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Reservior Characterization of The Hartha Formation, Southern Iraq

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Abstract:
Well log analysis of selected sections in southern Iraq revealed that primary porosity is the most effective parameters. Secondary porosity seems to be related mainly to dissolution and dolomatization. The Hartha Formation has good water saturation and low production except in the eastern and central part of the study area. Two reservoir units were recognized in Mj-2 whereas only one in Ga-1.

The values of velocity deviation in most wells show high positive deviation, this may indicate relatively high velocity in regard to porosity where pores are commonly not connected such as in interaparticle or moldic porosity. A positive deviation also may indicate low permeability. Negative deviation zone (Only in Ak-1) may represent caving or irregularities of the borehole wall despite the fact that fracture porosity has always been included in the secondary porosity.

The primary porosity of the upper reservoir unit shows a clear increase to the southeast mainly towards the deep outer ramp area where deep and baisnal facies dominated. It is located within the Highstands Systems Tract (HST) where the effect of mixing dolomitization is present. The effective porosity values show little variation in the whole study area with a clear increase eastward.

Keywords: Reservior characterization, Hartha Formation, Southern Iraq

الصفات المكمنية لتكوين الهارثة جنوب العراق

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الخلاصة :
يعتبر تحليل المجسات هو الاكثر فعالية في تحديد المسامية الاولية والثانوية وكذلك ارتباطهما وعلاقتهما بالعمليات التحويرية كالإذابة والدلمته. يعتبر تكوين الهارثة مكمن مائي وبإنتاجية قليلة ما عدا في مناطق جنوب ووسط منطقة الدراسة، حيث تم تحديد وحدتين مكمنيتين في بئر مجنون2 وواحدة اخرى في بئر غراف 1. كانت قيم السرعة الانحرافية لمعظم الابار ذات قيم موجبة وهذا يعطي مؤشر بان المسامات غير متصلة مع بعضها (مسامية بينية او قالبية). وهذه القيم الموجبة تشير الى النفاذية القليلة للتكوين في منطقة الدراسة ، اما القيم السالبة كما في بئر ابو خيمة 1 تشير الى مسامية تكهفية او وجود تكسرات في التكوين وهذا يشير الى وجود مسامية ثانوية. المسامية الاولية في الوحدة المكمنية العليا للتكوين تبين الزيادة الملحوظة في المسامية باتجاه الجنوب الشرقي حيث هنالك سيادة للسحنات العميقة، قيم المسامية المؤثرة في منطقة الدراسة ذات تباين بسيط مع زيادة باتجاه شرق منطقة الدراسة.

Introduction:

The Hartha Formation (Late Campanian-Early Maastrichtian) is an important Upper Cretaceous formation in Iraq due to its reservoir characteristics making it a good reservoir in central and southern parts of the country.

The Hartha Formation was defined by Rabanit in 1952 from well Zubair-3 in the Mesopotamian Zone of South Iraq [1].

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The upper contact of the Hartha Formation with the Shiranish Formation is conformable. The lower contact of the formation is unconformable with the Sa'adi Formation and is often marked by conglomeritic basal beds [2].

The aim of this study is to use well log data to identify the distribution of porosity and fluid saturation, classifying types of porosity visually and by well logs , log interpretation and assessment of reservoir fluid saturation including water saturation (Sw) and hydrocarbon saturation (Sh) of selected wells Figure-1.

Porosity and water saturation are among the important parameters used to evaluate reservoir quality. The volume and distribution of pores control both parameters. Various logs can be used to calculate porosity and water saturation, and to determine reservoir compartmentalization. In this study, self Potential, gamma ray, resistivity and porosity logs were used to evaluate these parameters.

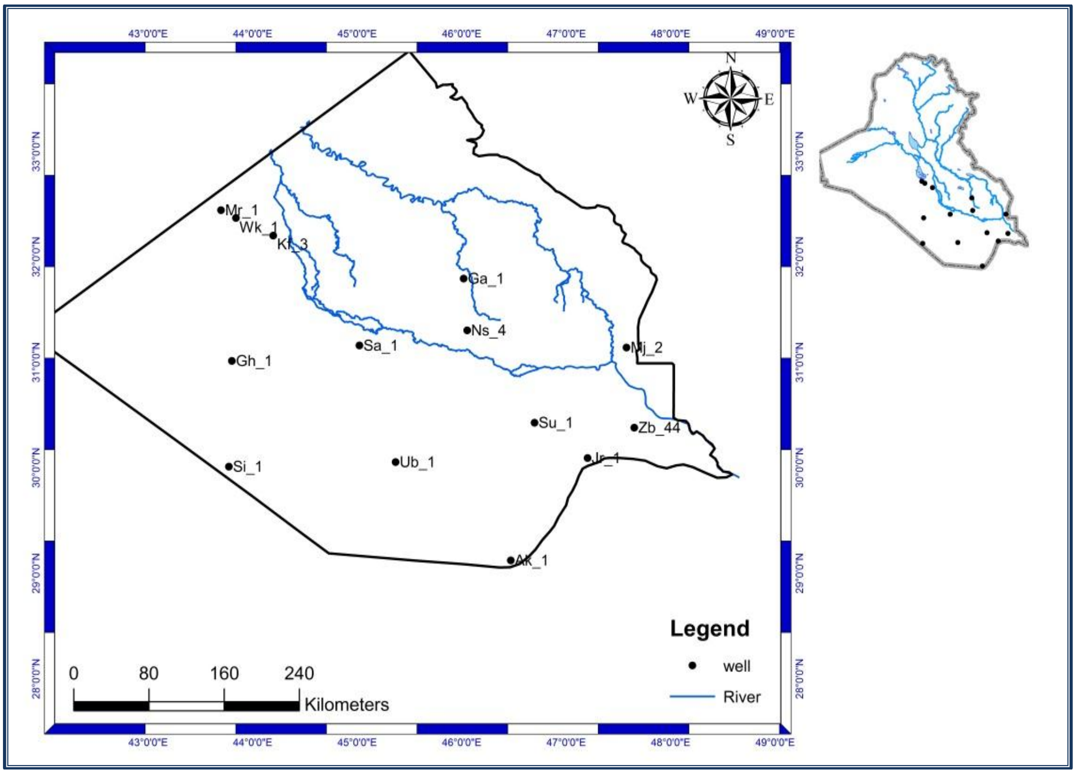

Figure 1- Location map of the study area

Well Log applications:

The interpretation of well logs was carried out through direct reading as well as through established relationships and profiles of different log parameters in order to find the important lithological and petrophysical properties.

1- Effective and Secondary Porosity:

The effective porosity is the ratio of interconnected pore space to the total bulk volume of the rock. [3]. It is computed by : Schlumberger's (1997) formula:

$$\phi_{N.D} = \frac{(\phi_D - \phi_N)}{2}$$

$\phi_{N.D}$ = *Effective porosity.*

ϕ_D = *Density porosity*

ϕ_N = *Neutron porosity.*

$$SPI = (\phi_{N.D} - \phi_{sonic})$$ by [4]

SPI = *Secondary porosity Index*

ϕ_{sonic} = *Primary porosity by sonic log*

Table 1-Range and arithmetic means of effective porosity in the studied wells

Well No.	Range	Arithmetic mean
Ak-1	0.01-0.356	0.183
Ub-1	0-0.357	0.178
Si-1	0-0.28	0.14
Jr-1	0-0.36	0.18
Ga-1	0.052-0.305	0.178
Su-1	0-0.33	0.165
Zb-44	0.011-0.272	0.141
Lu-5	0.003-0.44	0.221
Kf-3	0-0.24	0.12
Wk-1	0.012-0.295	0.153
Mr-1	0-0.38	0.19
Mj-2	0.046-0.609	0.350

The values of effective porosity (Tables 5-1) are good in most boreholes, but the effective porosity values are relatively higher than Secondary porosity, this due to the effect of digenesis.

2. Water and hydrocarbon Saturation.

In formations containing oil, gas, and water which are electrical factor (F) and Resistivity of water formation (R_W), but also the water Saturation (S_w). The Water Saturation (S_w) is the fraction of the pore volume.

Table 2- Range and arithmetic means of secondary porosity index in Ga-1 and Mr-1 wells.

Well No.	Range	Arithmetic mean
Ga-1	0-0.109	0.054
Mr-1	0-0.606	0.303

Hydrocarbon saturartion (1 – S_w) is the fraction of the pore Volume occupied by hydrocarbon. [5]. The S_w is computing by

$$S_w = \left(F.R_w / R_t\right)^{1/n}$$

$$S_{xo}\left(F.Rmf / Rxo\right)^{1/n}$$

S_w = Water Saturation from uninvaded zone
S_{xo}= Water Saturation from flushed zone
F = Formation factor
R_w = Resistivity of Uninvaded zone (Ω m)
R_t = true Resistivity by log (Ω m)
R_{mf} = Resistivity of Mud filtrate (Ωm)
R_{xo} = Resistivity of flushed zone (Ωm)
n = saturation factor (for limestone=1)

3. Volume of Shale (V shale):

The volume of shale is very important on water saturation, but it must be greater than 10-15% [6].
The Gamma ray index IGR is computed by :-

$$IGR = \frac{(GR\log - GR\min)}{(GR\max - GR\min)}$$ (Shlumberger, 1978)

I GR = Gamma ray index
GR log = Gamma ray recorded by log (API)
GR max = Maximum value of Gamma ray .

GR min = Minimum value of Gamma ray .
The Volume of shale (V. shale) computed by :-
$V_{sh} = 0.33 (2^{(2 \times IGR)} - 1)$ [8]
Figure-2 shows the relation of V shale with the depth.

4. Velocity deviation Logs:

The velocity deviation logs which are calculated by combining the sonic log with the neutron porosity or density logs. provide a tool to obtain down hole in formation on the predominant pore type.

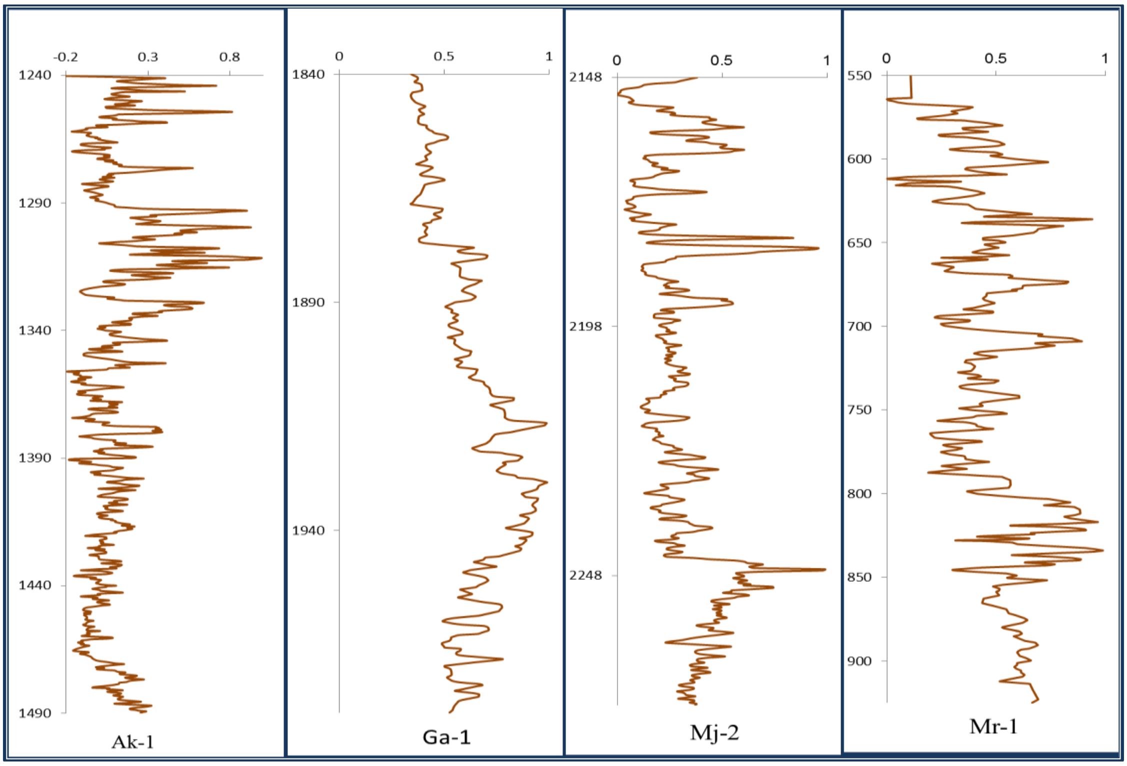

Figure 2- Relationship between volume of shale and depth for Ak-1, Ga-1, Mj-2, and Mr-1

Carbonates. The log can be used to trace the down hole distribution of diagenetic processes and estimate trends in permeability [9].

$$\frac{1}{V_{Rock}} = \frac{1-\phi}{V_{Matrix}} + \frac{\phi}{V_{Fluid}} \quad [10]$$

ϕ = porosity (Neuron , density)
V_{matrix} = 6530 m/s (Velocity deviation of calcite)
V_{fluid} = 1500 m/s (Velocity deviation of fluid (water)
Velocity deviation = Sonic log velocity (1.000.000/ Δt) – velocity calculated by Neutron or density porosity
$VD\phi n$ = *velocity deviation of neuron porosity*
$VD\phi D$ = *velocity deviation of density porosity*

Figures -3, 4, 5 explain neutron porosity and velocity deviation by porosity and velocity of sonic from borehole are studied.

1. The values of velocity deviation in most wells show high positive deviation Figure-3, the positive deviation indicates relatively high velocity in regard to porosity where the pores commonly are not connected such as in interafossils or moldic porosity. A positive deviation also may indicate low permeability[9].
2. Zone with ± zero deviation.
   Zero with small deviation (± 500 m/s) or less represent section that follow the predications by the time average equation, there zone are dominated be either interparticle, intercrystalline or high micro porosity. Figure-4. All these pore types are particularly predominate in dolomite just after

deposition. Most of the zone is with small velocity deviation; thus indicate zones with little diagenetic alterations [9].

3. Zone with Negative Deviation

There are two possiblilities of the Negative Deviation zone.

a. Caving or irregularities of the borehole wall.

b. Despite the fact that fracture porosity has always been included in secondary porosity Figure-5.

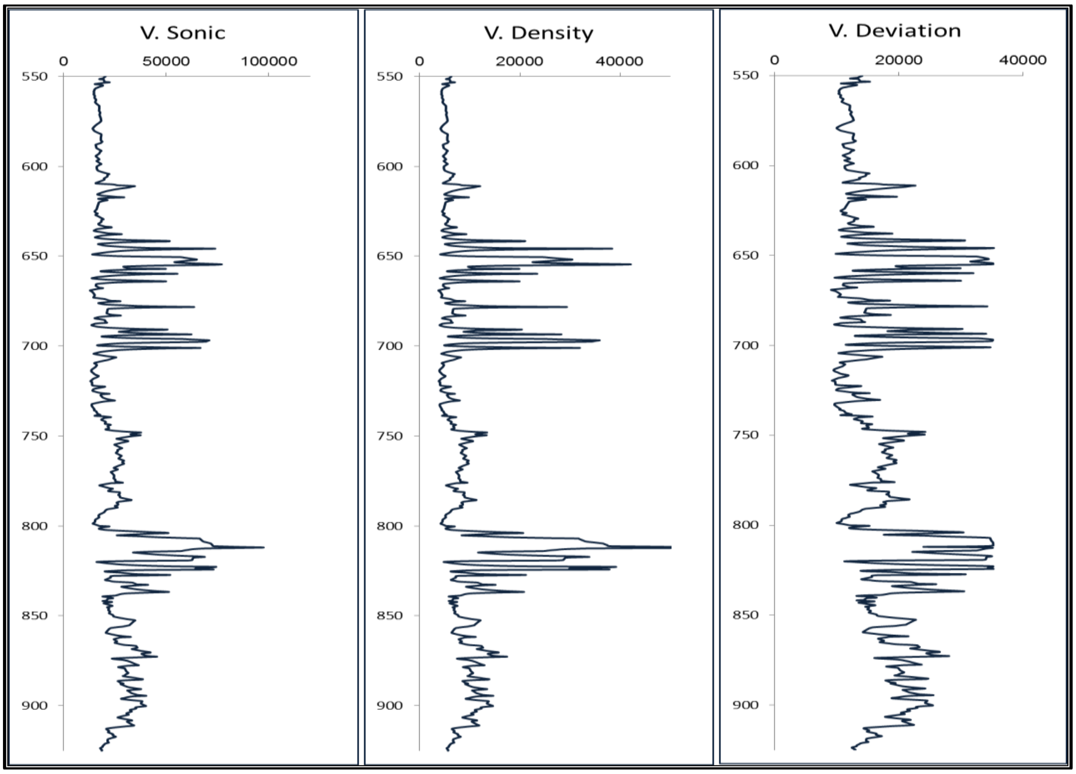

Figure 3- Velocity Deviation for Mr-1.

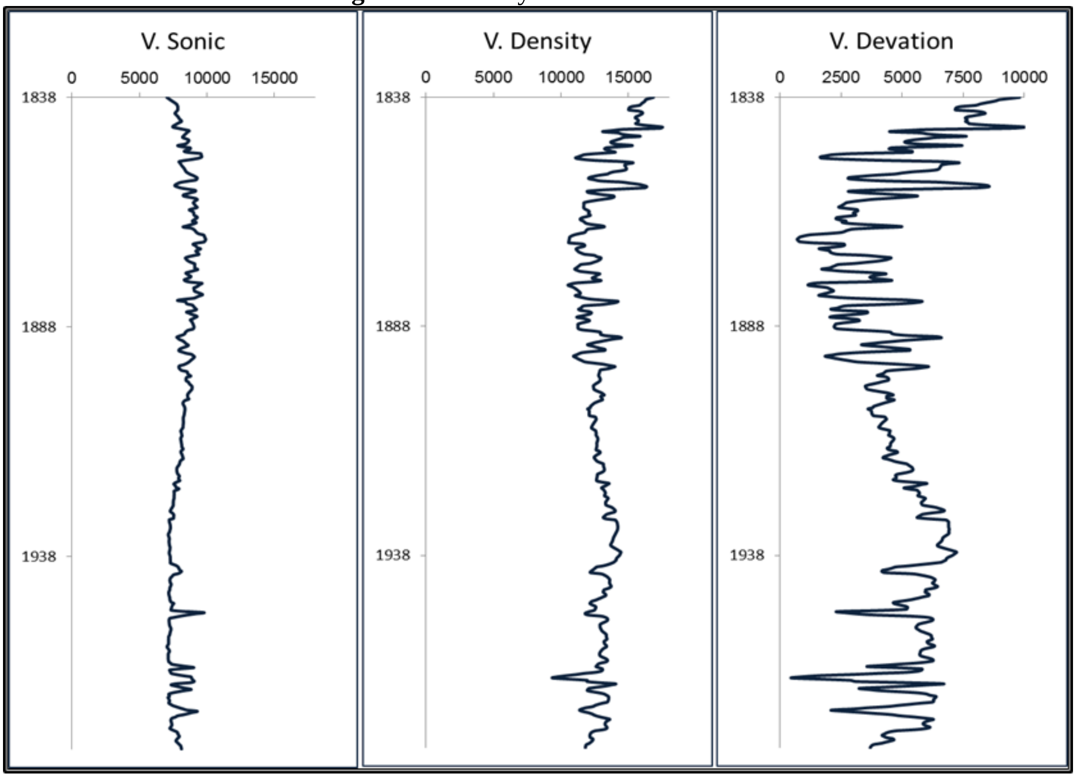

Figure 4- Velocity Deviation from Ga-1. well.

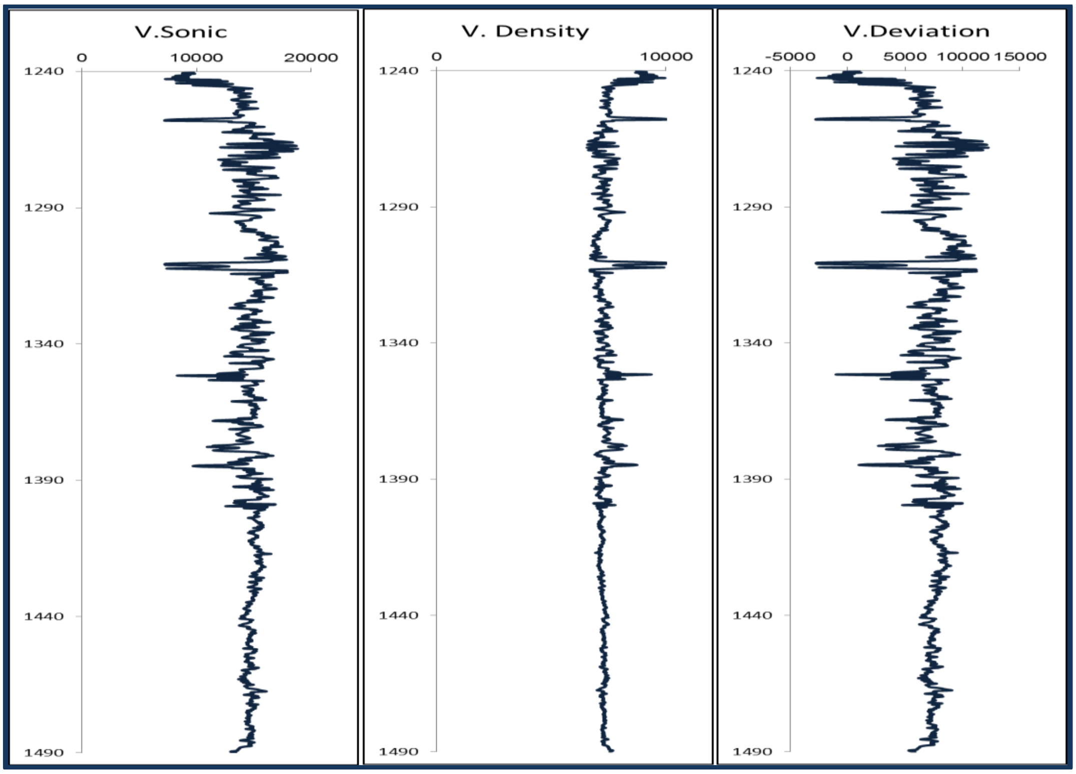

Figure 5- Velocity Deviation for Ak-1.

5. Neutron- Gamma ray cross plot

This plot used Gamma ray log with API units on the X-axis and the neutron porosity in Y-axis (normal scale), in this study this plot was used to estimate or explain the relation between the water saturation, porosity and the production potential in some wells study (Ga-1 , Ak-1 and Kf-3), Figure-6,7 and 8 show the low porosity, low production potential and high water saturation in most points in selected wells.

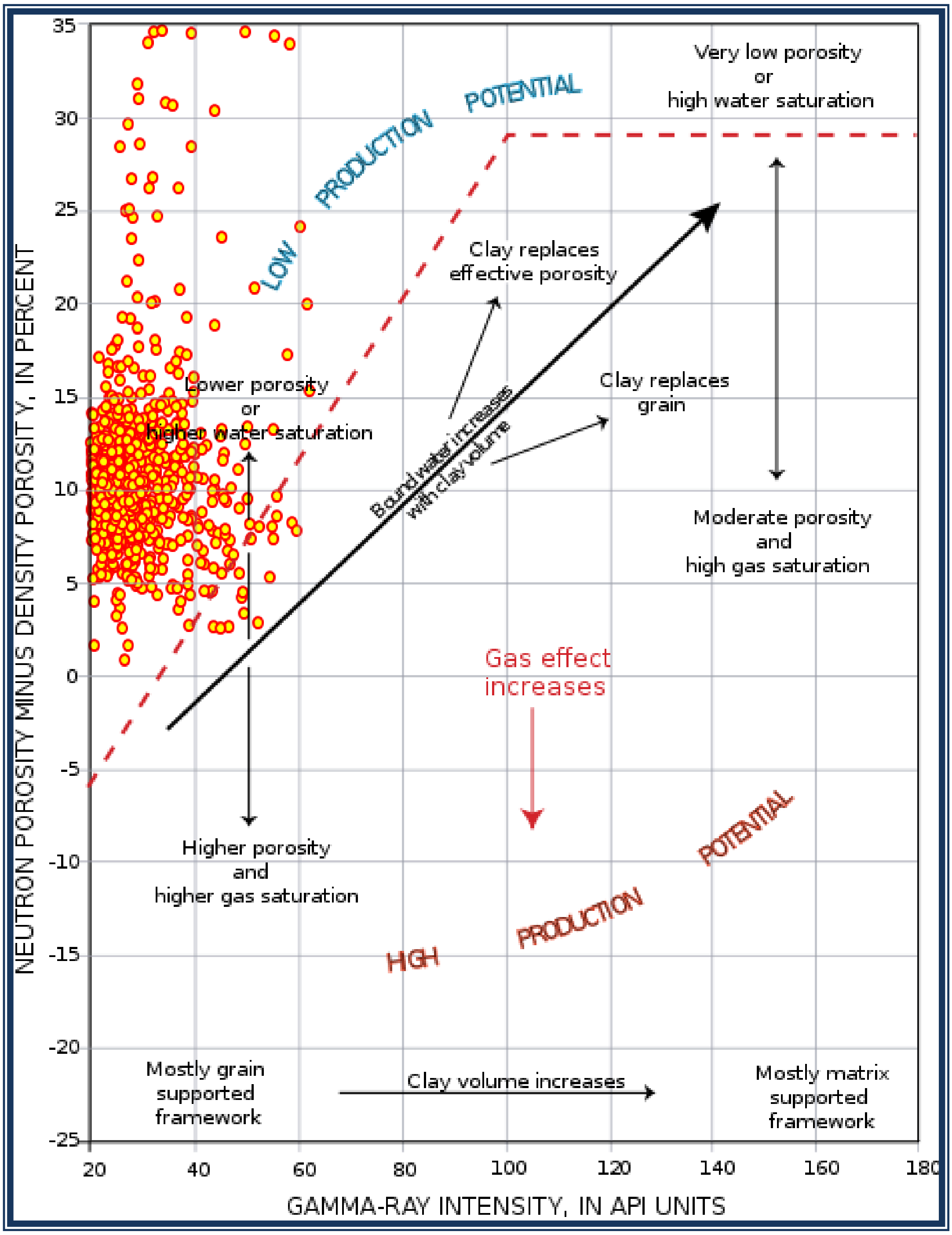

Figure 6- Neutron-Gamma Ray plot for Ga-1

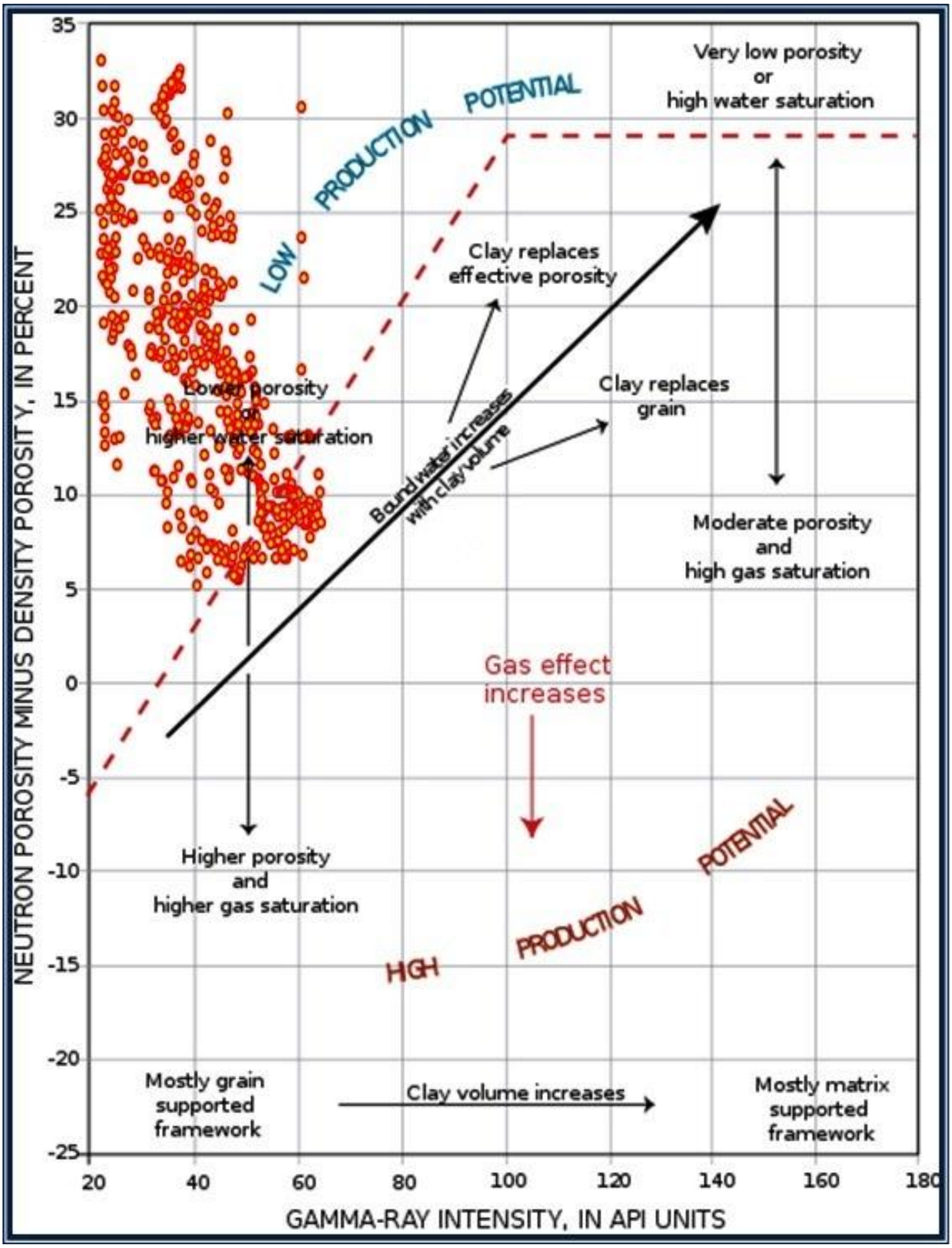

Figure 7- Neutron-Gamma Ray plot for Ak-1

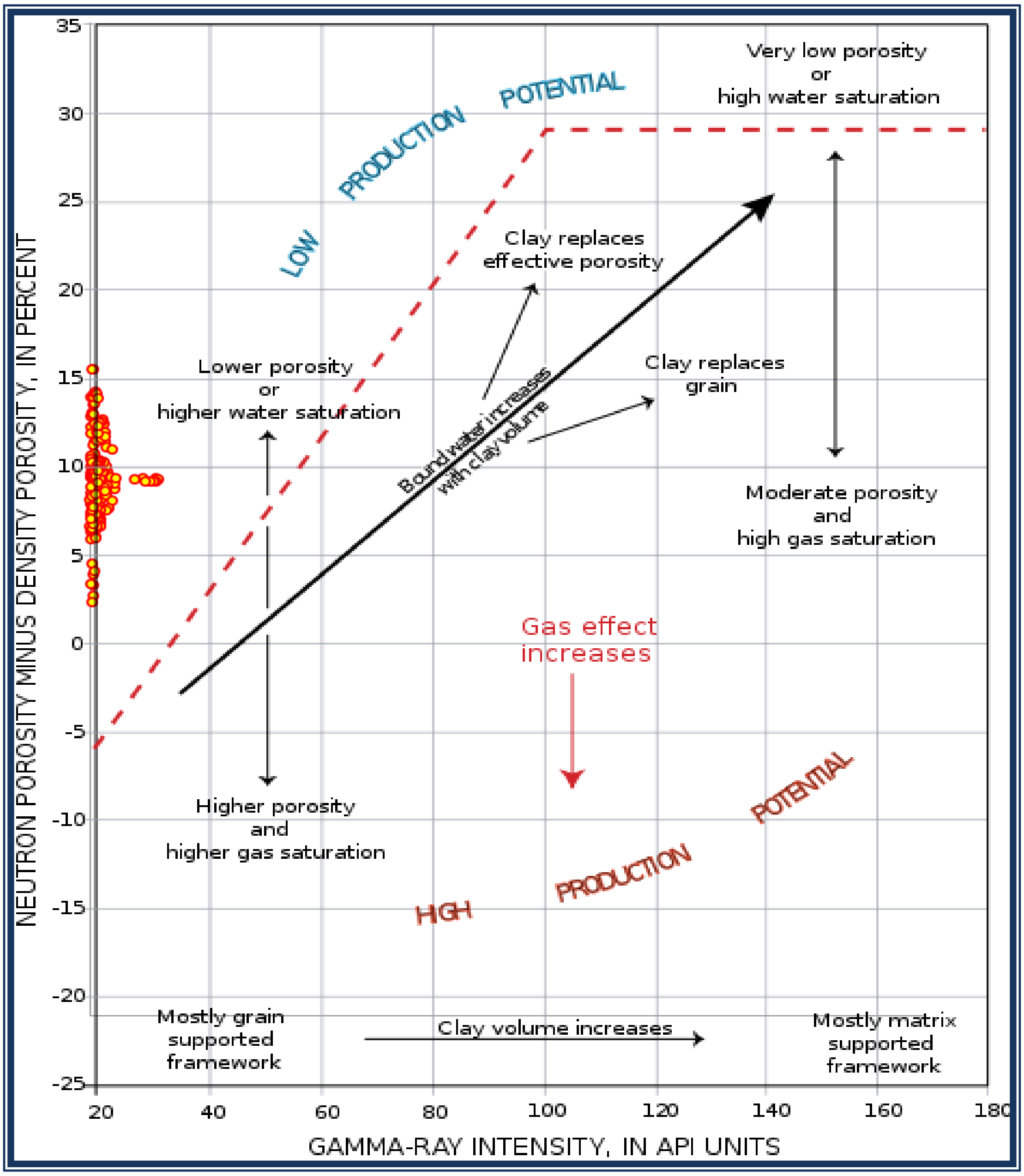

Figure 8- Neutron-Gamma Ray plot from Well Kf-3.

6. Pickett Cross plot Methods:

The pickett plot is one of the most effective methods to estimate water saturation and we can used it to determine formation water (Rw),Cementation factor (m) and Matrix parameters for sonic and density logs (Asquith and Kryqowski, 2004).

This cross plot used the Rt on the X-axis (logarithmic scale) against density porosity (φ) on the Y-axis (on logarithmic scale), in this study the packet plotting was used to estimate or to get a clear idea about saturation of some wells that is lack of sufficient information from the log Figures-9,10.

The Pickett plot is a mixture of water bearing and hydrocarbon points:

1. Water bearing points of different porosities plot along a straight line of water saturation line Figure-9.
2. Hydrocarbon bearing points lie away from the line moved horizontally to the right from water bearing line by increasing resistivity Figure-10 (Asquith and Kryqowski,2004).
3. In some wells we noticed that the points are irregular and condense within the region of high-resistivity due to diffraction in lithology or diagenesis processes.

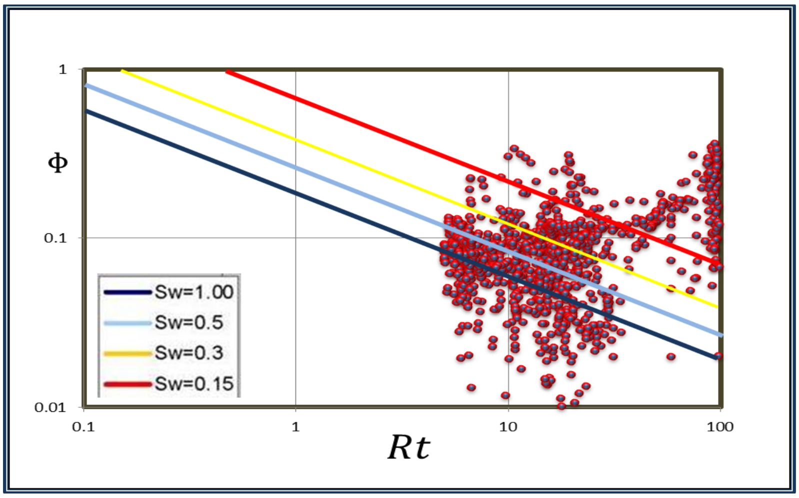

Figure 9- Pickett plot for Ub-1.

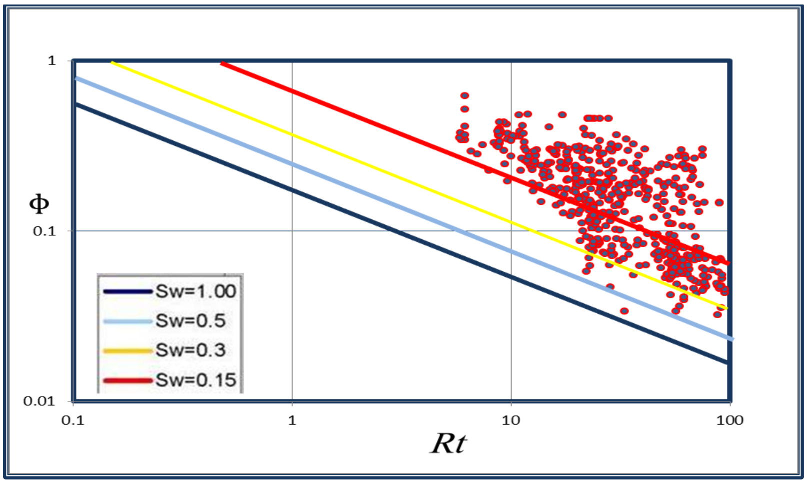

Figure 10- Pickett plot for Mj-2.

Reservoir units:

By study and intepretation of well log reservoir units of the Hartha formation can be recognized as in Table-3 and Figure-11,12.

Table 3- Reservoir Units of the Studied wells.

No.	Well ID.	Unit-1 Interval m	Unit-2 Interval m	Unit-3 Interval m
1	Jr-1	1654-1665	1670-1683	1765-1785
2	Si-1	630-639	671-683	721-739
3	Ak-1	1240-1290	1390-1435	-
4	Ub-1	960-1130	-	-
5	Gh-1	631-688	697-763	-
6	Mj-2	2149-2203	2217-2244	-
7	Mr-1	554-648	658-673	700-739
8	Kf-3	860-930	-	-
9	Wk-1	753-765	-	-
10	Ns-5	1471-1498	1515-1525	1568-1583
11	Ga-1	1838-1906	-	-
12	Zb-44	1706-1750	-	-
13	Lu-5	1478.5-1625	-	-
14	Su-1	1650-1725	-	-
15	Sa-1	936-1005	1035-1155	-

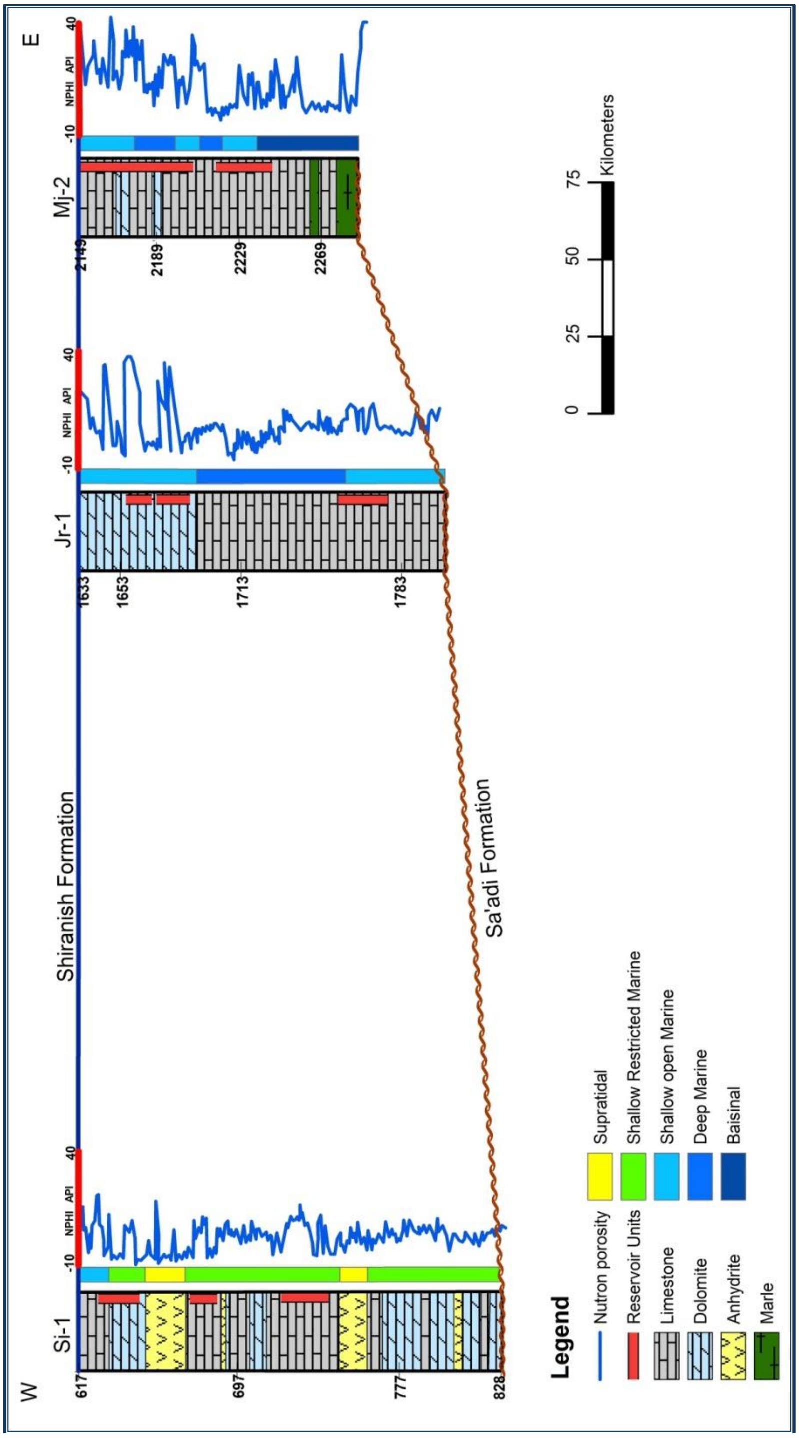

Figure 11- E-W Cross section showing distribution of reservoir units in the study area

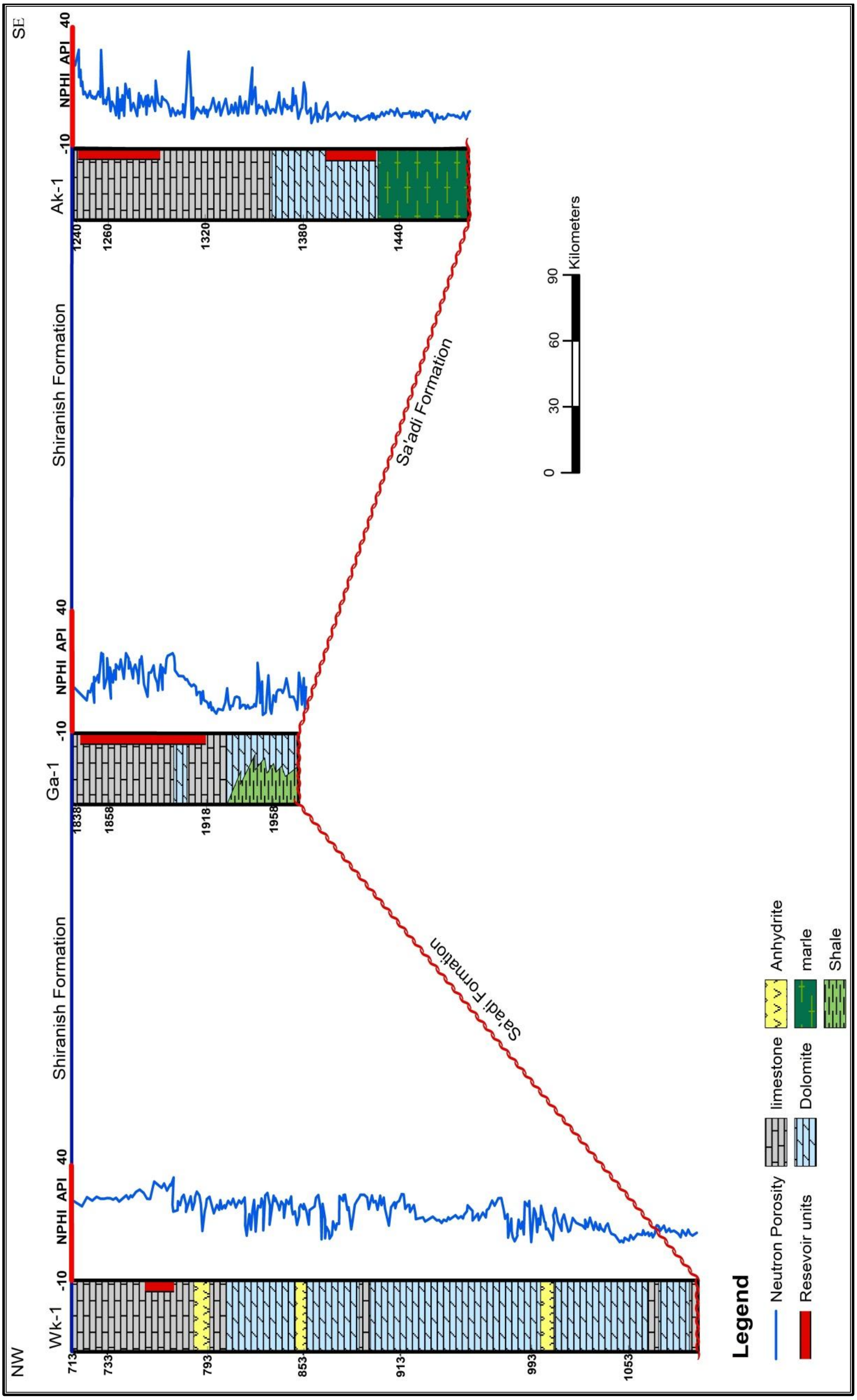

Figure 12- NW-SE Cross section showing distribution of reservoir units in the study area

The available data enabled mapping porosity of the upper reservoir unit Figure-13 the arid distribution of primary porosity of this unit shows a clear increase to the south east mainly towards the deep outer ramp area where deep and baisnal facies dominated.

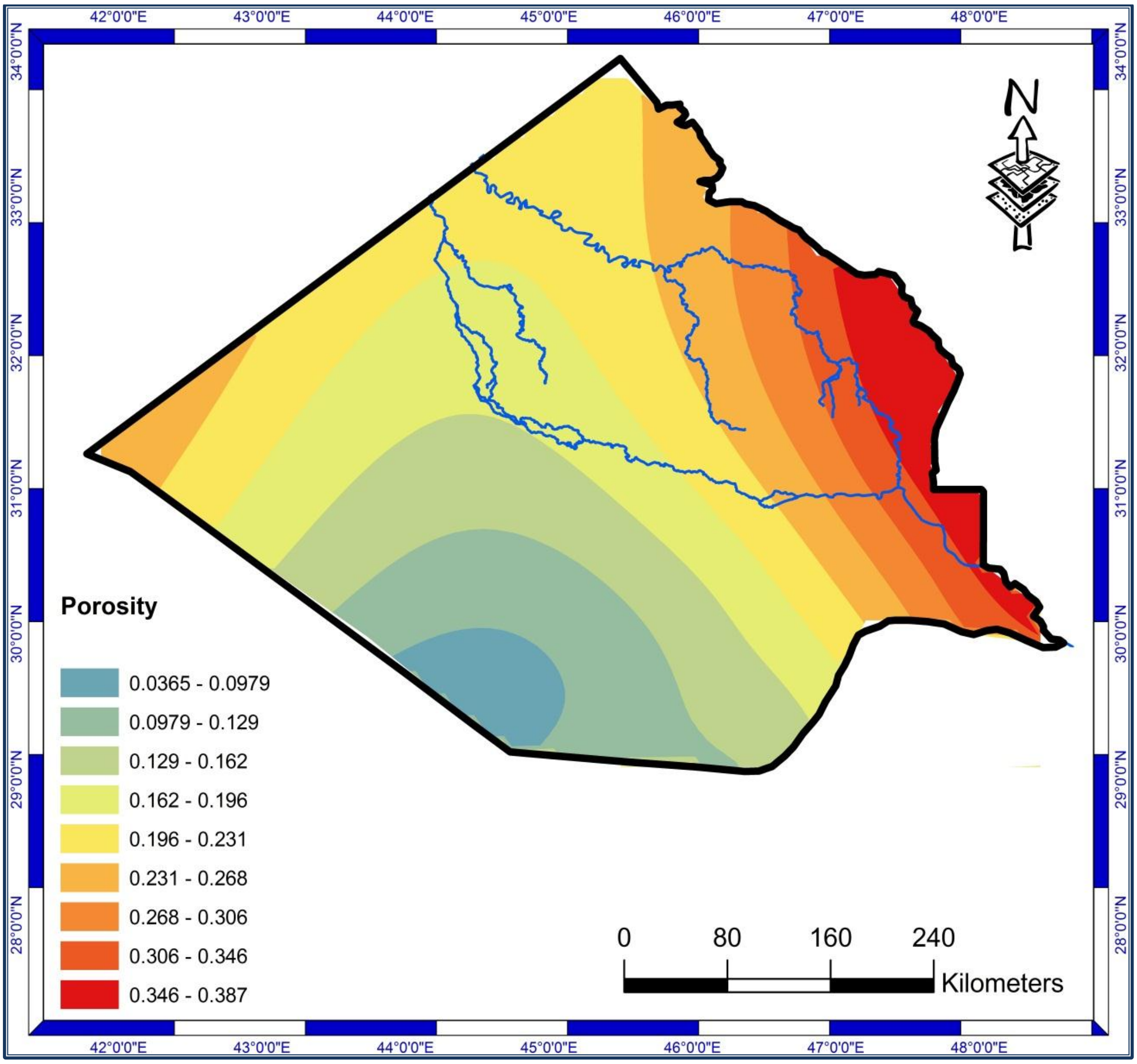

Figure 13- Primary porosity distribution of the upper reservoir unit of the Hartha Formation in the studied area

Conclusions:

The effective porosity values show little variation in the whole study area with a clear increase eastward (At Mj-2). The water and hydrocarbon saturations of the Hartha Formation in most wells were detrmined by calculation methods or by Cross plots (pikett and GR-N). It shows that the Hartha Formation has a good water saturation and low production in the study area except in the eastern and central part (Mj-2 and Ga-1), two reservoir units were recognized in Mj-2 whereas only one in Ga-1 . The volume of shale was calculated for four wells and it is less than 10%, the volume of shale is of a very important factor that effects on water saturation but it must be greater than 10-15%. The values of velocity deviation in most wells show high positive deviation, the positive deviation indicates relatively high velocity in regard to porosity where the pores commonly are not connected such as in intera- particel or moldic porosity. A positive deviation may also indicate low permeability. Negative deviation's zone (Only in Ak-1) may represent caving or irregularities of the borehole wall despite the fact that fracture porosity has always been included in the secondary porosity.

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