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Investigation of Sedimentary Environment Changing Effects on Sarvak Formation Facies from the viewpoint of Petrophysics in two Subsurface Sections of Tang-e-Bijar Region (Well Nos. 6 and 7)

Faranak Dalvand and Mir Reza Moussavi

Shahid Beheshti University, Tehran, Iran

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ABSTRACT

Three sections of Sarvak formation in Tang-E- Bijar and Siyahkuh in Ilam province were selected and investigated in order to perform geological studies. Two subsurface sections and a surface section were selected to study the Sarvak formation. Therefore, this research includes two steps. One field study and another is laboratory study. The reservoir properties of Sarvak Formation in different zones were analyzed by investigating the well logging (gamma ray log, sonic log, density log, neutron log and cross-plots of different log combinations). These results were corresponded with the results of drilled cores and cuttings evaluation. According to these results, it can be said that the high reservoir properties in some zones is due to the big channel porosities, fractures and sometimes dolomitization (especially in 3 and 4 zones of well number 6). In addition, it can be said that in under study wells, the changing process of stone saturation from hydro-carbon trends to the changing of porosity; so that the percent of hydro carbon saturation was higher than water in depths with higher porosity and lower Shale volume.
KEYWORDS: Reservoir Properties, Well logging, Cross Plots, Porosity, Hydrocarbon Saturation, Shale Volume

INTRODUCTION

Cretaceous system is one of the most important systems in geology history of Zagros folded region, because it provides desirable condition to create reservoir properties of formations and trapping oil. Hence, the Banqestan group creators (from lower Cretaceous to upper Cretaceous) in Zagros Mountains are important to study in economical point of view because of high hydro-carbon potentials. Among them, the Sarvak Limestone's formation of (Albian-Turonian) middle cretaceous in the role of reservoir rock and as an important Lithostratigraphic unit of Zagros has been paid much attention by internal and foreign geologist for long years (Motiei, 1995). Since the analysis of log is very important in relation to subsurface operations in order to identify physical properties of stones such as Lithology, porosity, permeability, depth and thickness of layers, estimation of hydro-carbon amount of reservoir and identifying exploitable stone horizons, so in this study the above matter was investigated by studying two subsurface sections (wells number 6 and 7) of Sarvak Formation in Tang-e–Bijar Gas field with the help of petrographic studies as well as log diagrams; first we investigated lithology and diversity of facies and then we went through reservoir characteristics of Sarvak Formation in the two mentioned subsurface sections.

The geographical location of under study region

Three sections of Sarvak Formation in Tang-e–Bijar and Siyahkuh of Ilam province were selected and investigated in order to perform geological studies. These three sections were included: two subsurface sections in wells number 6 with geographical location of 33˚ 41'57.5" Longitude and 45˚58'2.7" latitude and well No. 7 with geographical location of 47˚57'10.27" latitude and 33˚39' 32.74" (in Tang-e-Bijar gas field) and a surface section in Siyahkuh with geographical location of 33˚45' 28" longitude and 46˚1' 42" latitude (Figure1). The well number 6 is located in Kamankuh anticline and well number 7 is located in Tang-e-Bijar anticline.

Corresponding author: Faranak Dalvand, Shahid Beheshti University, Tehran, Iran; Email: Dalvand@ppars.com

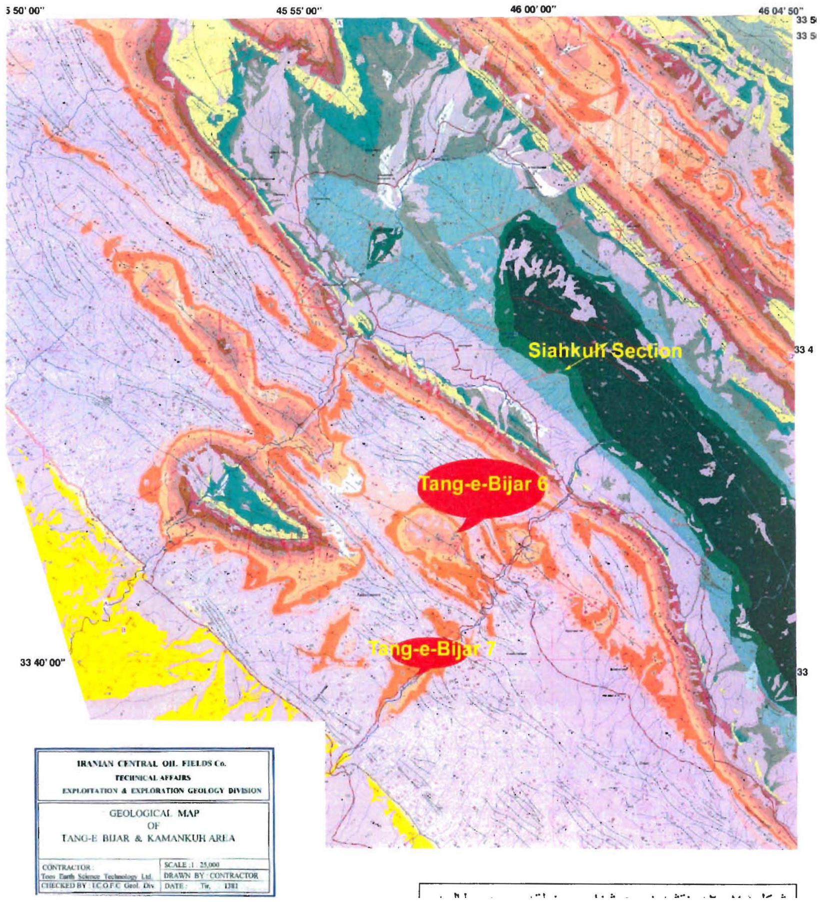

Figure 1. Geological map of the region

The background of previous studies on the region

- Wood and Lacassange [1] have investigated the facies and depositional environment of Sarvak and Elam formations in the region of Fars, Khuzestan and Lorestan.
- James and Wynd [2] performed studies about Biostratigraphy of Bangestan formations including Sarvak and Elam and classified them with several Bio-Zens.
- Adams et al. [3] performed studies about Oligostegina of Bangestan Group especially Sarvak in Lorestan province and identified a number of bio-zones and zero-zones based on this fossil species.
- Setudenia [4] studied the Palaeogeography and Lithostratigraphy of Bangestan Group and compared them with neighbour regions. However, got help from Jamees and Wynd [2] in the studies related to Paleontology.
- Amin Afshar [5] studied the depositional environment, digenesis and geochemistry of carbonate deposits of Sarvak Formation in the anticlines of Giskan and Mond (Boushehr).
- Nasseri [6], geochemistry, dispositional environment and digenesis Sarvak in Bangestan Mountain anticline in the sample and compared it with the underground section of Ahvaz underground section.
- Agh [7] investigated the Microstratigraphy of Sarvak and Elam, emphasizing on their boundaries in Tang-Rashid and Abs Timor oil field.

MATERIAL AND METHODS

Two subsurface sectionsin 6 and 7 wells of Tang-e- Bijar gas field were selected to study Sarvak formation. Since special parameters predicted before any drilling based on related studies, only for sonic, gamma, Norton and density logs of under study well were selected and analyzed.

Geology of Sarvak Formation

The name of this formation has come from Sarvak strait in Northwest of Behbahan in Khuzestan province [8]. This formation was considered as a part of Bangestan Limestones, Hippurite limestones, Rudist limestones, Lashtegan Limestones and mid-Cretaceous Limestones.

The section sample of this formation is located in southern slope of Bangestan Mountain anticline in 40 Kilometers to North West of Behbahan.

Two Facies are clear in Sarvak Formation of Zagros which includes [9]:

A. Shallow Marine Facies, Sarvak neritic, similar to what is seen in sample section
B. Deep marine Facies, Sarvak pelagic which have outcrops in Lorestan.

A. Shallow Marine or Neritic marine facies with total formation thickness of 822 meters in sample section that its Lithology is as follow:

It contains fine-grained gray Limestones and clay in the bottom section and has several signs of small ammonites and foraminiferas like Oligostegina, Rotalipora, Hedbergella and such. In the middle part Lithlogy Sarvak Formation is in the form of Limestonescontaining siliceous nodules and rarely Oligostegina. In some parts like Khark area, neritic facies consisting of foraminifers like Troculina, Lenticulina, Orbitolina and Nezzazata were observed.

Massive Limestoness with Rudists cuttings were found on depositions of middle part. Which contain fossils such as Valvulina, Nezzazata and Dicyclina. Algae and Echinoderm cuttings are other types of Limestones cuttings in these depositions [9]. Scorpion the lower boundary of Sarvak Formation is isoclines with formation, but its upper boundary is clear with Marls and Shales. Sarvak Limestones are rusty and impregnated with ferric compounds in this boundary and can be a sign of discontinuities erosion [2].

In Shore Fars, shallow marine Facies of Sarvak was differ from the selected section and was similar to Facies of Kuwait and South East of Iraq. Sarvak Formation is divided in to two parts of Modood and Ahmadi in this region.

Sarvak Formation in under study region

Generally, Sarvak Formation only existed in North East of under study region and forms anticline core which slowly disappear from east to west. Therefore the base of this formation in ground surface is not clear and the upper part of this formation which has deep or pelagic Facies, located under the Shale formation of Sorgah. The thickness of lagers Limestones is 20 to 25 cm. As it can be seen, the Limestones formation of Sarvak form anticline core. The well known fossils of this formation include:

Hedbergella, Oligosteginids, Python, Kelsey Asforvla, Aynovmynata, Globotruncanahelvetica, Hulovtyka which show Cenomanian-Turonian.

The stratigraphy of Sarvak in outcropped section of Siyahkuh from base to top is as follow:

30 meters of limestone, composed of thick layers or in massive form with light gray fracture surface

12 meters medium thickness Limestones layer with light brown fracture tolerance

24 meters thin Shale Limestone slayer with dark gray fracture tolerance

16 meters medium to thick Limestones layer with light gray fracture tolerance

28 meters medium thick Limestones layer with light brown fracture tolerance

8 meters thin to medium Limestones layer with dark gray fracture tolerance

34 meters thin Shale Limestones layer with dark gray to black fracture tolerance

8 meters thin to medium Limestoneslayer with dark gray fracture tolerance

24 meters thin Shale Limestones layer with dark gray to black fracture tolerance

6 meters medium Limestones layer with light brown fracture tolerance

15 meters medium Limestones layer with light brown to cream fracture tolerance contain brown spots due to the iron oxides

12 meters thin Shale Limestones layer with dark gray fracture tolerance

10 meters Marine Sheets with dark to black fracture tolerance

12 meters thin to medium Shale Limestones layer with dark brown fracture tolerance

6 meters thin Limestones layer with light brown to cream fracture tolerance containing Bioturbation effects

10 meters thin Shale Limestones layer with dark gray fracture tolerance

18 meters medium to thick Limestones layer with light gray fracture tolerance contain iron Oxide effects.

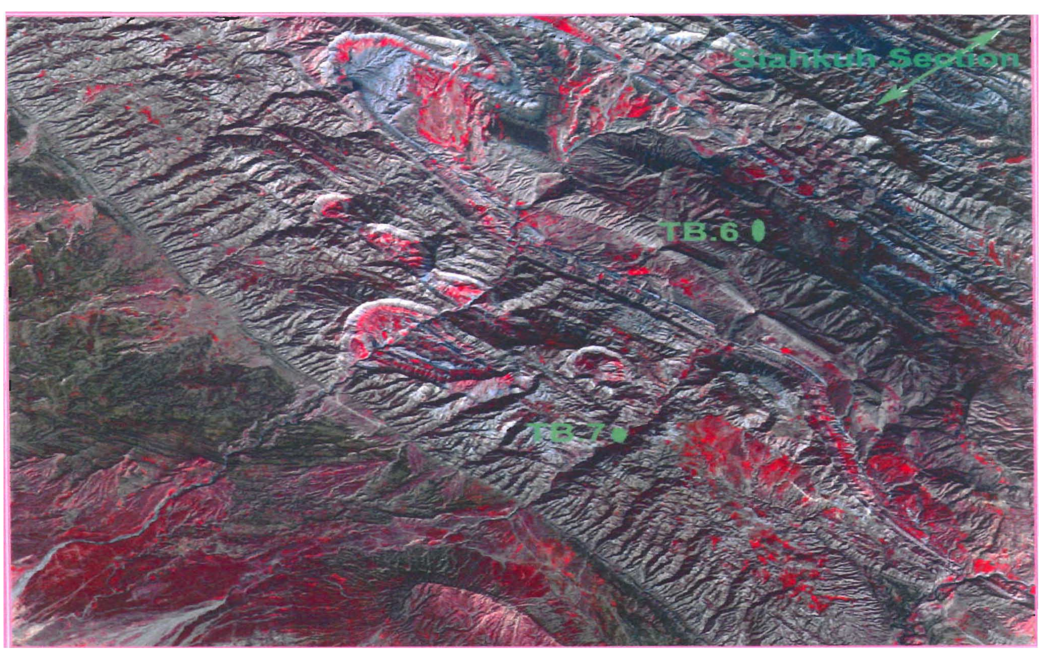

Figure 2. The location of the region, wells and sections in satellite images (images whit average filter)

Investigation of Petrophysical properties of Sarvak Formation

The effects of depositional environment changing on Sarvak Formation were investigated in Petro – Physical point of view. For this purpose, at first the Litho logy and diversity of stone facies were investigation were investigated in two underground cuttings of wells numbers 6 and 7.

The used Logs:

Sonic log, density log, neutron log and gamma ray log Analyzing the information obtained from logs and their corresponding with each other and the results of drilled cores and cuttings.

According to the logs (Sonic, density, neutron and gamma ray) and stratigraphic columns of under study wells, the thickness and Petro – Physical and reservoir properties of Sarvak Formation changed from well No.7 of Tang-e-Bijar to well number 6 of Tang-e-Bijar. The cores and drilling retail study was also confirmed this matter.

The microscopy analysis of drilled cores and cuttings of well No.7 showed the gradual changing of reservoir Limestones from base to top of formation and from Mudestone to Packstone and finally to Wackestone. This lithology changing was also observed in well No.6, but with this difference that it was from Packstone/grainstone to Packstone/ Wackestone and Wackestone/ Mudestone and finally Wackestone from base to top.

To facility of work, correlation action of wells was performed in different zones of Sarvak formation. Tang – Bijar field of Sarvak Formation consists of 4 zones. Tables 1 and 2 show the comparison of thickness and Petro – Physical properties of different zones. There was not any significant difference between two wells. The existence of partial differences in Gas field indicated that the conditions of carbonates sedimentation was very low [10].

According to the logs, porosity and saturation of hydro carbon used for browsing various breaks were observed and the depositional condition of middle parts of formation from base to top was gradually improved and could be observed in logs browsing. The Lithology changing and fluid maker was not server but the reservoir condition was improved. The lithology study indicate that Limestones of packstone / Wackestone / grainstone were formed in well No.7 at this part (middle part), while there was low percentage of packstone and grainstone in low depth of well No.6 and a little packstone and grainstone formed in middle depth of well No.6.

The down part of Sarvak Formation had low porosity and with fine stone pores (often moldic porosity) and in up direction porosity improved and the pores become bigger (which are usually channel porosity and fracture porosity). In lower parts of formation, the dolomitization phenomenon was observed in local form and with weak development which didn't have effect on porosity. But in middle parts of formation and especially in well No.6, the dolomitization was relatively wider and had been considered as one of the factors of porosity creation. Diagram 1 shows the relationship of porosity and permeability. The changing process of mean saturation of hydrocarbon in porosity changing in two wells was studied. It means that the percentage of hydro-carbon saturation is more than water saturation in depth with better porosity and lower Shale volume (the max amount of hydro-carbon saturation in well No.6 of Tang-e-Bijar was equal to 0.1273 percent). It should be noted that the hydro-carbon was gas type in this field and lower saturations were due to this matter.

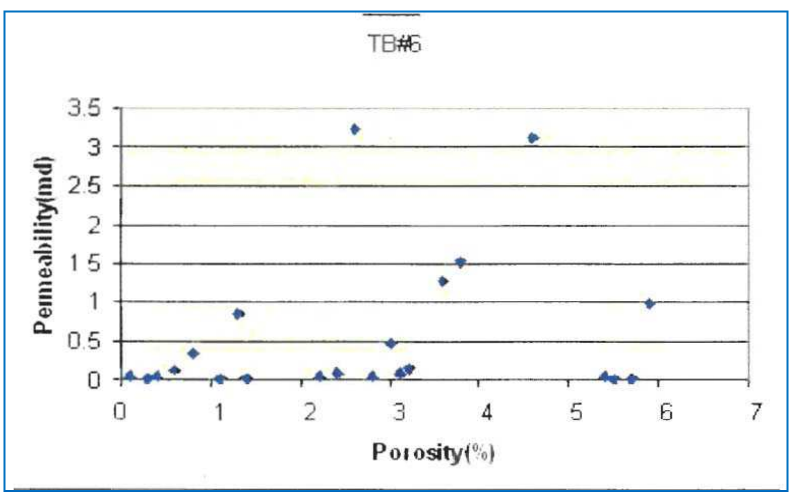

Diagram 1. The amount of porosity V.S permeability of Sarvak Formation obtained from data of core analysis in well No.6 of Tang-E-Bijar

As it can be seen in diagram 1, porosity increasing didn't have effect on permeability in some cases. The study of thin microscopy section of cores in these depth showed that porosity increasing was related to pore porosity in this area. Since these porosities didn't have relationship with each others, didn't have any effects on permeability. The study of thin section also showed that the points in which permeability was increased with porosity increasing were mostly related to development of channel porosities. Therefore it can be said that the amount of permeability depends on pores, in addition to the amount of porosity.

The increasing of hydro-carbon saturation, along with porosity increasing indicated that with the porosity increasing and stone outlets developing in existence of water and hydrocarbon fluids, the hydro carbon fluid replaced by reduction of capillary pressure of outlets [11].of course it should be noted that :since the amount of shale is low here(under study region), it doesn't have significant effect on other parameters, so other parameters in addition to porosity increasing percentage effect on hydro-carbon saturation such as Micro porosity [12]. In some parts of Sarvak Formation base in well No.6, the amounts of porosity, Shale volume and hydrocarbon saturation is decreased. Core study of lithology showed cementation in this part. In well No.7, the Sarvak base has very low porosity and the Shale volume is higher than well No.6 because of its faces type.

In each well and with the development of Faces, the porosity increased in down to top direction. Therefore lithology can be considered as an effective factor in porosity changing.

Table 2. Data obtained from investigation of drilled cores and cuttings and logs data in well No.6 of Tang-Bijar

The results of core and drilling retail investigation		**Logs Data**				
Type of porosity	**Lithology**	**Porosity average (%)**	**Shale volume average**	**Thickness (m)**	**Depth(m)**	
Good porosity Channel and pore type	Wackestone	5/78.6	0.021	47	2348-2395	Zone 1
Good porosity is mainly a big hole in the ground	Wackestone /Mudestone ne/ Wackestone	3/4701	0.018	32	2395-2427	Zone 2
Good porosity Channel , pore and fracture types	Packstone/grainstone/Vace stone	4/5534	0.029	96	2427-2523	Zone 3-1
Medium to good porosity whit fine pore type	Wackestone / Wackestone / Packecstone	4/1121	0.027	87	2523-2610	Zone 3-2
Weak to medium porosity with fracture type	Wackestone / Wackestone / Packecstone	2/6239	0.008	34	2610-2644	Zone 4-1
Weak porosity with fracture type	Packecstone// grainstone Packecstone/ Packecstone/ grainstone	1/9024	0.006	195	2644-2839	Zone 4-2

Table 3. Data obtained from investigation of drilled cores and cuttings and logs data in well No.7 of Tang-Bijar

The results of core and drilling retail investigation		**Logs Data**				
Type of porosity	**Lithology**	**Porosity average (%)**	**Shale volume average**	**Thickness (m)**	**Depth(m)**	
Moderate to low porosity and fine fracture and pore porosity	Wackestone	4/26	0.054	50	1372-1422	Zone 1
Weak to moderate porosity of the cavity and internal particles	Packstone Wackestone /	4/98	0.09	26	1422-1448	Zone 2
Weak to moderate porosity of the cavity and internal particles	Packstone Wackestone /	4/46	0.061	78	1448-1526	Zone 3-1
Moderate Fine pore and channel porosity	Pack stone	5/96	0.065	72	1526-1598	Zone 3-2
Weak frame type porosity	Pack stone Wackestone /	4/68	0.051	55	1598-1653	Zone 4-1
Very Weak frame type porosity	Mudestone ne/ Wackestone	2/26	0.082	47	1653-1700	Zone 4-2
Moderate to low porosity and fine fracture and pore porosity	Wackestone	4/26	0.054	50	1372-1422	Zone 1

The calculation of Shale Volume

Generally, Shale volume of formation is calculated by gamma ray logging and according to the following question

In this question, ISh is the Shale index. The min Gr is selected from pure clean intervals (without Shale s) and Shale layers of well are used to determine Gr max

The Gamma which was the Shale member in Gamma logs considered as max Gamma of well in order to calculate the Shale volume of Sarvak formation. The min Gamma was also selected among carbonate intervals which had the lowest amount of Gamma. Shale volume changing of Sarvak Formation in 6 and 7 wells of Tang-Bijar and its frequency has been shown in diagram 4. The highest volume of Shale in well comprised with well No.7 confirms this diagram.

In well No.6, intervals with 0.05% have 30% frequency. While in well No.7, intervals with 0.05% have 20% frequency and lower than 0.05% intervals are not significant. It means that, in well No.6 the maximum rate of Shale reaches to 0.08 which is lower than %10 frequency. In well No.7, this amount is %2 and its frequency reaches to %10. Moreover the types of clay minerals by drawing the amounts of POTA V.S THOR can be observed in diagrams (2) and (3). These diagrams showed the higher amount of minerals and therefore, indicate the reduction and increasing of POTA. The amount of THOR is very little due to the lack of this component in above minerals. Moreover, the type of Clay minerals by POTA values V.S Clay mineral obtained by THOR can be observed in diagram 2 and 3. The diagrams showed that the Potassium mostly is obtained from Glauconite, mica Potassium feldspar.

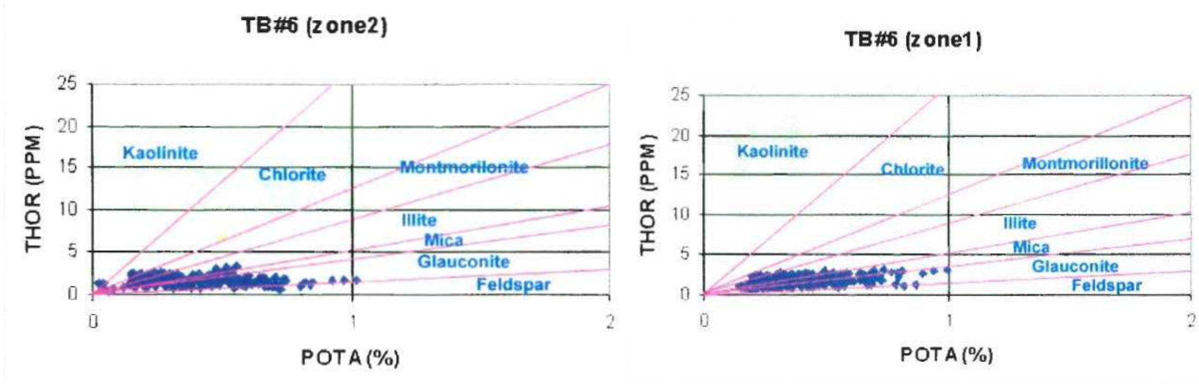

Diagram 2: the amounts of POTA V.S THOR in order to determine the types of clay minerals in zones of 1 and 2 in Sarvak Formation at well No. 6

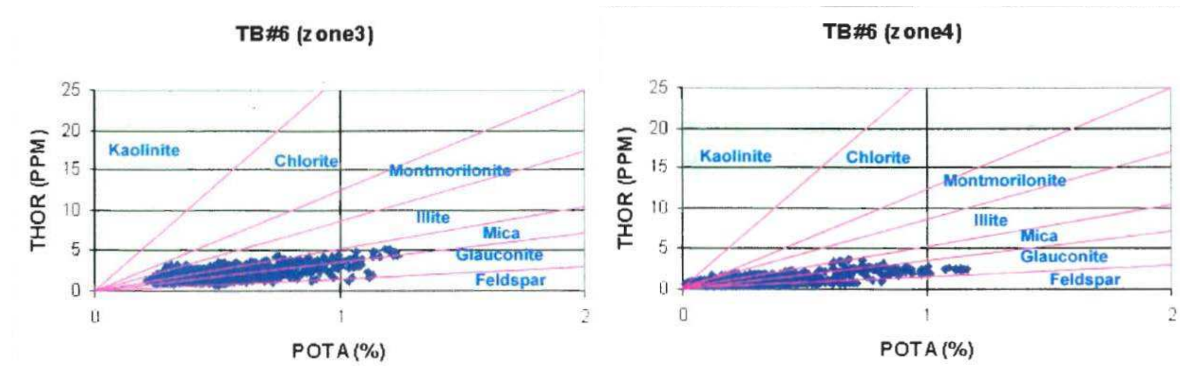

Diagram 3. The amounts of POTA V.S THOR in order to determine the types of minerals clay in 3 and 4 zones of well No. 6 of Sarvak formation

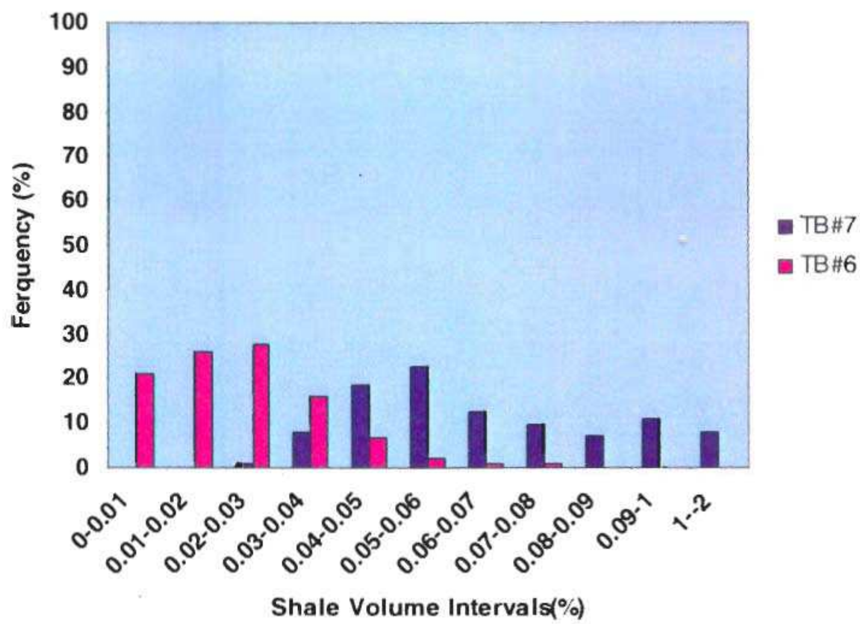

Diagram 4. The comparison of Shale volume in wells 6 and 7 of Tang-E-Bijar

Determination of Lithology and mineralogy compositions

None of logs cannot lonely identify the Lithology. The binary combinations of logs which called cross-plot are used to determine lithology and the most important of them are neutron-sonic, crossplot and neutron-density crossplot.

Here, two samples of mentioned cross-plots in 1 to 4 Zones of Sarvak Formation in 6 and 7 wells of Tang-Bijar were drawn and investigated.

Neutron-Density Cross-plot (NPHI-RHOB)

The signs of Neutron and Density logs in wells are NPHI and RHOB, respectively, which are used to determine the Type of drilling mud. The NPHI cross-plots in 1 to 4 zones of Sarvak Formation in under study wells showed that certain areas of Sarvak Formation (specially, 3 and 4 zones) in well No.6 are differ from equivalent area of well No.7 in Lithology components point of view. In this area, well No.6 is mainly Limestones type but well No.7 is marly limestone. In RHOB-NPHI cross-plot (diagram 5), the changing of density amounts by Neutron mounts changing can indicate Lithology changing; so that the RHOB rate increased with reduction of clay rate and changing from marine Limestones to Limestones components(due to the lower density of Clay minerals compare to Carbonate minerals). But Neutron log rate increasing without density changing can be due to the porosity increasing or minerals clay reduction. GR-NPHI cross-plot was used in these cases. In this regard, Gamma increasing with NPHI increasing in GR-NPHI cross-plot indicates the minerals clay rate increasing. NPHI increasing without Gamma changing shows porosity increasing (due to the Gamma log sensitivity to mineral clay).

The density rates of 1 and 2 zones in well No.7 were lower than 1 and 2 zones in well No.6, therefore these areas (1 and 2 zones in well No.7) had higher rate of clay that indicated Marine Limestones combinations (these areas are Limestones in well No.6).

In 3 and 4 zones of well No.7, the density was increased due to the corresponding of this cross-plot with GR-NPHI cross-plot and can be related to porosity increasing. In 3 and 4 zones of well No.6, high RHOB with NPHI increasing indicated low rate of clay mostly calcareous (lime) compositions.

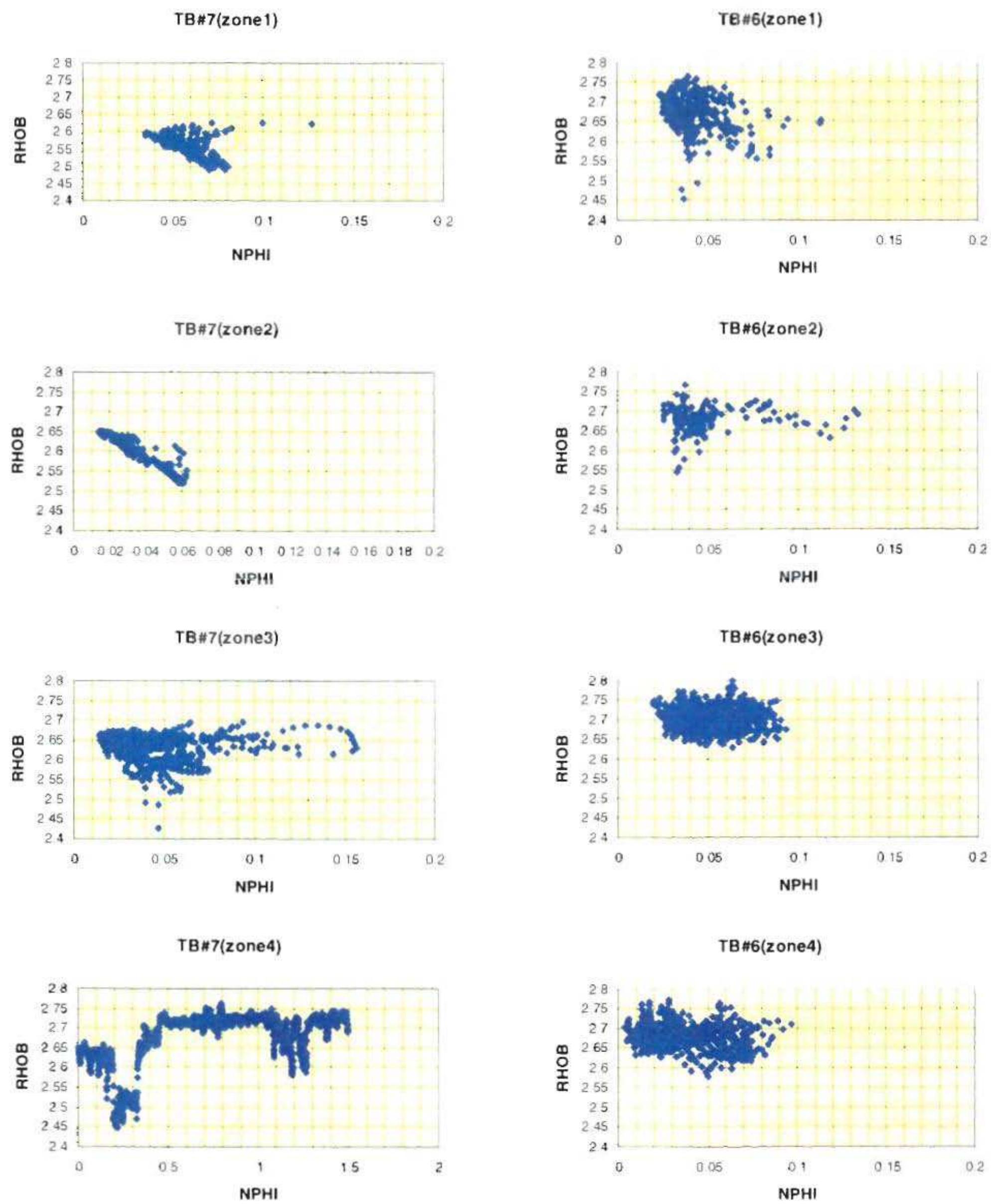

Diagram 5: NPHI-RHOB cross-plot in 1 to 4 zones of Sarvak formation in wells 6 and 7 of Tang-E-Bijar

-Neutron-Sonic cross-plot (DT-NPHI) has also been used in lithology identifying of formation. Here Neutron and volume logs are in DT and NPHI types. This cross-plot showed mostly calcareous (lime) compositions formation in well No.6 and marine Limestones formation in well No.7 (Diagram 6).

Porosity

Neutron logs were used to calculate porosity rate (empty space volume of stone). This work was performed by measuring hydrogen ions in the pore fluids. But they cannot lonely identify Hydrogen existed in fluid from hydrogen of waters which is inside the clay mineral structure due to the high sensitivity to Shale s of formation and consider their integration as porosity. Hence the Shale effects should be removed from Neutron log surface.

Removing Shale effect from Neutron log

In above question, ØNsh is Neutron porosity in Shale layers. In this porosity, the Shale volume of each point is deducted from Neutron log porosity of that point. The mean rate of Neutron log in Shale member of Tang-e-Bijar well was used as Ø Nsh in order to remove. The effect of Shale on this log in wells 6 and 7. The comparison of modified porosity in intervals from 6 and 7 well with didn't show Gas effects (low frequency of Hydrogen ions in Gas led to lower rate porosity of Neutron log and higher porosity of density log compared with real amount) showed significant differences. The obtained amount of logs diagram V.S porosity obtained from cores analysis have been shown in diagram (6-8).

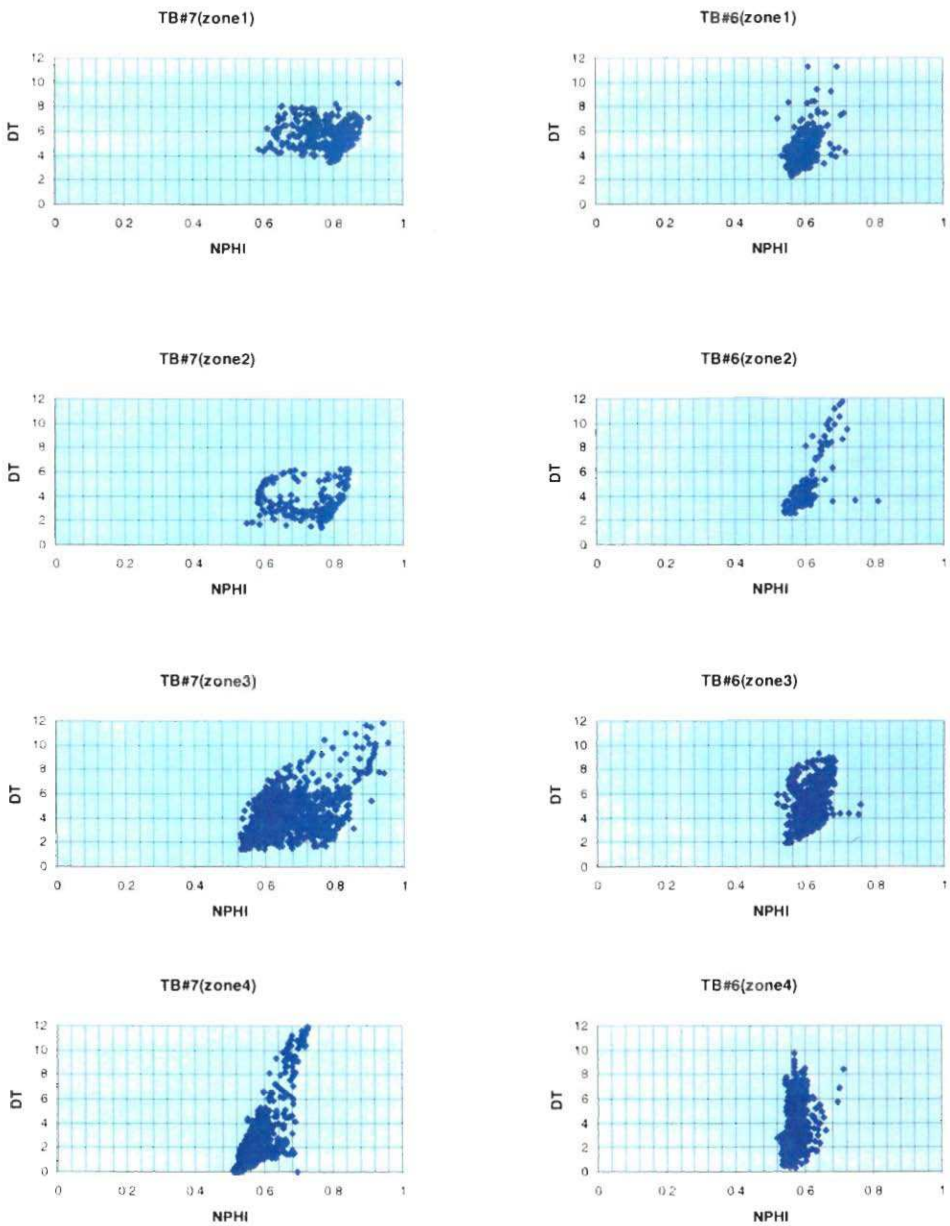

Diagram 6: DT-NPHI cross-plot in 1 to 4 zones of Sarvak formation of 6 and 7 wells

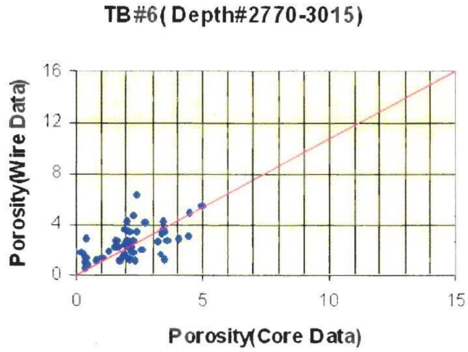

Diagram 7. porosity obtained from cores data analysis V.S porosity obtained from log data

The integration of most of points in a certain area and their close to each other at this diagram indicates the matching of log data with data obtained from cores analysis. A few scattered points are due to the thin sections result in deep cores. The investigation of stone sections and lower rate of porosity obtained from log diagrams compared with cores porosity indicate this porosity filling by hydro-carbon. Hydrocarbons occupy pore porosities as well as Stylolites and lead to reduction of porosity rate read by logs.

Neutron log-Gamma log cross-plot (Gr-NPHI)

This cross-plot is used to evaluate the porosity of Neutron log cross-plot is used to evaluate the porosity of Neutron log cross-plot is used to evaluate the porosity of Neutron log cross-plot V.S Gamma-log (Gr-NPHI). In this cross-plot, the relation of Shale parts is in hot line, because both of logs are sensitive to Shale existence in formation. This hotline named Shale line (Schlomberger). Although in cleaner parts, both logs response to Shale existence but Neutron log also reacts to porosities which are filled by fluid. Therefore their relation in cross plot existed from hotline and identifies the existence of porosity.

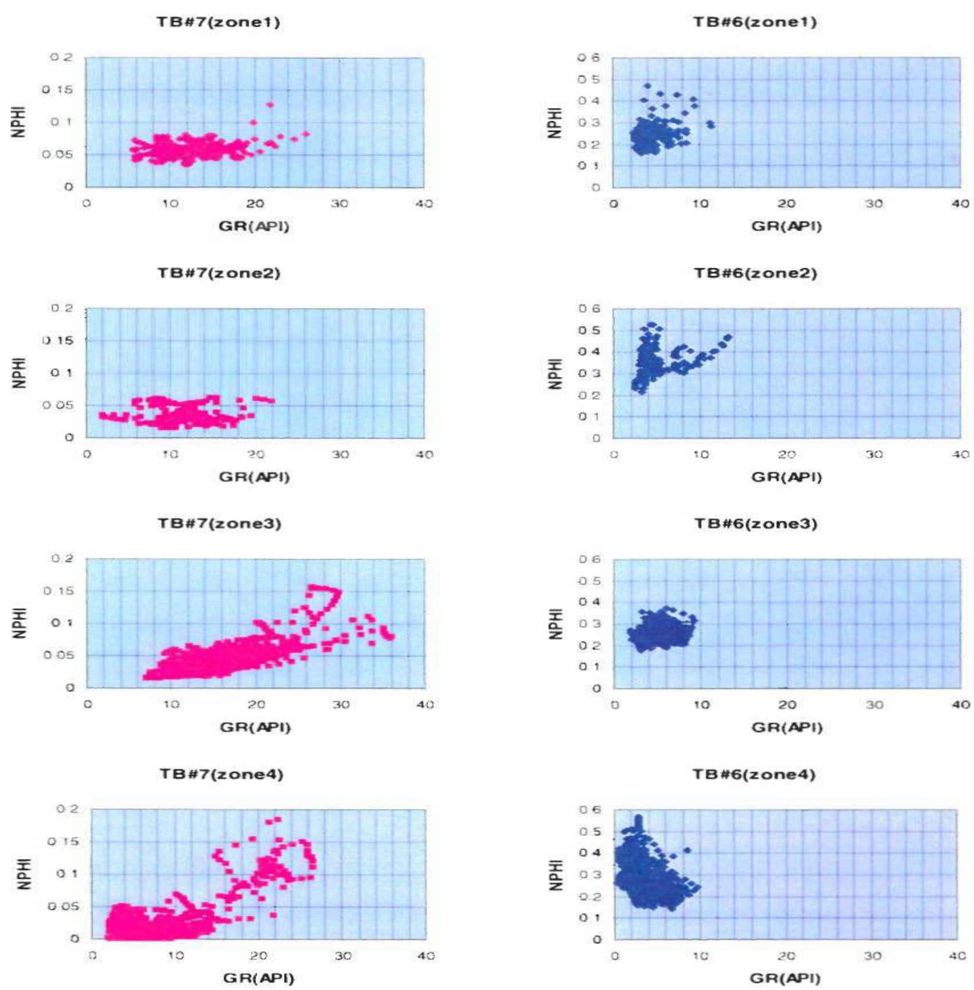

Diagram 8. GR-NPHI cross-plot in 1 to 4 zones of Sarvak formation in wells 6 and 7 of Tang-E-Bijar

Diagram 8 shows the GR-NPHI cross-plot related to 1 to 4 zones in 6 and 7 wells of Tang-Bijar the right side diagrams confirm the linear relationship of Neutron and Gamma logs, in which most of Neutron logs porosity in clean intervals with lower clay are related to well No.7 and are mostly in microfractures porosity.

In well No. 6 (left side diagrams) there is Shale line, but data don't correspond with it and show dispersion. Therefore, it can be concluded that in well No. 6 of Tang-Bijar (left side diagrams), cleaner intervals with lower amounts of clay (mostly Dolomite Facies) have porosities which can maintain fluid, in addition to micro fractures porosity. Microfractures porosity such as Micrite Matrix and the structure of some allochems were observed in microfractures of carbonate [13].

Based on more frequency of Mode stone /Vackestone Faces among the facies of Sarvak Formation of well No. 7 of Tang-E-Bijar, it can be said that most of porosities in this formation are allocated to microfractures porosity. It should be noted that this type of porosity can only keep irreducible water and therefore it does not have any role in useful porosity of formation which can be used in Hydro-carbon saturation [13].

Conclusion

The reservoir properties of Sarvak Formation in different zones were analyzed by investigations performed on logs diagram (Sonic logs, Neutron logs, Density logs and Gamma logs) and these results were corresponded with results obtained from drilled cores and cuttings investigations. According to this, it can be said that high level reservoir properties creation in some zones is due to the big channel porosities, fractures and sometimes dolomitization (especially in 3 and 4 zones of well No. 6).

In addition, it can be said that in under study wells, the saturation process of reservoir from hydrocarbon trend to mean porosity changing. In depth with better porosity and lower Shale, the percent of hydrocarbon saturation is higher than water. The log diagrams and drilling retail and cores investigation showed that the depositional condition was improved in middle depth to deeper parts compared with early parts. Generally there was no significant difference between two wells. The existence of little difference in Gas field indicate this important point that depositional condition of carbonate had little changing and the existence of some differences in tissue were due to the after deposition changing.

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