Petrophysical Properties of the Kahasib Formation in Missan Region, South Iraq

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Abstract

The present paper deals with the study of petrophysical and dynamic properties of (207) plugs which were taken from rock cores of Khasib Formation at five oil wells (No.2, AM-1 AM-2, HF-3, and HU-1) located in Missan area, South of Iraq.

A comparison was made for the studied properties deduced from laboratory and from the available well logs. (35) predictive equations are established to estimate the effective porosity, permeability, in terms of the properties that are obtained from resistivity sonic, radioactivity and neutron porosity logs. These equations showed that multiple correlation coefficients ($\overline{R}$) have ranged between weak and excellent. Statistical relations regarding the calculated and the observed values of these properties have also been estimated.

Using the same procedure, another (25) predictive equations were established for (75) plugs of the reservoir unit at the studied wells, in terms of the properties deduced from well logs. The estimated correlation factors for these equations are generally ranged between fair to very excellent. Also some statistical parameters were established to describe the relations between the observed and the calculated properties.

الخلاصة

يتعلق البحث الحالي بدراسة الخصائص الفيزياوية الصخرية والحركية المقاسة لـ(207) نموذجا مأخوذا من اللباب الصخري لتكوين الخصيب (العصر الطباشيري العلوي) لخمسة ابار نفطية وهي نور-1 وعمارة -2 وعمارة-1 وحلفاية -3 وحويزة -1 الواقعة في محافظة ميسان ومقارنتها مع تلك الخصائص المستنبطة من المجسات البئرية المتوفرة في هذه الآبار.

ثم استنباط (35) معادلة تنبؤية للتكوين وذلك للتكهن عن قيم المسامية الفعالة والنفاذية والكثافة الحجمية والسرعة الطولية والسرعة العرضية بدلالة المعلومات المستقاة من المجسات الكهربائية والصوتية والإشعاعية والنترونية حيث بينت هذه المعادلات درجة ارتباط تتراوح بين الضعيفة والممتازة. كذلك فقد تم إيجاد العلاقات الإحصائية بين القيم المحسوبة باستخدام هذه المعادلات التنبؤية مع القيم المختبرية للخواص الصخرية والحركية.

وبنفس الطريقة تم التوصل إلى (25) معادلة تنبؤية أخرى للتكهن عن نفس الخصائص المشار إليها لـ (75) عينة من عينات الوحدة المكمنية في التكوين ولجميع هذه الآبار بدلالة معلومات المجسات البئرية وبينت هذه المعادلات ارتباطا عاليا افضل من المعادلات السابقة فتراوحت قيم معاملات الارتباط بشكل عام بين المتوسطة إلى الممتازة جدا. إضافة لذلك فقد تم التوصل إلى بعض العلاقات الإحصائية بين القيم المختبرية والمحسوبة لهذه الخصائص

Introduction

In the rock physics domain field hundreds of paper were published regarding the use of dynamic properties such as compressional velocity (V_P), shear velocity (V_S), (V_P / V_S), dynamic elastic module and inelastic attenuation parameters in the study of the petrophysical properties for sediments and non saturated rocks; under different conditions (Cole, 1976), (Domenico, 1984), (Nur and Han, 1986, Rafison, 1988), (Jassim etal, 1996) [1-5] . Accordingly, many important conclusions were established concerning the effects of petrophysical properties such as porosity, permeability, size and shape of grains, degree of saturation, temperature, pressure, and chemical composition of sediments and rocks on the measured dynamic properties.

Khasib Formation (U. Cretaceous) of Mesopotamian basin is considered to be one of several the oil bearing formations in Iraq. It attracts the attention of many workers to study its petrographic, sedimentologic, and petrophysical properties in terms of the dynamic properties (Al-Khayat and Razaim, 1977) [6], (AL-Kindi, 1980) [7], (Al-Jubbory, 1992) [8] … etc. Khasib Formation consists of a carbonate rocks slightly argillaceous to argillaceous limestone containing several reservoir units with alternations of a homogeneous, porous and massive layers.

Khasib Formation occur in the southern of Iraq in the eastern part of the stable continental shelf .Its thickness increasees towards the Mesopotamian basin while it decreases in Kuwait where it disappears in the Burgan area .Also its thickness decreases towards North and North-West where it disappears to the west of falloja. (Buday & Jassim 1987) [9] According to(Hassan &Arsen ,1992)[10] ,the depositional environment of Khasib Formation includes two types. The open shelf deposits which is located at the lower part of the Formation,whereas the second one is the foreslope which is located at the upper part.

In the present study, five oil-producing wells located at the governorate of Missan, south of Iraq, were studied. These wells are geographically distributed from Iraqi-Iranian border, in the east, to near Amara City in the west. The locations of these wells are shown in Fig-1, which are HU-1, HF-3, NO-2, AM-2, and AM-1. Thickness of Khasib Formation in the studied wells ranges between 65.5 m (at well No-2) and 84 m (at well HF-3). (Al-Hussaini, 1996) [11].

Laboratory Work

For the wells under study we have chosed some parts of the following logs, which corresponds to the available cores of Khasib Formation:

1/ Electrical logs:
a) Self potential, SP
b) Resistivity log, SFL, MSFL
c) Electromagnetic log, EPT
2/ Radioactivity logs:
a) Gamma ray, GR
b) Neutron log, NPHI
d) Density log, RHOB
3/ Acoustic log: (Sonic log, SON)

The first step in the present work is to pick the well logs curves data, which are presented in analog form, by using a digitizer. The picked values for each well represent the log data in function of depth using a sample interval of (0.3m). Then logs have been plotted for these values. (Fig-2). At the **same** time the measured petrophysical properties have been plotted as function of depth together with the logs curves. One point which must be taken in consideration, regarding erroneous depth produced from the lack of some cores during drilling which will cause depth difference between drilling and logs. To eliminate this efect, depth correction was made for all the studied well by comparing log and laboratory curves.

Statistical Analysis

Basically, a sample linear regression equation is expressed by:

$$\mathbf{Y_i = a + b\, X_i}$$

Where: (X_i) is independent variable, (Y_i) is dependent variable,
(a) is the intercept of the slope line with Y-axis when
(X_i) equal to zero, and (b) is the slope of regression.
The degree of correlation between the two variables (X) and (Y) could be expressed by correlation coefficient (R) ranging between zero and (±1). Increasing the value of (R), whether it is positive or negative, suggests an enhancement of the correlation. On the contrary, if (R) approaches zero it will mean a deterioration of

the correlation between the two variables which is related to the distribution of data points.
Moreover, multiple regression analysis was carried out for the available data. Statistically, it is an approach for analyzing the interrelationship between one independent variable, or more, and a dependent variable, as described in (AL-Rawi, 1987) [12] . The multiple regression equation is:

$$Y_i = B_0 + B_1X_{i1} + B_2 X_{i2} + \dots + B_m X_{im}$$

(Y_i) and (X_i) are consequently the dependent and independent variables where ranging between (1) to (m).
(B_0) is the intercept of the slope plane with the ordinate, ($B_1, B_2, \dots , B_m$) are the partial regression coefficients.
The input data to the utilized statistical package (the stepwise selection procedure) is the independent and dependent variables, while the output data is a series of predicted equations which relates the dependent variables (observed petrophysical and dynamic properties) with the independent variables (well logs data). These properties are listed in table-1, where (GD) is denoted to grain density log values, and (V_{arm}) is the variable matrix log.

Table (1): Dependent and independent variables used in the study.

Dependent variables	Effective porosity (pora), permeability (K), Bulk density (BD), Compressional velocity (V_P), shear velocity (V_S).
Independent variables	SP, GR, SON, MSFL, SFL, EATT, V_{arm}, RHOB, NPHI, GD.

The velocities (V_P and V_S) were measured in both horizontal, parallel to bedding plane, and vertical direction (V_{SH}, V_{SV}, V_{PH}, V_{PV}) then taking the average (V_{Pa} , V_{Sa}) in both directions.
The clay content ratio, at a given depth interval is calculated by taking the highest and lowest values of the (SP) and (GR) logs, which in turn they are used to compute Gamma ray coefficient (IGR) and self potential coefficient (ISP) applying the following relations (Schlumberger, 1974) [13] :

$$IGR = \frac{GR - GR_{min}}{GR_{max} - GR_{min}} \quad or$$

$$ISP = \frac{SP - SP_{min}}{SP_{max} - SP_{min}}$$

The minimum calculated values deduced from these equations represent the clay content ratio (C. C.) at the corresponding depth.
The laboratory and logs data, for the same depth interval at each well were introduced to the package, where the final equations were estimated. One point to be mentioned here, is that the program neglects all the independent variables when they have a negligible effect on the dependent variables. Also, the program introduces the independent variables in many steps till obtaining the final predictive equation, which will be used to estimate the dependent property in function of the other independent variables. At each step the partial correlation coefficient is calculated and its value is supposed to be increased with introducing a new independent variable. This process is continued till a final predicted equation which relates all the variables is obtained. This is followed by applying the linear regression to the different data sets for each property, for the calculated values (y_i) and the observed values (X_i) measured in laboratory.
Moreover, the percentage of the difference between the observed and calculated values to the observed values are expressed in the following relation:

$$\Delta m = \frac{observed\ value - calculated\ value}{observed\ value} \times 100$$

Decreasing (Δm) value suggest a good approximation till Δm=0 where the best coincidence is obtained.

Results and Discussion

In the present work two groups of samples have been treated: the first represents the formation as a whole whereas the second group concerns the reservoir unit only.
For each group the final predictive equations have been calculated to evaluate the effective porosity, permeability, bulk density, longitudinal

and shear velocities in terms of petrophysical and dynamic properties deduced from well log data at the studied wells. As an example of these computed equations, the predictive equations of well (No.-2) have been listed in table 2. For other wells the multiple correlation values ($\overline{R}$) have been only reported given in table-2. On the other hand, a comparison is made between the calculated values from the equation with the observed (laboratory values). This comparison was made by examining the calculated parameter (Δm) and the simple correlation coefficient (R), where their values are listed in table – 3. Basically, listed decreasing comparison parameter (Δm) and increasing (R) indicate a good estimation of the studied property and suggesting a more confidence of the investigated predictive equation.

Well No-2

Nine available logs (SP, GR, NPHI, RHOB, MSFL, EATT, SON, V_{arm} and C. C.) and (21) plugs representing a thickness of (65.6m) of Khasib Formation were used to estimate the predictive equations for both horizontal and vertical samples .

Examination of these equations of the first group, which are listed in table–2, reveals that ($\overline{R}$) is ranged between (0.58) and (0.80). The equations of (Kv, pora, V_{PV}, V_{SH}, Bda and KH) show good values of ($\overline{R}$ > 0.70), whereas the equations of (V_{Sa}, V_{Pa}, P_{PH}, and V_{SV}) have fair values of ($\overline{R}$ < 0.70). The weakness of ($\overline{R}$) is noticed for equations of the average velocities (V_{Sa} and V_{Pa}), which it is probably due to the effect of layering on these properties.

The comparison parameter (Δm) values, listed in table–3, are ranged between (0 – 2.33)%, which indicate a good estimation of the calculated properties. Hence, it is interesting to use the predictive equations for the Formation as a whole and for the investigated depth interval of the well. The simple correlation coefficients (R) values are generally fair to good except those of (KV) equation where (R) equal to (0.35). This suggests the scattering of data pairs about the mean regression line inspite of the decreasing (Δm) value, where (Δm) equals to (1.28%).

The second group of equations for both vertical and horizontal samples of the reservoir unit are also listed in table–2. It is clearly seen that only four to five variables are included, while the others are automatically neglected by the program because they have no significant effect. The values of ($\overline{R}$) are ranged between (0.987 – 0.999) which indicate high correlation between the dependent and independent properties, and the usefulness of using these predictive equations in the estimation of (V_{Sa}, V_{Pa}, Bda, pora, and K_a) in the studied unit. The values of (Δm) and (R) between the calculated and observed properties, are given in table – 3. For the properties (Pora, Bda, and V_{Sa}) the values of (Δm) are low ranging between (0.0 - 0.68)% and having good to very good correlation.For (V_{Pa}) and (Ka) equations, (Δm) have high values which are consequently (30.4)% and (87.7)% which are supported by very poor values of R ranging between(-0.21) to (-0.02) for (V_{Pa}) and (K_a) respectively.. This may be attributed to the presence of microfactures which cause a significance increment in the permeability and decrement of velocity, while it has a less effect on the other properties.

Well AM-1

The available logs (SP, GR, Son, NPHI, RHOB, SFL, and C. C.), and (45) plugs representing (79.7m) thickness were used to estimate the predictive equations at this well. The multiple correlation coefficient, ($\overline{R}$) of the equations of the first and second groups are reported in table–4.

For the first group of equations, general looking on the ($\overline{R}$) values suggests good to fair correlation where (R) is positive ranging between (0.72 – 0.54) ordered in the following sequence (K, V_P, Por, V_S and Bd). ($\overline{R}$) values of the second group are better, ranging from excellent to good (R = 0.99 - 0.73) arranged according to the following sequence (K, V_S, Por, V_P, Bd).

The parameters (Δm) and (R) values for both groups are listed in table–3. For the first group of equations, (Δm) values ranged between (0 – 2.8)% which considered to be low. The equations of (Bd, V_P, and V_S) have very low values of (Δm) not exceeding (0.14)%, whereas, (Δm=2.8%) for (K & P_r) equations,the values of (R) are ranged between (0.54 – 0.73).

For the second group of equations, (Δm) values are generally less than (1.0)% except that of the (Bd) where (Δm= 12.47%). Also (Bd) equation has a less value of (R=0.50) than others, where it ranges between (0.84 – 1.00) for other equations. Increasing (Δm) and decreasing (R), as in the case of (Bd) equation, suggests a less confidence on the calculated values.

Well AM-2

In the estimation process of the predictive equations, seven logs (SP, GR, Son, NPGI, RHOB, SFL, and EATT) and (81) plugs representing an interval thickness of (77.5m) were taken in account.

The multiple correlation coefficient values ($\overline{R}$) for both groups of equations are reported in table–4. It is clearly indicated that for the equations of the first group, ($\overline{R}$) values range between (0.28 – 0.48) except that of porosity where ($\overline{R}$ =0.65), whereas (R) of the second group is very good equals to (0.79-0.88).

The values of (Δm) and (R) are listed in table–3 where it is clearly shown that for the equations of the first group, (R) values are weak ranging between (-0.06 – 0.33), while (Δm) values are ranged between (1.34 - 13.6%). The equations of the second group indicate moderate to good (R) ranging between (0.6 - 0.8) except that of the permeability where (R=0.002). (Δm) values range between (5.47 – 11.14 %) except that for the permeability where (Δm=43.06 %). This means that the estimated value of the average permeability is weak, whereas the estimation of the other properties is good. This behavior is mostly attributed to the presence of microcracks, which cause a considerable weakness of the estimation.

Well HF-3

Six logs (GR, NPHI, RHOB, SFL, GD, and C. C.) and data of (37) plugs representing an interval thickness of (84m) were used to complete the final predictive equations. Table–4 reveals that for equations of the first group, the values of ($\overline{R}$) are good to very good ranging between (0.67) and (0.87) ranged in the following order (V_S, K, V_P, Bd, Por). Equations of the second group shows that for the properties (V_S & K) the values of ($\overline{R}$) are consequently equals (0.42 & 0.58), whereas for the properties (Por, Bd, and V_P), the values of ($\overline{R}$) are about (0.85).

On the other hand, examination of table–3 indicates that for the simple linear relations considering the calculated and observed properties of the first group of samples, (R) is ranged between (0.59 – 0.86) and (Δm) values are in the range (0.13 – 0.16)%. An exception for this behavior was noted for (K) where (Δm=63 %). The reservoir relations show that the values of (R) are ranged between (0.43 – 0.86). The lowest value of R (=0.43) corresponds to the (V_S) equation in spite of its low (Δm) value which is equal to (0.56 %). For (K) relation, fair values of (R) and (Δm) are noticed (R=0.60, Δm=42.5 %) while good to very good estimation are indicated for the relations (Por, Bd, and V_P) where (R) ranging between(0.76 – 0.86) and (Δm< 0.5%).

Well HU-1

The available logs (MSFL, NPHI, RHOB, Son, SP, GR and C. C.) with the data of (23) samples representing an interval thickness of (67) were used to compute the predictive equations for the properties of both groups of samples (the Formation and the reservoir). Examination of the multiple correlation coefficient ($\overline{R}$) of these equations, which are listed in table–4 shows that ($\overline{R}$) values of the first group are good to very good (0.75 – 0.85) except that for (V_S) where ($\overline{R}$ =0.53). In case of the second group equations, ($\overline{R}$) values are very good to excellent where they are ranging between (0.79 – 0.97) except for the property (Bd) where ($\overline{R}$ = 0.62).

(R) and (Δm) of the simple relations considering the calculated and the observed values, presented in table–3, shows that for the properties of the first group, we have moderate to good (R) values ranging between (0.59) and (0.70), and (Δm) values are ranging between (0.06 - 16)%. Exception for this behavior is noticed for (V_S) relations where a very weak correlation coefficient (R=0.14) in spite of the low (Δm) value which is equal (1.67)% .

For the second group relations very good correlation is indicated for all the properties where (R) values ranging between (0.80 – 0.92) except that of (Bd) relation which has moderate (R) equals to (0.62). The values of (Δm) are very low ranging between (0 - 0.06)% which allows a very good estimation of the studied properties.

For all Wells

In the same manner, as mentioned above, the numerical values of the common logs of Khasib

Formation of the studied five logs have been introduced. These logs are (GR, RHOB, NPHI, SFL and C. C.), with the corresponding properties of (207) samples, were introduced to the program to compute the final predictive equations for all the studied properties. The ($\overline{R}$) of these equations are listed in table–4, which is clearly seen that the correlation is weak for the properties (V_S & K) where ($\overline{R}$) is subsequently equal to (0.45) and (0.34) whereas the correlation is moderate for the properties (V_P, Bd, and Por) where ($\overline{R}$) values are consequently equals to (0.58, 0.60, and 0.66).

The parameters (R) and (Δm) of the simple relations regarding the calculated and the observed properties are tabulated in table–3. It clearly shows moderate and direct proportionality of the properties (Por & K) where R=0.59. For (Bd) relations, moderate (R) equal to (-0.52) is indicated, where the negative sign means an inversed relation. The relations of (V_P) & (V_S) indicate a weak correlation and inversed behavior where (R) values are consequently (-0.21) & (-0.10).

The comparison parameters (Δm) values, for all the properties ranges between (213.4 –1072)% which suggests a weak estimation and hence it is not interesting to calculate the average values..

The departure in (R) and (Δm) values is due to the absence of (SON, SP) logs where they have a major contribution in increasing (R) value. Besides, (GR) logs have wide range between the lowest values (in rocks without clay) and the highest values (in shale layers). Also the salinity of reservoir water has an important effect on the measured electrical log (SFL).

It seems that the using of these predictive equations is generally not interested due to different causes which are:

-The geologic and tectonic setting are different from one well to another which have a great effect on the lithological and physical properties of Khasib Formation. As an example , the wells of Hwaiza field are nearest to the folding zone than other wells located to the West and South-West. This leads to stress the rocks at this field more than other sites .The exerted stress produces microcracks which have an effective influence on the permeability.

-The facies changes have an important effect on the petrophysical & dynamic properties like the presence of clay which reduces the effective porosity and wave velocity.Also the effective porosity has its greater value in the South –West where the facies are located near the shore, and decreases toward the North-East ,whereas bulk density and velocities have reversed behavior.

On the contrary, the using of the predictive equations which are separately deduced from each well is more convenient.

Conclusions

Based on the results and the discussions given in this study the following conclusions can be made:

1. (60) predictive equations have been established relating the petrophysical and dynamic properties for Khasib Formation. These properties were measured from rock cores and from well logs in five oil wells.The predictive equations deduced for reservoir units show very good multiple correlation coefficient ($\overline{R}$) relative to those of the Formation as a whole
2. Another (60) simple equations relating the calculated values deduced from the empirical relations with the observed (laboratory) values have been presented. In general the degree of estimation of the properties is good except that of the permeability where it is greatly influenced by the microcracks. The presence of microcracks in the rock samples have a large effect on the laboratory measured permeability values, while they have a less effect on the resistivity logs which is only sensible to large cracks.
3. The unified predictive equations for all the wells indicate weak to moderate estimation. This is mainly attributed to the facies changes of Khasib Formation where the petrophysical and dynamic properties are varied from one well to other according to its location relative to the shore and basin axis. Moreover the using of a limited number of common logs and the missing of sonic and self potential logs have additional effect on the estimation of these equations.

List of Figures

Table 2: The predictive equations of the petrophysical and dynamic properties of the Khasib Formation and the reservoir units at well (No–2).

Properties	*Predictive equations of the Formation*	$\overline{R}$
KV	3.91-1.02 Varm – 0.002 Sp – 0.01 EATT – 0.03 CC + 0.04 GR – 0.30 Son – 0.36 NPHI – 6.24 RHOB – 0.01 MSFL	0.73
V_{PV}	456.3 – 34.97 CC – 24.15 GR – 111.47 NPHI – 80.04 Son + 183.37 Varm + 2728.26 RHOB + 3.13EATT + 4.7 MSFL – 1.51 Sp	0.77
V_{SV}	2414.7 – 10.32 GR – 2.19 CC - 139.63 Varm + 39.63 NPHI – 27.78 Son – 465.06 RHOB – 2.95 MSFL + 0.025 EATT	0.70
KH	2.47 – 1.52 Varm – 0.01 GR + 0.19 Son – 0.17 NPHI – 0.03 CC + 0.01 MSFL – 0.001 EATT – 1.075 RHOB	0.80
V_{PH}	-24115.3 – 1155.5 Varm + 9872.39 RHOB + 12.17 EATT – 139.63 NPHI + 35.46 MSFL – 31.08 GR – 8.85 Sp – 53.06 Son – 7.24 CC	0.66
V_{SH}	627.2 + 8.78 NPHI – 7.68 GR – 39.44 Varm – 50.58 Son – 9.67 CC + 7.42 MSFL + 1.49 EATT + 1297.22 RHOB – 0.21 Sp	
Pora	124.87 – 1.79 NPHI – 56.31 RHOB – 0.04 EATT + 0.22 GR + 0.92 Son + 0.06 Sp – 2.23 Varm – 0.1 CC	0.76
Bda	5.06 + 0.09 NPHI – 0.07 Son + 0.01 CC + 0.01 MSFL – 0.11 Varm – 0.01 GR + 0.28 RHOB	0.80
Vpa	10138.8 – 4356 MSFL + 1304 Varm + 8324.5 RHOB + 8.49 EATT + 294.14 NPHI – 233.78 Son + 41 CC – 19.41 GR	0.62
Vsa	554.2 + 32.34 CC – 23.95 MSFL – 90.55 Son + 442.37 Varm + 91.07 NPHI + 1707.67 RHOB + 1.29 EATT + 2.92 Sp + 2.37 GR	0.58
Properties	*Predictive equations of the reservoir unit*	$\overline{R}$
Ka	7.44 + 0.002 EATT – 2.65 Varm – 0.01 Sp – 0.13 RHOB	0.999
Pora	96.70 – 12.19 RHOB + 14.28 Varm – 1.35 Son	0.998
Bda	11.69 + 0.14 NPHI + 0.01 MSFL + 0.01 Sp – 0.17 Son	0.992
Vpa	-2812.44 – 14.44 RHOB – 317.64 Varm + 1.83 EATT + 41.33	0.996
Vsa	-48.2 + 8.01 Sp + 10.34 NPHI + 665.01 Varm + .027 EATT	0.987

Table3: The statistical parameter values for the equations relating the calculated & the observed values of the petrophysical & dynamic properties of Khasib Formation & its reservoir unit.

Well No.	First group (Formation)					Second group (reservoir)				
	Properties	m_{obs}	m_{cal}	Δm%	R	Properties	m_{obs}	m_{cal}	Δm%	R
NO-2	Kv	0.62	0.61	1.28	0.35	Ka	0.77	1.45	87.7	-0.02
	Vpv	3402	3397	0.15	0.78	Pora	18.53	18.53	0.0	0.889
	Vsv	1606	1606	0.0	0.70	Bda	2.20	2.19	0.18	0.903
	KH	0.56	0.54	2.33	0.78	Vpa	3015	2097	30.4	-0.213
	V_{PH}	2983	2983	0.0	0.62	Vsa	1556	1449	6.8	-0.506
	V_{SH}	1356	1366	0.73	0.59					
	Pora	14.9	15.10	1.27	0.75					
	Bda	2.33	2.30	1.21	0.72					
AM-1	K	6.8	6.99	2.79	0.73	K	26.56	26.82	0.97	0.999
	Por	16.69	17.17	2.8	0.55	Por	20.42	20.49	0.36	0.921
	Bd	2.25	2.25	0.0	0.54	Bd	2.20	2.48	12.47	0.498
	Vp	4188	4190	0.05	0.683	Vp	3816	3810	0.157	0.836
	Vs	1948	1945	0.14	0.552	Vs	1817	1818	0.055	0.964
AM-2	K	0.47	0.52	11.7	0.33	K	16	9.11	43.06	-0.002
	Por	17.4	15	13.6	0.21	Por	15.97	14.19	11.14	0.597
	Bd	2.32	2.37	2.24	0.18	Bd	2.26	2.30	1.63	0.613
	Vp	4739	4836	2.04	-0.06	Vp	4568	4627	1.29	0.796
	Vs	2224	2254	1.34	-0.01	Vs	2009	2118	5.47	0.658
HF-3	K	25.8	9.54	63	0.701	K	17.15	9.85	42.5	0.596
	Por	18.86	18.67	1.0	0.859	Por	20.46	20.53	0.34	0.863
	Bd	2.2	2.19	0.13	0.845	Bd	2.14	2.15	0.46	0.700
	Vp	4246	4178	1.6	0.764	Vp	3968	3952	0.40	0.834
	Vs	1876	1870	0.31	0.591	Vs	1778	1768	0.56	0.434
Hu-1	K	0.53	0.62	16	0.588	K	1.28	1.28	0.0	0.853
	Por	7.49	8.34	11.3	0.602	Por	14.64	14.64	0.0	0.917
	Bd	2.56	2.73	6.68	0.700	Bd	2.33	2.33	0.0	0.623
	Vp	5232	5235	0.06	0.588	Vp	4742	4739	0.06	0.881
	Vs	2685	2640	1.67	0.144	Vs	2316	2315	0.04	0.802
All wells	K	15.03	176.2	-1072	0.588					
	Por	18.82	58.99	-213.4	0.59					
	Bd	2.20	7.87	-258	-0.516					
	Vp	3947	14673	-2717	-0.206					
	Vs	2147	8205	-282.1	-0.092					

Table 4: The multiple correlation values ($\overline{R}$) of the predictive equations relating the petrophysical and dynamic properties for Khasib Formation and its reservoir units.

Well	available logs	($\overline{R}$) for the first group					($\overline{R}$) for the second group				
		K	Por	Bd	Vp	Vs	K	Por	Bd	Vp	Vs
AM-1	Sp, GR, Son, NPHI, RHOB, SFL & CC.	0.722	0.658	0.540	0.687	0.544	0.999	0.924	0.731	0.838	0.964
AM-2	Sp, GR, Son, NPHI, RHOB, SFL & EATT.	0.476	0.650	0.344	0.385	0.277	0.843	0.874	0.883	0.850	0.788
HF-3	GR, NPHI, RHOB, SFL, GD, & CC.	0.734	0.866	0.850	0.780	0.665	0.583	0.839	0.842	0.842	0.419
Hu-1	MSFL, NFHI, RHOB, Son, Sp, GR, & CC.	0.854	0.863	0.795	0.753	0.529	0.971	0.917	0.623	0.868	0.792
All wells	GR, RHOB, NPHI, SFL, & CC.	0.343	0.659	0.597	0.580	0454					

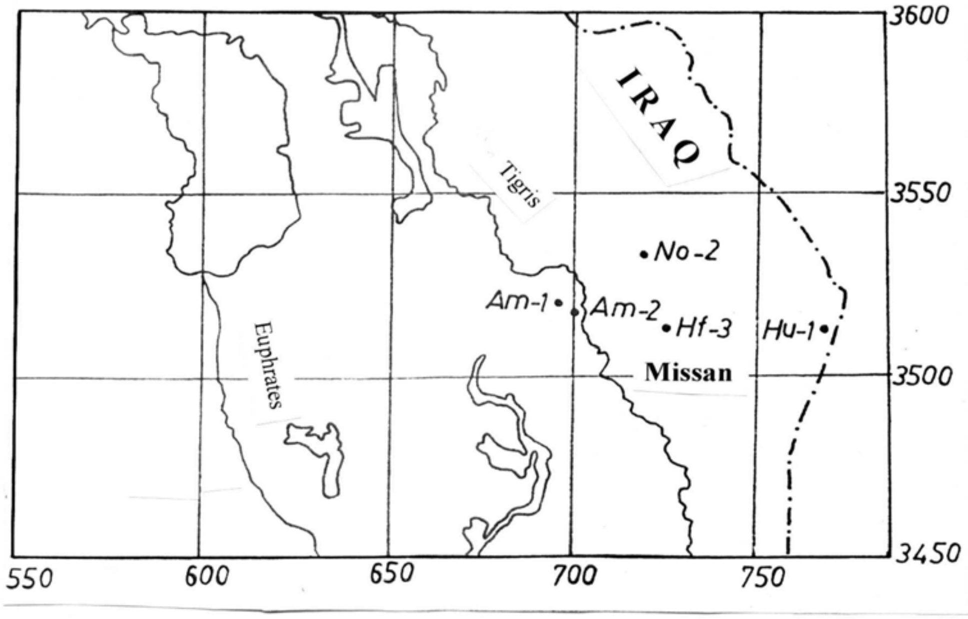

Fig-1 : Location map of the studied wells.

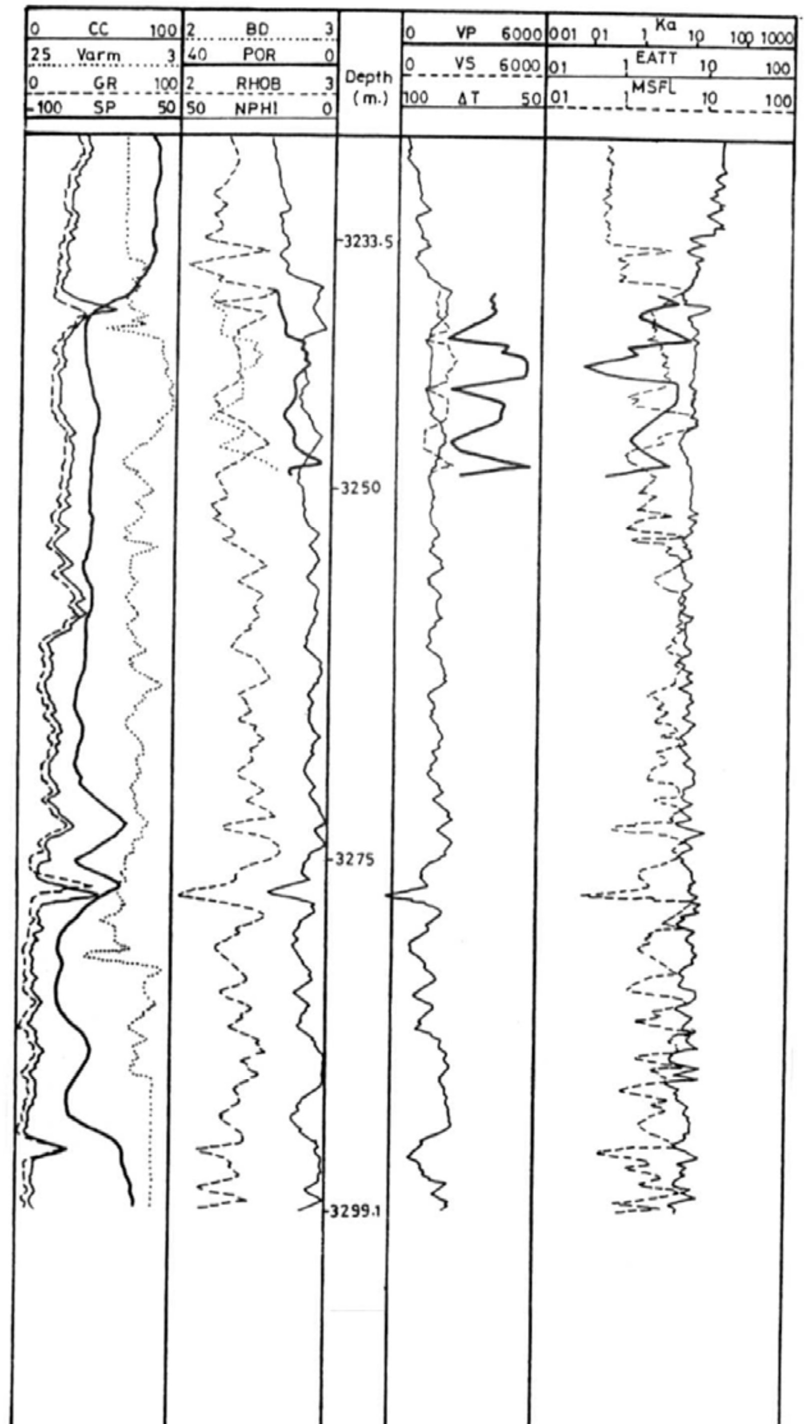

Fig-2 : Plots of the recorded well logs , and laboratory data of the petrophysical and dynamic properties of Khasib Formation at Well (NO-2)

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