Penerbit Akademia Baru

Journal of Advanced Research Design
ISSN (online): 2289-7984 | Vol. 3, No.1. Pages 22-32, 2014

How to Determine Heterogeneity Using Image Logs

M. Alizadeh[*,1,a], *Z. Movahed*[1,b], *R. Junin*[1,c], *R. Mohsind*[1,d], *M. Alizadeh*[2,e] *and M. Alizadeh*[3,f]

[1]Faculty of Petroleum and Renewable Energy Engineering, Universiti Teknologi Malaysia, 81310 (UTM) Johor Bahru, Johor, Malaysia
[2]Gachsaran Oil and Gas Production Company – GOGPC, 7581873849 Gachsaran, Iran
[3]Mechanical Engineering Department, Tarbiat Modares University, 14155-111 Tehran, Iran
[a,*]*mostafa.alizadeh88@yahoo.com,* [b]*zmovahed@gmail.com,* [c]*radzuan@petroleum.utm.my,*
[d]*rahmat@petroleum.utm.my,* [e]*alizadeh.me@gmail.com,* [f]*ymohsen.alizadeh@yahoo.com*

Abstract – *This work will explain the processes that follow a reservoir heterogeneity analysis that is conducted using image logs. The data for this work comprises of image logs of tree wells, which are obtained from Gachsaran field. The main formations under study in this work are the Asmari formation, Pabdeh formation and Gurpi formation. This work will explain the process through a number of valuable log interpretation examples.*

Keywords: Reservoir heterogeneity, Oil and gas reservoirs, Image logs

1.0 INTRODUCTION

Gachsaran is an anticline structured field, located in southwest Iran (Figure 1). The sequence stretches an 80 km long, 300-1500 m thickness and 8-18 km wide of anhydrite/salt; this provides an excellent seal for the overlying Asmari, Pabdeh, Gurpi and other reservoirs [1] (Figure 2)

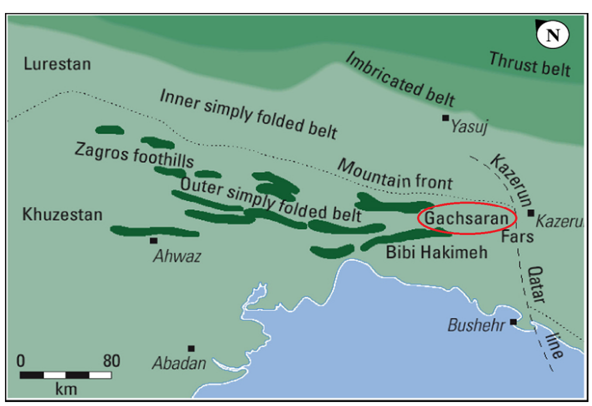


Figure 1: The location of the Gachsaran oil field [2]

Journal of Advanced Research Design
ISSN (online): 2289-7984 | Vol. 3, No.1. Pages 22-32, 2014

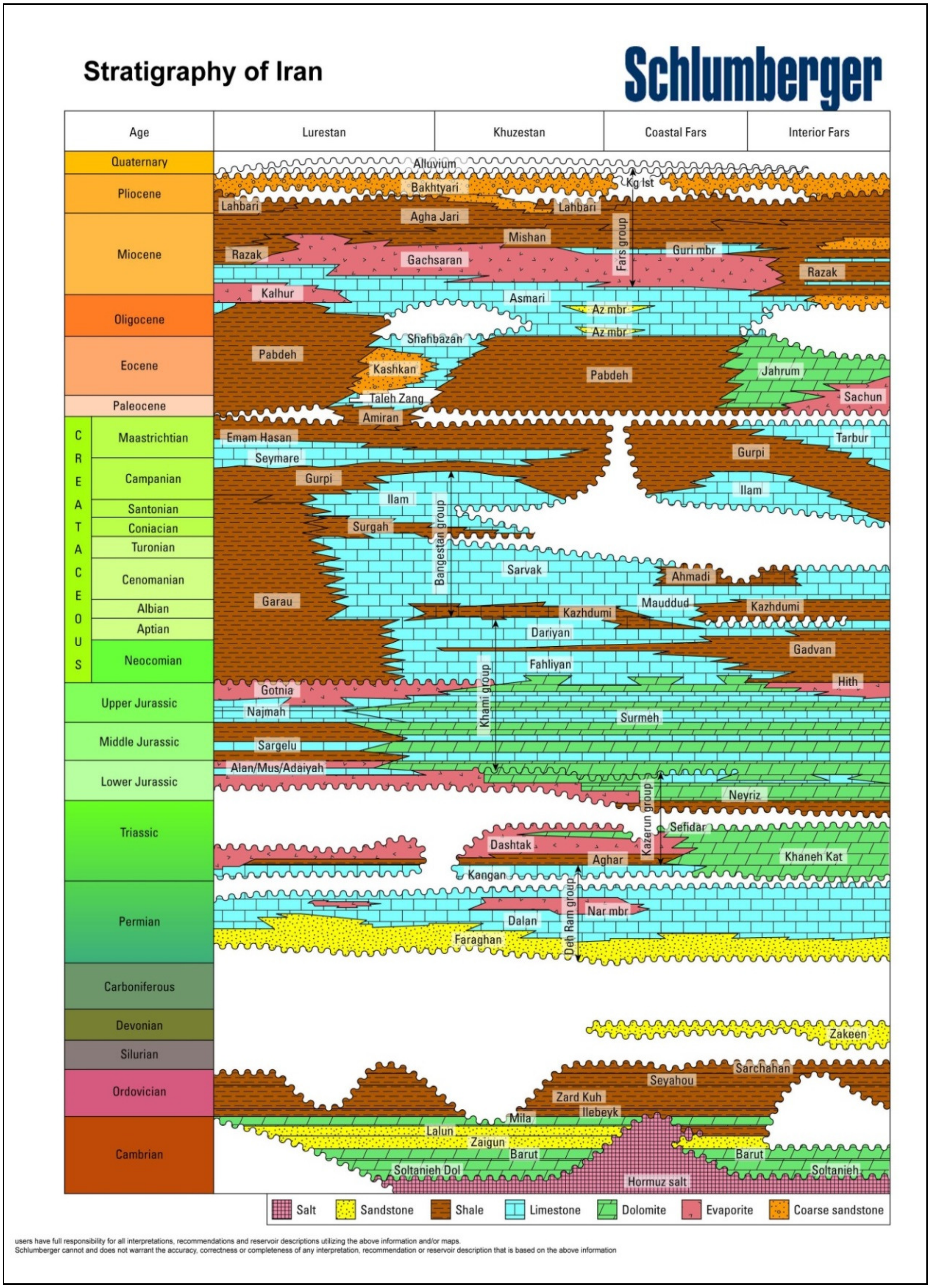


Figure 2: The location of Gachsaran field overlying the Asmari, Pabdeh, Gurpi and other reservoirs; Stratigraphic nomenclature of rock units and age relationships in the Zagros basin [3]

A carbonate reservoir could be layered or massive and its porous fraction could be comprised of vugs, moulds, karsts, channels, patches of inter-particle or intra-particle porosity or layers due to diagenesis, bioturbation or preferential cementation. Being resistive, the dense limestone areas or porous areas with residual hydrocarbon have light shades on the images; whereas shale, porous and mud invaded rocks, vugs, and moulds have dark shades [4, 5].

In addition to openhole logs, BorTex processing (software used to extract heterogeneities and layer details from images) provides five heterogeneity indexes that can be used as inputs to a neural-network program for identifying different rock-types or litho-types [6, 7].

In this work, 3 wells located in the Gachsaran oil field are selected to be analyzed with the reservoir heterogeneity analysis, using image logs and other geological logs interpretation. The reservoir heterogeneity analysis is conducted in order to obtain a better understanding on reservoir heterogeneity systems and also to explain the methodology by demonstrating the log interpretation through examples from this particular field.

2.0 MATERIALS AND METHODS

The main factor contributing to the heterogeneous nature of a reservoir is patchiness due to areas of different porosity and permeability, either caused from diagenetic processes or/and changes in lithofacies. For instance, it could be explained as a mixture of grainstone and packestone; where grainstone areas would be less permeable due to cementation of the pore space while packestone areas would be more permeable. Similarly, in bioclastic limestones, shell fragments are resistive or dense (hence appears as resistive spots or patches) while the leached parts of the same shells could be conductive or porous (hence appears as conductive spots or patches).

The heterogeneity analysis of the reservoirs from borehole images is carried out by employing BorTex (software used to extract heterogeneities and layer details from images). It may also involve more than one iteration to extract formation heterogeneities for parameter optimizations. The results for each iteration are validated using visual inspection of the images to see whether the heterogeneities could be identified and contoured. The resistive heterogeneities are contoured in dark blue while the large resistive events are contoured in cyan (Figure 3).

The conductive events are further classified into three types: large patches, connected spots, and isolated (across each image) spots. They are shown by different colours on the images: the patches are in dark magenta, connected spots in red, and the isolated spots are in orange.

The results of heterogeneity analysis are in the form of continuous depth indexed channels or curves for the proportion and size of each type of formation heterogeneity. Such curves can be averaged over any window length and outputted at any sampling rate. Generally, they are averaged over a 1.0 ft. window and outputted at 6 inches to be consistent with the conventional logs.

Complementing the openhole logs, the BorTex (software used to extract heterogeneities and layer details from images) processing output i.e., proportions of resistive and conductive heterogeneities, can also be used to identify different rock-types or litho-types through a classification software (i.e., cluster technique, neural network, multiple regression techniques, and so on) (Figures 4 and 5).

Journal of Advanced Research Design
ISSN (online): 2289-7984 | Vol. 3, No.1. Pages 22-32, 2014

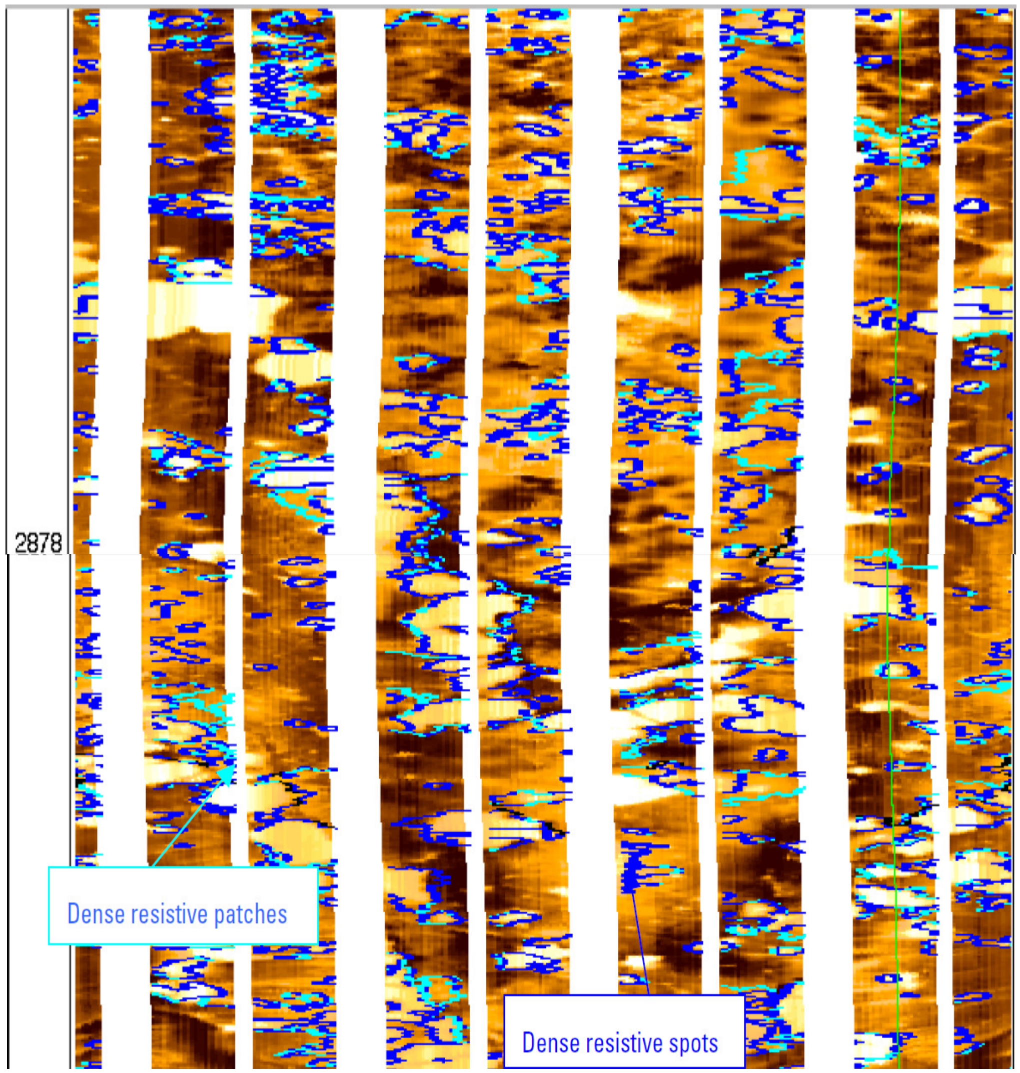


Figure 3: FMI calibrated images highlighting resistive features / areas in a carbonate section. Contoured in blue are resistive or dense features; patches are in cyan while spots are in blue. The spots are dense or resistive features / areas where dimensions are less than 0.003m^2

Journal of Advanced Research Design
ISSN (online): 2289-7984 | Vol. 3, No.1. Pages 22-32, 2014

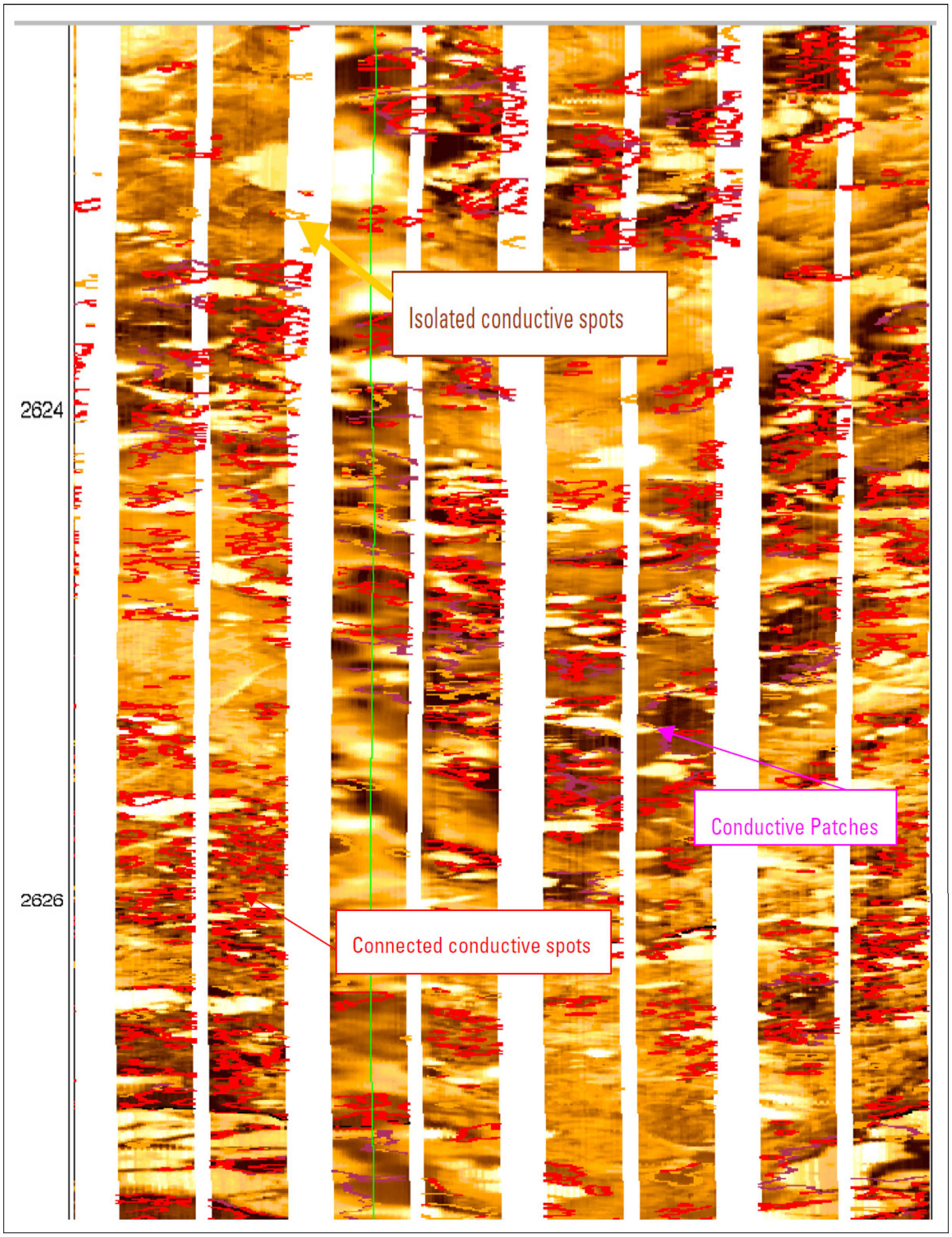


Figure 4: FMI calibrated images highlighting conductive features in a carbonate section. Contoured in red are conductive-connected spots (i.e. features smaller than 0.0003 m^2); in dark brown are isolated conductive spots while dark magenta are conductive patches (i.e. conductive features larger than 0.003 m^2)

Penerbit Akademia Baru
Journal of Advanced Research Design
ISSN (online): 2289-7984 | Vol. 3, No.1. Pages 22-32, 2014

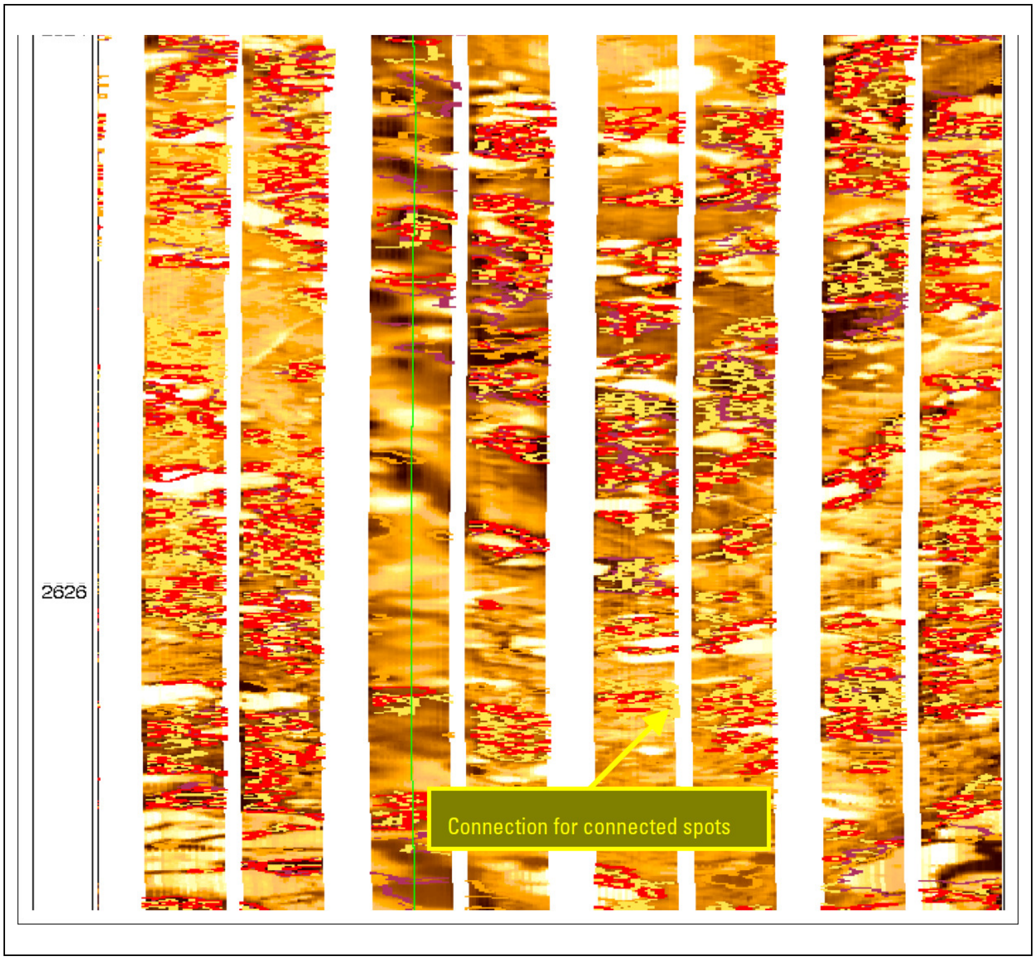


Figure 5: FMI calibrated images showing yellow lines (forming cluster of yellow lines) connecting the conductive spots (red contoured features) in a carbonate section, which is also shown in Figure 59. Additional, conductivity along these connections provides a measure of permeability. Higher connection density and conductivity result in higher permeability. The fluid type in the matrix affects the conductivity of these connections; consequently, it needs to be corrected for variations in water saturation.

3. RESULTS AND DISCUSSION

3.1 Reservoir Heterogeneity Analysis for the Well Number GS-A:

The FMI images from GS-A revealed varying amounts of heterogeneity in the form of conductive and resistive (dense) areas across the interval. The conductive heterogeneities are due to porous areas (i.e. patches of intergranular and intercrystalline porosity, mouldic/vuggy porosity and natural open fractures) of different sizes, shapes and conductivities. The resistive heterogeneities are due to dense cemented areas of lower or zero porosity. Observations based on heterogeneity variations are given in the following paragraphs.

• In terms of heterogeneity formations due to dense and conductive anomalies, the homogenous sections of the Asmari formation are 2520-2525m, 2535-2545m, 2580-2620m, 2630-2650m and 2710-2720m.

Journal of Advanced Research Design
ISSN (online): 2289-7984 | Vol. 3, No.1. Pages 22-32, 2014

• The intervals of 2450-2465m, 2470-2500m, 2550-2570m, 2670-2700m, and 2770-2870m are the most heterogeneous sections. Most of these sections comprises of porous patches of carbonate, abundance of dense and porous alternating layers/streaks, and dense patches/areas either due to anhydrite or dense/low porosity cementation.

3.1.1 Anhydrite Patches and Layers

At certain places, anhydrite patches and layers were observed over the reservoir interval. These features have a sharp resistive appearance on the image log as well as an anhydrite typical response on openhole logs. These anhydrite portions are at maximum in the upper sections of the Asmari formation, which is an indication of shallowing upward sequence that leads to deposition of evaporites in the Gachsaran formations. Anhydrite can damage the porosity of the formation by flowing as brine into the rock pore space, whereby it plugs and fills the pore space (Figure 6).

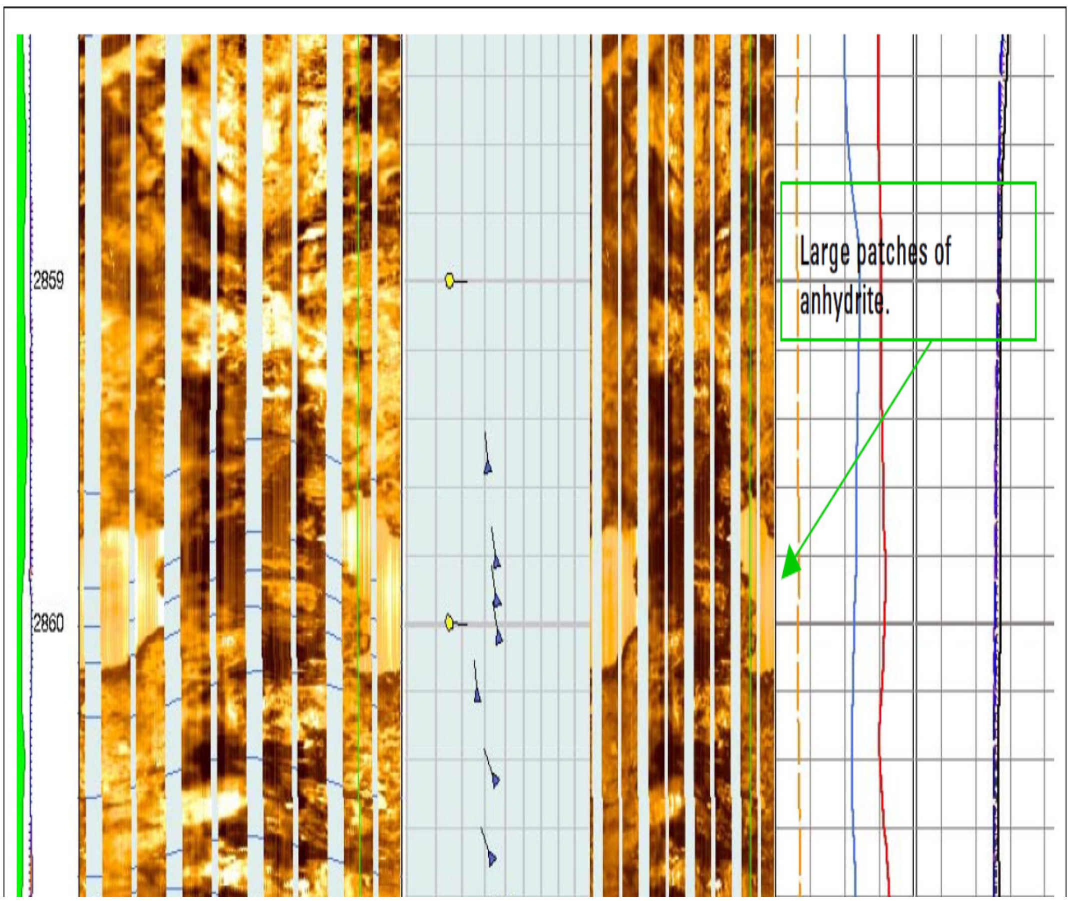


Figure 6: Large patches of anhydrite in the Asmari formation

3.2 Reservoir Heterogeneity Analysis for the Well Number GS-B:

Journal of Advanced Research Design
ISSN (online): 2289-7984 I Vol. 3, No.1. Pages 22-32, 2014

The FMI images from GS-B revealed varying amounts of heterogeneity in the form of conductive and resistive (dense) areas across the interval. The conductive heterogeneities are due to porous areas (i.e. patches of intergranular and intercrystalline porosity, mouldic/vuggy porosity and, natural open fractures) of different sizes, shapes and conductivities. The resistive heterogeneities are due to dense cemented areas of lower or zero porosity.

Observations based on heterogeneity variations are given in the following:

• In terms of heterogeneity formations due to dense and conductive anomalies, the homogenous sections of the Asmari formation are 1862-1870m, 1880-1890m, 1947-2012m, 2170-2210m, 2222-2314m and 2345-2375m.

• The intervals 1846-1862m, 1915-1940m, 2044-2081m, 2142-2170m, and 2375-2400m are the most heterogeneous sections. Most of these sections comprise of porous patches of carbonate, abundance of dense and porous alternating layers/streaks, and dense patches/areas either due to anhydrite or dense/low porosity cementation (Figure 7).

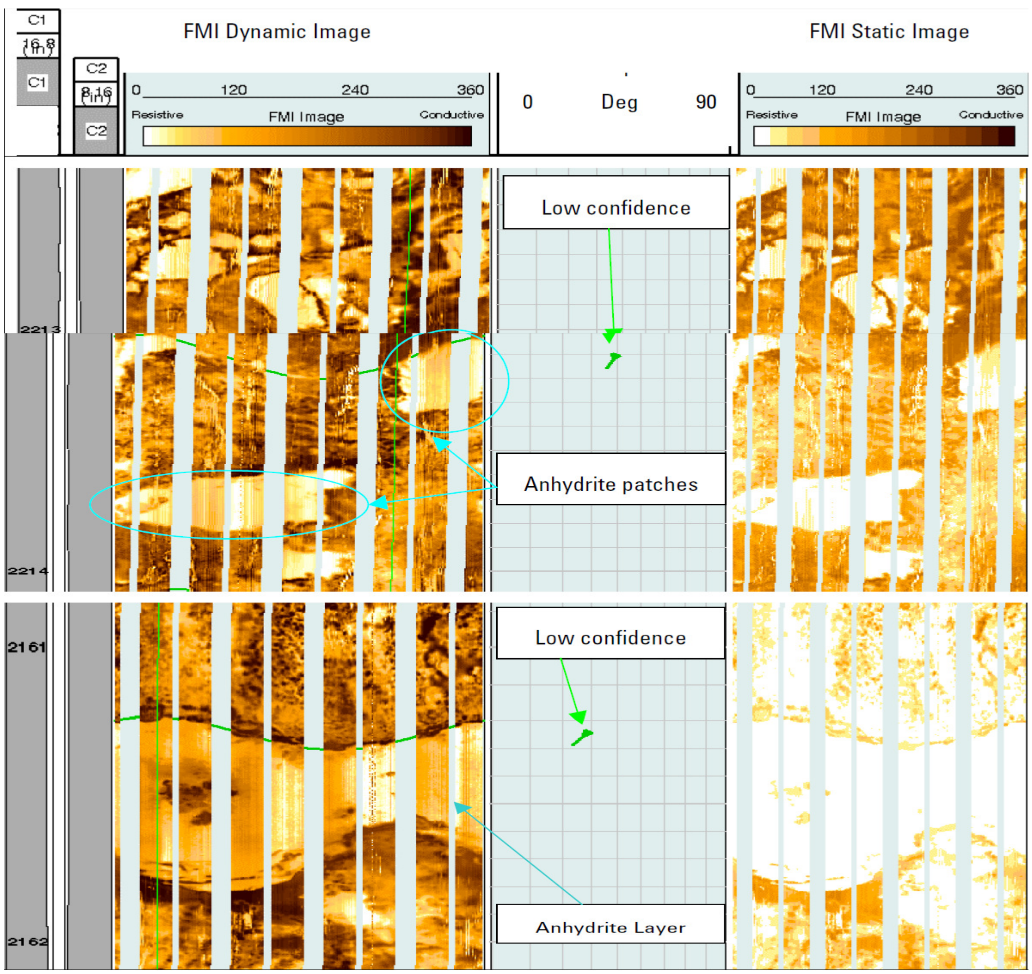


Figure 7: Example of different forms of anhydrite (patches and layer) in the Asmari formation

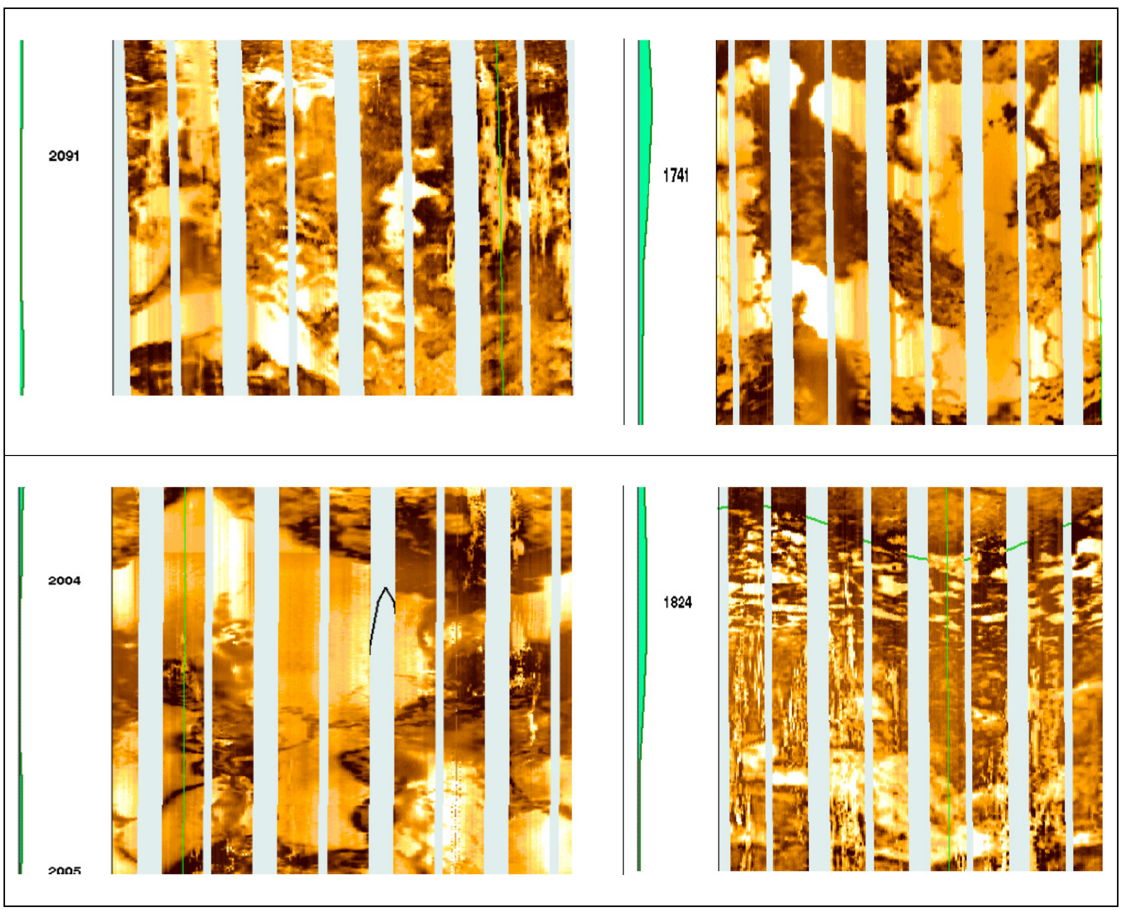
3.3 Reservoir Heterogeneity Analysis for the Well Number GS-C:

Journal of Advanced Research Design
ISSN (online): 2289-7984 I Vol. 3, No.1. Pages 22-32, 2014

The FMI images from GS-C revealed varying amounts of heterogeneity in the form of conductive and resistive (dense) areas across the interval. The conductive heterogeneities are due to porous areas (i.e. patches of intergranular and intercrystalline porosity, mouldic/vuggy porosity and, natural open fractures) of different sizes, shapes and conductivities. The resistive heterogeneities are due to dense cemented areas of lower or zero porosity. Observations based on heterogeneity variations are given in the following:

• In terms of heterogeneity formations due to dense and conductive anomalies, the homogenous sections of Asmari, Pabdeh and Gurpi formations are 1766-1750m, 1810-1792m, 1932-1928m, 1978-1944m, 2032-2014m, 2060-2050m, 2080-2070m, 2318-2254m, and 2422-2376m.

• The intervals 1742-1766m, 1792-1768m, 1966-1814m, 2014-1974m, 2048-2032m, 2072-2057m, 2190m-2086m, 2256m-2198m, 2376-2316m and 2440-2422m are the most heterogeneous sections. Most of these sections comprise of porous patches of carbonate, abundance of dense and porous alternating layers/streaks and dense patches/areas either due to anhydrite or dense/low porosity cementation (Figure 8).



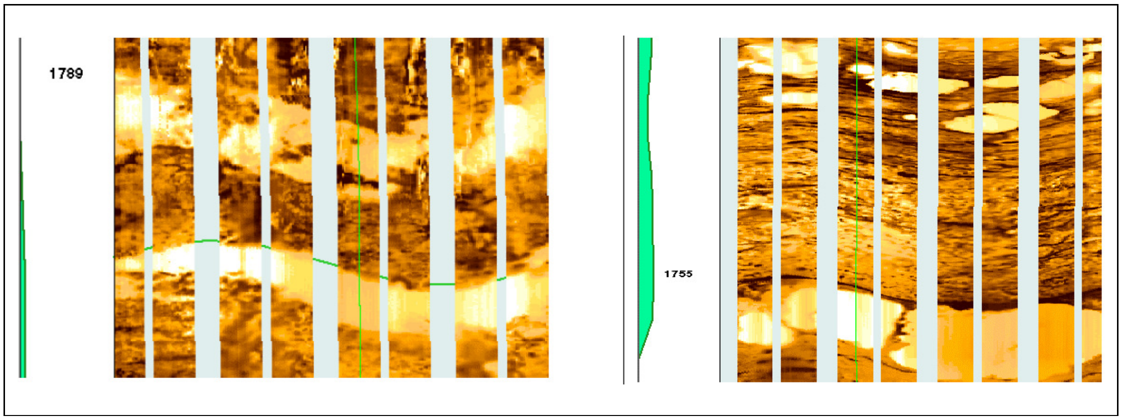


Figure 8: Example of different types of anhydrite occurrences in the Asmari formation

4.0 CONCLUSION

This work shows how the image log technology can be used to conduct the reservoir heterogeneity analysis in oil and gas reservoirs. It is also an example of the reservoir heterogeneity analysis that was done in the Gachsaran field, located south of Iran. This paper describes the method used to find out detailed information about reservoir heterogeneity systems in oil and gas reservoirs.

REFERENCES

[1] F. Khoshbakht, H. Memarian, M. Mohammadnia, Comparison of Asmari, Pabdeh and Gurpi formation's fractures, derived from image log, Journal of Petroleum Science and Engineering 67 (2009) 65-74.

[2] Z. Movahed, R. Junin, P. Jeffreys, Evaluate the borehole condition to reduce drilling risk and avoid potential well bore damages by using image logs, Journal of Petroleum Science and Engineering 122 (2014) 318-330.

[3] M. Alizadeh, Z. Movahed, R. Junin, W. R. Wan Sulaiman and M. Z. Jaafare, Image logs application for locating faults in oil and gas reservoirs, Advanced Research in Applied Mechanics 3 (1) 1-8.

[4] Z. Movahed, R. Junin, Z. Safarkhanlou, M. Akbar, Formation evaluation in Dezful embayment of Iran using oil-based-mud imaging techniques, Journal of Petroleum Science and Engineering 121 (2014) 23-37.

[5] Z. Movahed, Enhanced Reservoir Description in Carbonate and Clastic Reservoirs, Paper presented at the SPE Asia Pacific oil & Gas Conference and Exhibition, Jakarta, Indonesia, 30 October-1 November (2007).

[6] F. Khoshbakht, M. Azizzadeh, H. Memarian, G.H. Nourozi, S.A. Moallemi, Comparison of electrical image log with core in a fractured carbonate reservoir, Journal of Petroleum Science and Engineering 86 (2012) 289-296.

[7] M. Alizadeh, Z. Movahed, R. Junin, W. R. Wan Sulaiman and M. Z. Jaafare, Fault interpretation using image logs, Applied Mechanics and Materials 695 (2014) 840-843.