20.16	26.79
44V	3528.2	23.77	3.61	5.83	9.94	6.33	6.17	8.09
46H	3528.5	13.250	3.25	7.00	4.37			
46V	3528.5	4.550	4.41	7.33	10.47			
47H	3528.7	0.43	0.02	0.02	0.16	0.09	0.27	0.25
47V	3528.7	0.06	0.36	0.23	0.21	0.15	0.02	0.01
48H	3529.1	3.737	3.65	5.68	0.71	0.63	11.80	10.36
48V	3529.1	1.16	2.60	3.85	0.64	0.77	3.67	3.03
49H	3529.3	68.525	5.72	13.17	12.76	5.90	15.53	20.31
49V	3529.3	47.475	6.89	18.20	11.16	5.04	11.11	14.39
50H	3529.4	38.55	4.07	7.63	10.20	3.09	12.23	16.86
50V	3529.4	24.75	3.94	16.71	9.57	3.51	4.46	6.15
51H	3530.0	54.58	6.97	18.06	6.75	8.97	36.29	43.27
51V	3530.0	55.93	11.28	28.79	8.94	7.47	28.17	37.69
52H	3530.1	0.460	0.92	0.92	0.28			
52V	3530.1	0.160	0.73	0.70	0.02	0.14		
53H	3530.3	0.050	0.31	0.38	0.19			
53V	3530.3	0.020	0.23	0.37	0.05			
54H	3531.1	0.180	0.69	1.40	1.55			
54V	3531.1	0.130	0.97	0.82	1.55			

Table 6-1 (Continued), Measured and calculates permeability from bulk density, porosity, magnetic susceptibility, Spor, apparent and true formation resistivity factor for studied samples of the Bahariya Formation.

Sample Number	depth [m]	*K* [mD] Measured	*k** [mD] From (d_s)	*k** [mD] From (Φ)	*k** [mD] From (κ)	*k** [mD] From (S_{por})	*k** [mD] From (F')	*k** [mD] From (F)
55H	3531.2	5.58	6.22	9.99	0.80	0.82	10.21	9.63
55V	3531.2	1.25	5.78	8.62	0.79	0.67	2.19	2.27
56H	3531.6		3.05	3.64	0.34			
56V	3531.6	0.070	11.85	2.86	0.13			
57H	3531.8	0.070	0.13	0.08	0.13			
57V	3531.8	0.020	0.12	0.14	0.18			
58H	3532.4		0.78	0.25	0.30	0.21		
58V	3532.4			0.01		0.76		
59H	3533.0	0.09	0.29	0.37	0.10	0.63	0.22	0.14
59V	3533.0	0.11	0.59	1.02	0.31	0.51	0.37	0.29
60H	3533.1	0.320						
60V	3533.1	0.160						
61H	3533.3	4.290						
62H	3533.7	21.920	4.16	13.43	14.58			
62V	3533.7	9.240	5.00	16.79	5.24			
63H	3534.8	15.04	1.30	2.13	5.73	11.06	2.66	3.21
63V	3534.8	6.48	2.37	4.85	0.95	0.62	4.54	4.21
64H	3536.3	0.100						
64V	3536.3	0.020						
65H	3536.8	14.35	1.75	3.56	6.61	3.87	1.62	1.97
65V	3536.8	11.96	2.19	3.12	7.94	2.70	0.65	0.86
71H	3543.4	3.39	0.33	0.22	6.90	1.99	0.08	0.12
71V	3543.4	1.27	0.22	0.20	4.10	0.77	0.03	0.04
73H	3543.9	0.09	0.04	0.07	0.04	0.08	1.35	1.10
73V	3543.9	0.04	0.04	0.14	0.02	0.03	0.64	0.59
74H	3544.7	0.05	0.01	0.13	0.00	0.01	1.41	1.33
74V	3544.7	0.01	0.04	0.06	0.04	0.02	0.04	0.04
75H	3544.9	0.230	0.12	0.09	0.42	0.03	0.82	0.59
75V	3544.9	0.037	0.15	0.09	0.47	0.03	0.05	0.04
76H	3545.5	0.230						
76V	3545.5	0.010						
77H	3545.7	0.070						
77V	3545.7	0.010						
78H	3546.4	0.111	0.05	0.04	0.07	0.01	4.50	3.51
78V	3546.4	0.007	0.04	0.04	0.12	0.27	0.03	0.02
79H	3546.6	0.090	0.03	0.03	0.09			
79V	3546.6	0.010	0.44	0.23	0.15	0.04		
80H	3547.4	0.010	1.60	0.06	0.08			
80V	3547.4	0.010	1.86	0.06	0.06			

Table 6-2 Calculates permeability from (Φ and Spor), (Spor and F), (ρ" and F), (Φ, Spor and F) and (Φ, Spor, F and ρ"), for studied samples of the Bahariya Formation.

Sample Number	depth [m]	k^* [mD] From (Φ & S_{por})	k^* [mD] From (S_{por} & F)	k^* [mD] From (ρ'' & F)	k^* [mD] From (Φ, S_{por} & F)	k^* [mD] From (Φ, S_{por}, F & ρ'')
1V	3512.0	8.90				
2H	3512.9					
3H	3513.6	1.13	0.89	0.45	1.19	0.68
3V	3513.6	1.52	0.28	0.07	0.49	0.24
4H	3513.8	1.46	1.58	0.43	1.79	0.69
4V	3513.8	1.66	1.09	0.59	1.49	0.98
5H	3514.6	6.74				
5V	3514.6	0.60				
6H	3514.7	0.20				
6V	3514.7					
7H	3515.2	0.08	0.08	0.04	0.08	0.03
7V	3515.2	1.71	0.63	0.05	0.39	0.13
8H	3515.4					
8V	3515.4					
9H	3515.6	0.03	0.07	0.12	0.04	0.03
9V	3515.6	0.48	0.24	0.05	0.13	0.07
10H	3516.3					
10V	3516.3					
11V	3516.5					
12H	3517.1	3.23	19.11	22.05	15.65	13.48
12V	3517.1	3.18	10.25	16.59	9.24	11.29
13H	3517.2					
13V	3517.2	10.05				
14H	3517.4	2.48	4.48	15.05	3.47	8.69
14V	3517.4	2.44	3.72	28.48	3.18	13.78
15H	3518.1	6.36				
15V	3518.1	18.06				
16H	3518.2	15.92	22.65	6.92	16.42	11.96
16V	3518.2	10.45	13.88	9.25	11.75	12.68
21H	3519.5	0.08				
21V	3519.5	0.03				
22H	3519.7					
22V	3519.7					
24H	3520.0	0.16	0.13	0.08	0.13	0.07
24V	3520.0	0.33	0.09	0.11	0.14	0.15
25H	3520.9	0.12				
25V	3520.9	0.06				
26H	3521.0					
26V	3521.0					

Table 6-2 (Continued), calculates permeability from (Φ and Spor), (Spor and F), (ρ" and F), (Φ, Spor and F) and (Φ, Spor, F and ρ"), for studied samples of the Bahariya Formation.

sample Number	depth [m]	k^* [mD] From (Φ & S_{por})	k^* [mD] From (S_{por} & F)	k^* [mD] From (ρ'' & F)	k^* [mD] From (Φ, S_{por} & F)	k^* [mD] From (Φ, S_{por}, F & ρ'')
27H	3521.3					
27V	3521.3	0.17				
28H	3521.6	0.75				
28V	3521.6	1.15				
29H	3521.9	1.47				
29V	3521.9					
30H	3522.5	2.77	1.91	1.67	1.83	2.18
30V	3522.5	2.20	0.71	0.69	0.82	1.14
31H	3522.7					
31V	3522.7	0.01	0.01	0.02	0.01	0.01
39H	3525.4					
40H	3526.3	0.00				
40V	3526.3	0.01				
41H	3526.4	0.87	1.24	2.24	1.11	1.53
41V	3526.4	0.83	0.79	0.64	0.73	0.64
42H	3527.3	6.41	23.48	67.51	22.03	41.61
42V	3527.3	6.97	15.66	38.81	16.97	31.10
43H	3527.5					
43V	3527.5	0.08				
44H	3528.2	5.85	24.39	35.76	21.87	25.49
44V	3528.2	8.65	16.24	12.20	15.18	14.71
46H	3528.5					
46V	3528.5					
47H	3528.7	0.01	0.10	0.20	0.03	0.03
47V	3528.7	0.20	0.01	0.01	0.03	0.03
48H	3529.1	2.32	4.91	2.36	6.19	2.93
48V	3529.1	2.20	2.21	0.81	3.03	1.40
49H	3529.3	11.46	30.88	33.47	29.87	34.14
49V	3529.3	11.81	21.74	23.65	24.37	28.74
50H	3529.4	6.42	18.25	31.65	17.84	25.14
50V	3529.4	9.33	9.31	13.68	12.47	18.74
51H	3530.0	16.33	69.62	26.39	59.50	33.08
51V	3530.0	17.40	56.31	50.02	55.47	55.35
52H	3530.1					
52V	3530.1	0.37				
53H	3530.3					
53V	3530.3					
54H	3531.1					
54V	3531.1					

Table 6-2 (Continued), calculates permeability from (Φ and Spor), (Spor and F), (ρ" and F), (Φ, Spor and F) and (Φ, Spor, F and ρ"), for studied samples of the Bahariya Formation.

sample Number	depth [m]	k^* [mD] From (Φ & S_{por})	k^* [mD] From (S_{por} & F)	k^* [mD] From (ρ'' & F)	k^* [mD] From (Φ, S_{por} & F)	k^* [mD] From (Φ, S_{por}, F & ρ'')
55H	3531.2	3.37	5.44	2.90	7.55	4.14
55V	3531.2	2.84	1.65	1.46	2.91	2.57
56H	3531.6					
56V	3531.6					
57H	3531.8					
57V	3531.8					
58H	3532.4	0.25				
58V	3532.4	0.03				
59H	3533.0	0.60	0.20	0.05	0.25	0.11
59V	3533.0	0.93	0.31	0.14	0.47	0.28
60H	3533.1					
60V	3533.1					
61H	3533.3					
62H	3533.7					
62V	3533.7					
63H	3534.8	7.65	11.42	3.70	8.99	5.71
63V	3534.8	2.15	2.48	1.49	3.51	2.13
64H	3536.3					
64V	3536.3					
65H	3536.8	5.31	4.23	2.62	4.80	4.34
65V	3536.8	4.09	1.84	2.09	2.45	3.45
71H	3543.4	0.84	0.36	1.26	0.32	0.99
71V	3543.4	0.46	0.10	0.62	0.11	0.50
73H	3543.9	0.06	0.27	0.38	0.17	0.12
73V	3543.9	0.06	0.10	0.36	0.10	0.13
74H	3544.7	0.03	0.10	0.70	0.11	0.16
74V	3544.7	0.02	0.01	0.06	0.01	0.03
75H	3544.9	0.04	0.09	0.17	0.08	0.06
75V	3544.9	0.04	0.01	0.04	0.02	0.03
76H	3545.5					
76V	3545.5					
77H	3545.7					
77V	3545.7					
78H	3546.4	0.01	0.16	0.75	0.09	0.08
78V	3546.4	0.08	0.03	0.02	0.02	0.02
79H	3546.6					
79V	3546.6	0.09				
80H	3547.4					
80V	3547.4					

"نمذجة بتروفيزيقية لمعامل التكوين - المسامية والتشبع لمتكون البحرية بالصحراء الغربية– مصر"

رسالة مقدمة من الطالب

هشام حسن سعد أبوسعدة

ماجستير فى العلوم چيولوچيا ٢٠٠٥

باحث مساعد بمعهد بحوث البترول

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رسالة دكتوراه الفلسفة فى العلوم فى الجيوفيزياء

عنوان الرسالة: "نمذجة بتروفيزيقية لمعامل التكوين - المسامية والتشبع لمتكون البحرية بالصحراء الغربية- مصر"

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ختم الإجازة

أجيزة الرساله بتاريخ ٢٠١٠/٣/٢٠

موافقة مجلس الكليه بتاريخ ٢٠١٠/٤/١٢

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الملخص العربي

ملخص الرسالة باللغة العربية

عنوان الرسالة: **"نمذجة بتروفيزيقية لمعامل التكوين – المسامية والتشبع لمتكون البحرية بالصحراء الغربية – مصر"**

إن الدراسات البتروفيزيقيه التفصيليه تكون على جانب كبير من الأهميه لتحسين طرق تقييم الخزانات البتروليه حيث أن معظم الطرق تركز على التنبؤ بقيم المساميه والنفاذيه لطبقات صخور الخزان وذلك أنطلقا من القياسات الروتينيه الأخرى والرساله تحتوي على نتائج القياسات والتي أجريت على عينات من صخور رمليه تابعه لمتكون البحريه بالصحراء الغربيه – مصر والتي بلغ عددها أكثر من 80 عينه لبيه مما تهدف الى إنجاز علاقات بتروفيزيائيه تهدف إلى توصيف صخور الخزانات والنطاقات المشبعه والتي توجد ضمن صخور متكون البحريه وذلك بدراسة مواصفات وخواص الصخور الخازنه للهيدروكربونات من الناحيه الليثولوجيه والبتروفيزيقيه في شمال الصحراء الغربيه. وتهدف الدراسة إلى تحديد معامل عدم التجانس البتروفيزيقي للمعاملات المختلفه مثل النفازيه - المقاومه الكهربائيه النوعيه - سرعة الموجات الطوليه فى الصخور وكذالك التوصيل الحرارى وتأثير الترقق الموجب على الدراسة البتروفيزقية وحساب المعامل الحسابى للعينات ذات الترقق الموجب والعينات ذات الترقق السالب وكذالك عمل علاقات بين المتغيرات المختلفه. وتم عمل جميع القياسات فى معامل جامعة عين شمس بالقاهره – جامعة كلاوستال بألمانيا – معهد بحوث البترول المصرى والرساله تقع في ستة أبواب مرتبه كالتالي:

1- الباب الأول:

وهو عباره عن مقدمه لموضوع البحث موقع الدراسه مع عرض للدراسات الجيولوجيه والجيوفيزيقيه السابقه والمنشوره عن المنطقه في المجلات والرسائل العلميه المتخصصه بالإضافه إلى الهدف من إجراء الدراسات الحاليه. وكذا الوضع الجيولوجي الخاص بالمنطقه والتتابع الصخري وتقسيماته المختلفه لكل من منطقة الدراسه وما يتعلق بها من تواجدات للبترول في الصحراء الغربيه. وقسمت العينات موقع الدراسه إلى نوعين أساسيين مختلفين في الترقق أحدهما وصف بالترقق الموجب والآخر وصف بالترقق السالب وكذا عرض بعض النتائج الخاصه بدراسة المعادن المكونه لصخور متكون البحريه بالصحراء الغربيه.

2- الباب الثاني:

يقدم المعاملات البتروفيزيائيه الحجميه والتي أجريت على معظم العينات تحت الدراسه ومن ثم معالجتها إحصائياً بإستخدام منحنيات التوزيع المختلفه من حيث الترقق الموجب والترقق السالب مما أظهر فروق واضحه في قيم المساميه والمساحه النوعيه السطحيه للفراغات البينيه والقابليه المغناطيسيه.

3- الباب الثالث:

يتناول هذا الباب دراسه بتروفيزيائيه للمعاملات المتجهه حيث أخذ في الإعتبار نوعية العينه من حيث أنها عموديه أو موازيه لمستوى التطبق عند كل عمق تحت سطحي مما يسمح بتقييم ودراسة ظاهرة عدم التجانس البتروفيزيقي في صخور خزان متكون البحريه الحامل للهيدروكربونات وذلك بإستنباط معادلات رياضيه ونماذج تطبيقيه يمكن إستخدامها في تقييم الخزان عموماً أوضحت دراسة نتائج العينات الموجبه الترقق مستويات عاليه من عدم التجانس البتروفيزيقي حيث أن تداخل كل من مفهوم الترقق والتجانس البتروفيزيقي من عدمه تساعد على فهم خزان البحريه.

4- الباب الرابع:

يتناول هذا الباب ملخص لأكثر العلاقات أهمية والتي بنيت على أسس تطبيقيه من حيث الإستفاده منها حيث تظهر العلاقه بين المساميه والنفاذيه مضاهاة مقبوله للعينات سالبة الترقق فقط والتي يمكن أن تؤخذ في الإعتبار عند دراسة وتقييم متكون البحريه في المستقبل. وكذلك القابليه المغناطيسيه للصخور وعلاقتها بالمساميه توضح أسس يمكن إستخدامها في تقسيم الصخور من حيث درجات الترقق. وأن معامل التكوين الحقيقي للمقاومه الكهربائيه النوعيه يحقق علاقه مقبوله مع مسامية الصخور الخاصه بمتكون البحريه. كما اوضحت الدراسه أن العينات موجبة الترقق تتميز بمساميه منخفضه وقابليه مغناطيسيه عاليه.

5- الباب الخامس:

يتناول هذا الباب دراسة لتأثير التشبع بالموائع (مياه) على سرعة الموجات الصوتيه وتم قياس سرعة الموجات الطوليه والعرضيه فى الصخور لبعض العينات تحت الدراسه عند تشبعات مختلفه وأظهرت النتائج أن معامل بواسون يمكن تعريفه كمحدد تطبيقي للتفريق بين العينات المشبعه بالمياه والغاز. ويتناول هذا الباب أيضا مقاربة نظريه تدل على أن معامل بواسون مفيد لتحديد سرعة الموجات الطوليه والمستعرضه عندما تكون العينات مشبعه (100%) والتعرف على التشبع بدرجات مفاوته من الماء والغاز في كل من الحالتين.

6- الباب السادس:

لقد أجريت تجارب عديده تهدف إلى حساب النفاذيه لصخور البحريه وعمل نمذجه بتروفيزيقيه بطريقة عمليه وأكدت النتائج هذا الهدف وذلك بإستخدام دراسات إحصائيه متعدده الإختيارات وبإستخدام أكثر من معامل أتضح كيفية التنبؤ بقيمة النفاذيه لصخور متكون البحريه. وكما هو معروف من معادلات كوزوني بمزاوجة المساميه مع المساحه النوعيه السطحيه للفراغات البينيه ومعامل مقاومه التكوين وكذا الجزء التخيلي للتوصيل الكهربائي النوعي والتي أنتجت علاقات يمكن أن تستخدم بشكل تطبيقي في إستكشاف وإنتاج الهيدروكربونات من صخور متكون البحريه. كما يمكننا القول بأن إستخدام هذه البارامترات البتروفيزيقيه بعضهم مع بعض يؤكد أن التنبؤ بقيمة النفاذيه لصخور البحريه أصبح ممكنا إذا توافرت المعلومات ذات العلاقة بحجم الفراغات وشكلها الهندسي. كما يتناول الجزء الأخير من الرساله عرض مفصل لملخص المحتوى والإضافات العلميه ويعقبه قائمة المراجع العلميه المستخدمه أثناء إجراء البحث.