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How to Determine the Heterogeneity Using Image Logs

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Abstract – *In this work, the process that reservoir heterogeneity analysis can be done using image logs will be explained. The data for this work are image logs data of tree wells, located in Gachsaan field. The main formations under study in this work are Asmari formation, Pabdeh formation and Gurpi formation. This work will explain the process by a number of valuable log interpretation examples.*

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

1.0 INTRODUCTION

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

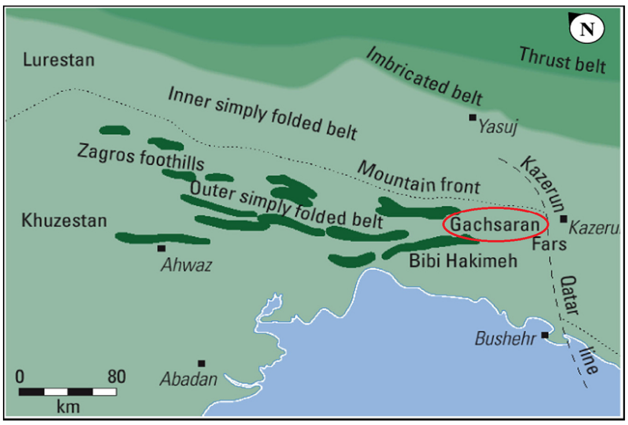

Figure 1: The location of the Gachsaran oil field [2]

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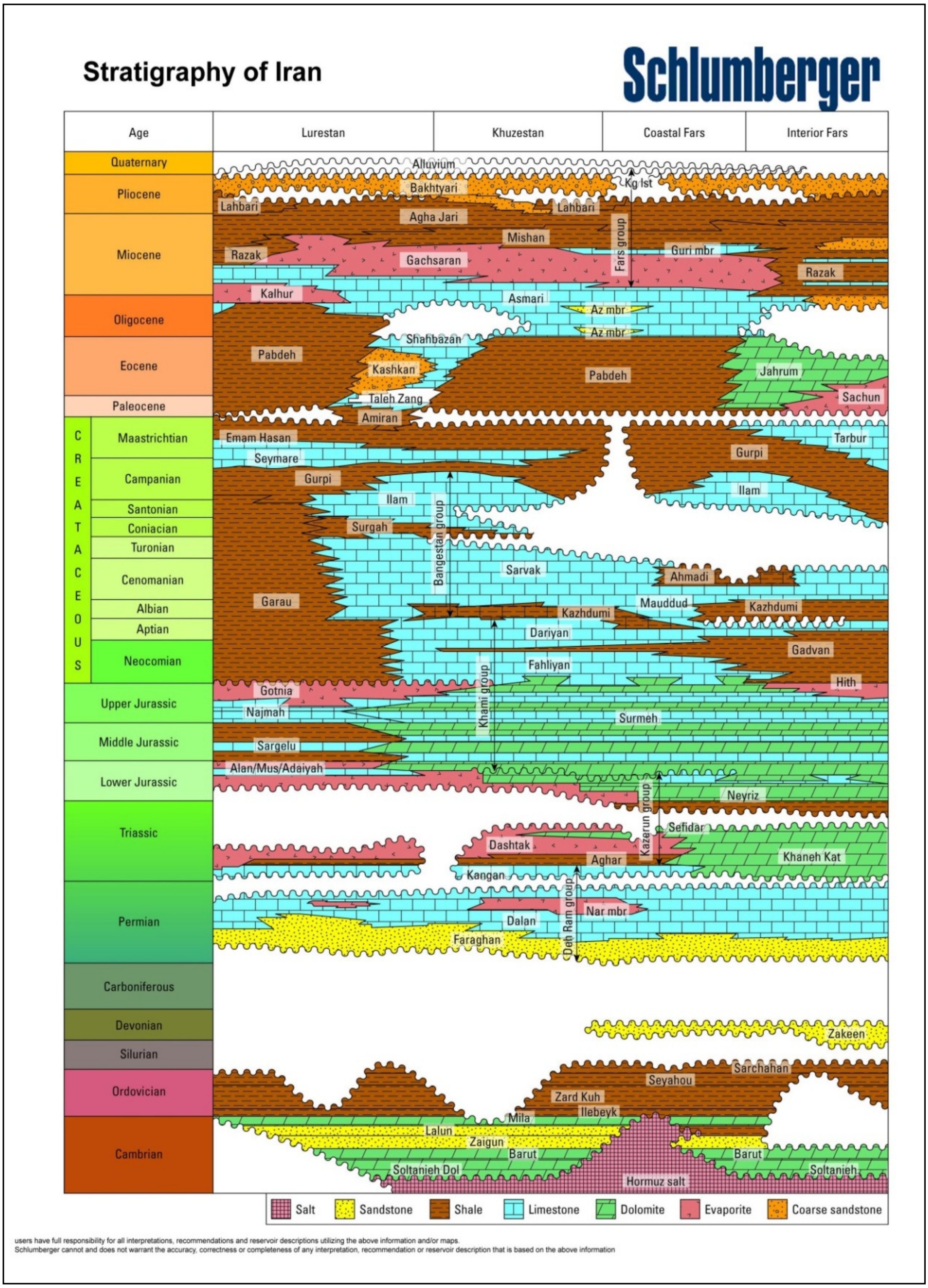

Figure 2: The location of Gachsaran field overlying the Asmari, Pabdeh, Gurpi and the other reservoirs; Stratigraphic nomenclature of rock units and age relationships in Zagros basin [3]

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A carbonate reservoir could be layered or massive and its porous fraction could be comprised of vugs, moulds, karsts, channels, patches of interparticle 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 input to neural-network program to identify different rock-types or litho-types [6, 7].

In this work, 3 wells located in Gachsaran oil field will be selected, and the reservoir heterogeneity analysis will be done in these wells by using the image logs and the other geological logs interpretation. We will do the reservoir heterogeneity analysis in order to both having a better understanding of reservoir heterogeneity system in this field and also explaining the methodology by showing the selected log interpretation examples from this 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 caused by diagenetic processes or/and change in litho-facies. For instance, it could be imagined as a mixture of grainstone and packestone; where grainstone areas could be less permeable due to cementation of the pore space and packestone areas could be more permeable. Similarly, in bioclastic limestone, shell fragments are resistive / dense (hence appear as resistive spots or patches) while the leached parts of the same shells could be conductive / porous (hence appear as conductive spots or patches).

The heterogeneity analysis of reservoirs from borehole images is carried out with BorTex (software used to extract heterogeneities and layer details from images). It may involve more than one iteration used for extraction of formation heterogeneities to optimize the parameters. The results of each iteration are validated by visual examination of the images to see whether all heterogeneities are 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 in different colors on the images: the patches are shown in dark magenta, connected spots in red, and the isolated spots in orange.

The results of heterogeneity analysis are 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 output at any sampling rate. Generally, they are averaged over 1.0 ft window and output at 6 inches to be consistent with the conventional logs.

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

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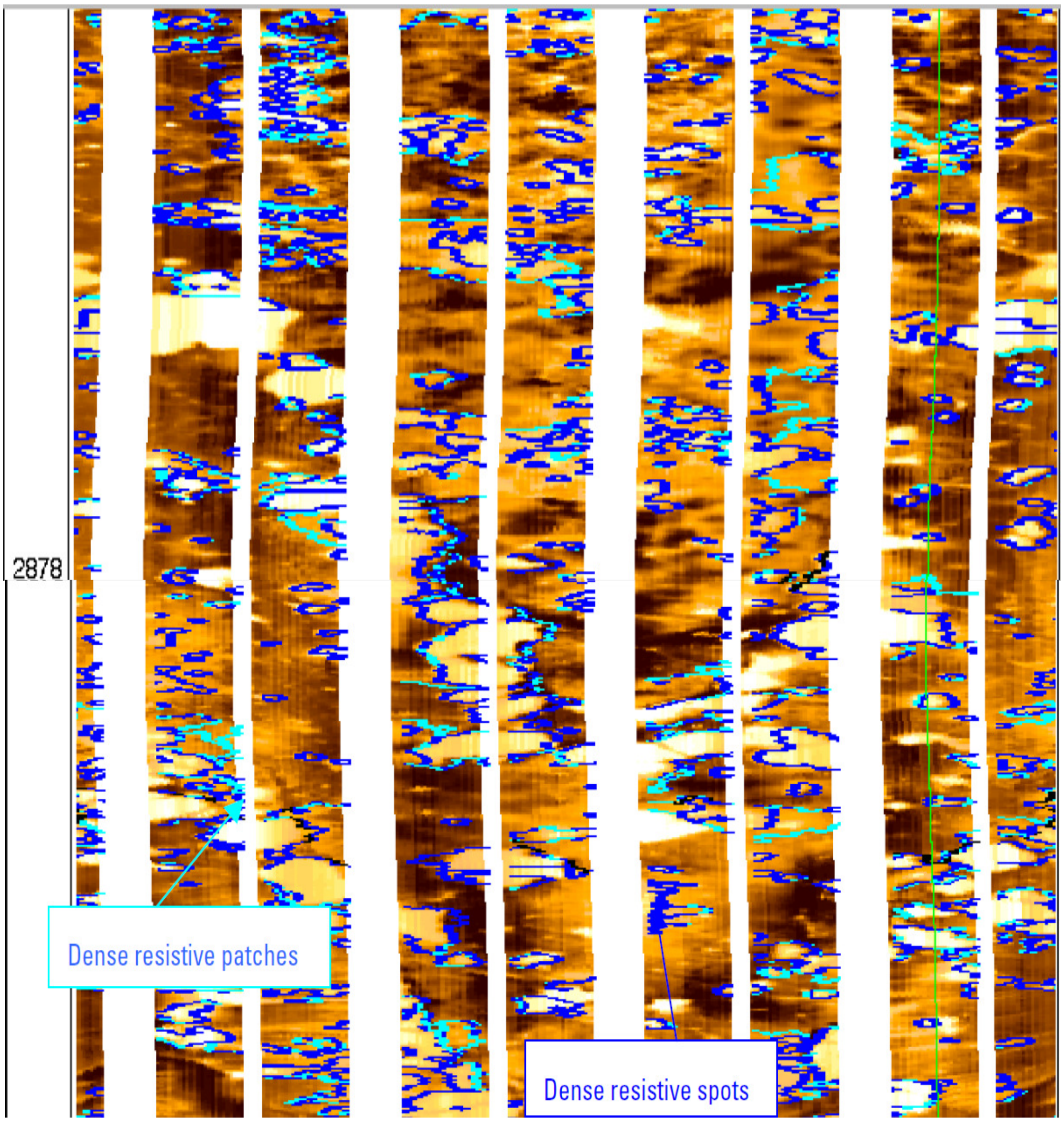

Figure 3: FMI calibrated images highlighting resistive features / areas in a carbonate section. Contoured / outlined in blue are resistive / dense features, patches in cyan and spots in blue. The spots are those dense / resistive features / areas whose dimensions are less than $0.003m^2$)

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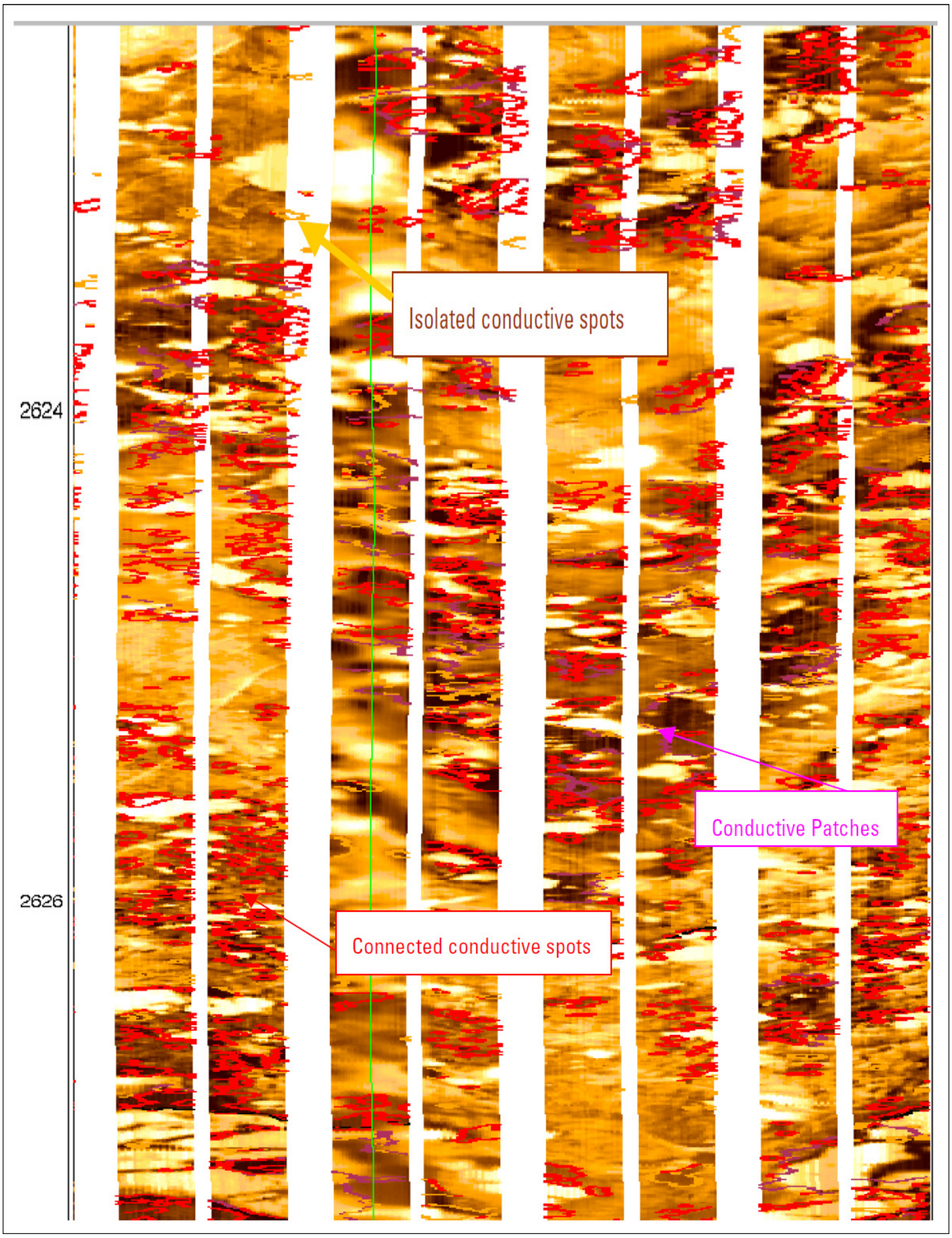

Figure 4: FMI calibrated images highlighting conductive features in a carbonate section. Contoured / outlined in red are conductive-connected spots (i.e., the features smaller than 0.0003 m2), in dark brown are isolated conductive spots, and in dark magenta are conductive patches (i.e. conductive features larger than 0.003 m^2)

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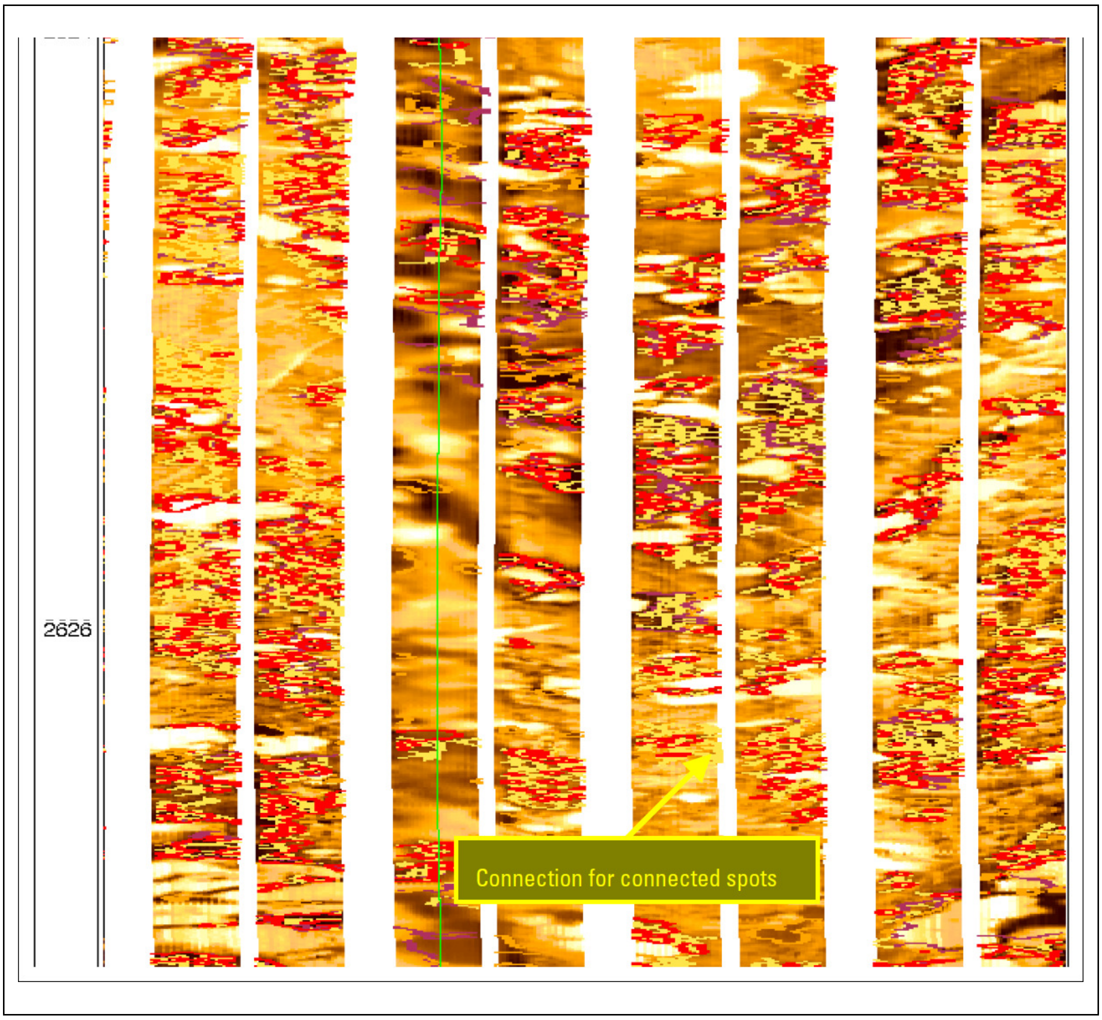

Figure 5: FMI calibrated images showing yellow lines (forming cluster of yellow lines) connecting the conductive spots (red contoured features) also shown in Figure 59 in a carbonate section. Additional conductivity along these connections provides a measure of permeability. The higher the connection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

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

• The intervals 2450-2465m, 2470-2500m, 2550-2570m, 2670-2700m, and 2770-2870m are the most heterogeneous sections. Most of these sections are comprised 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 places, anhydrite patches and layers were observed over the reservoir interval. These features have sharp resistive appearance on image log as well as anhydrite typical response on openhole logs. These anhydritic portions are maximum in the upper sections of the Asmari formation which is an indication of shallowing upward sequence that leads to deposition of evaporites of the Gachsaran formation. Anhydrite can damage the porosity of the formation by flowing as brine into the rock pore space and plug and fill this pore space (Figure 6).

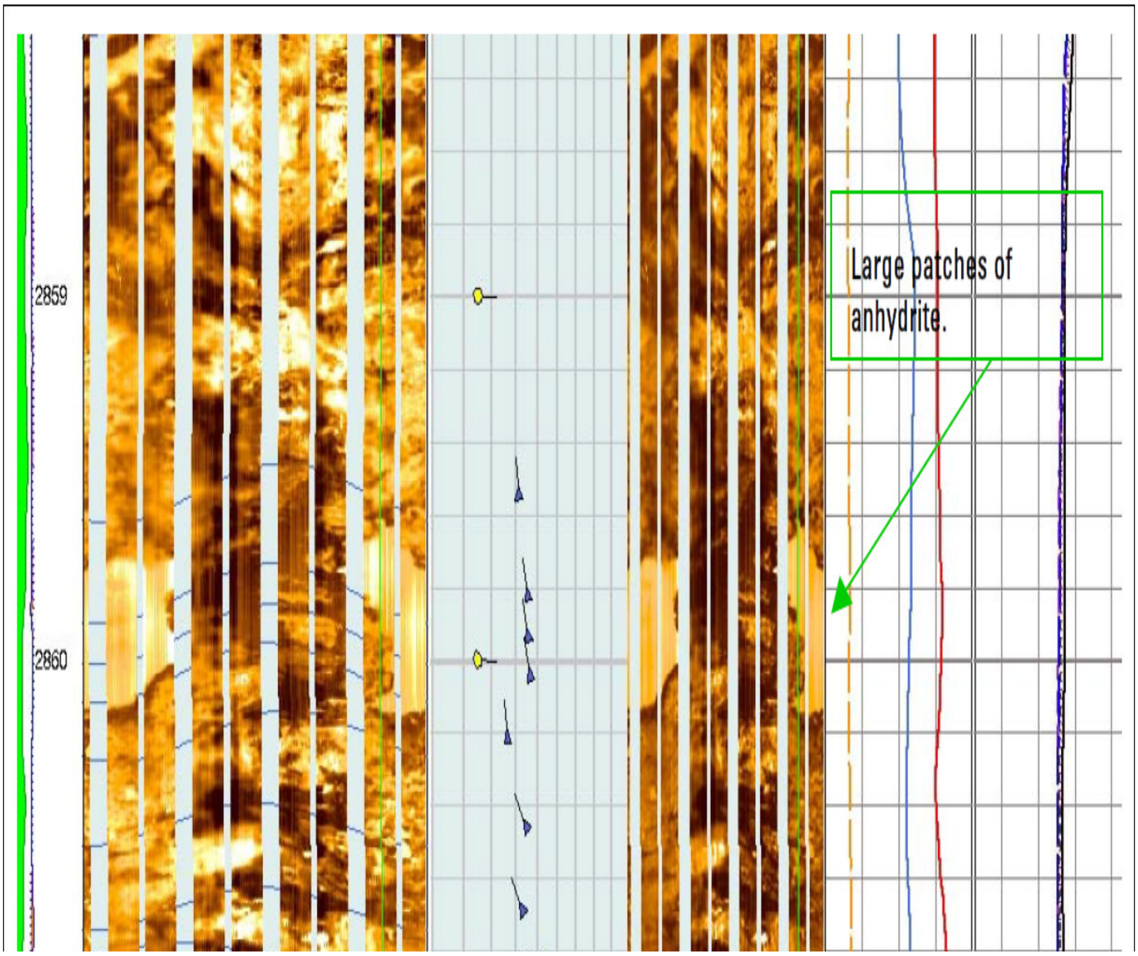

Figure 6: Large patches of anhydrite in the Asmari formation

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

The FMI images from GS-B revealed varying amount of heterogeneity in the form of conductive and resistive (dense) areas across the whole 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 size, shape and conductivity. 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 formations heterogeneities due to dense and conductive anomalies, the rather homogenous sections of 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 are comprised 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).

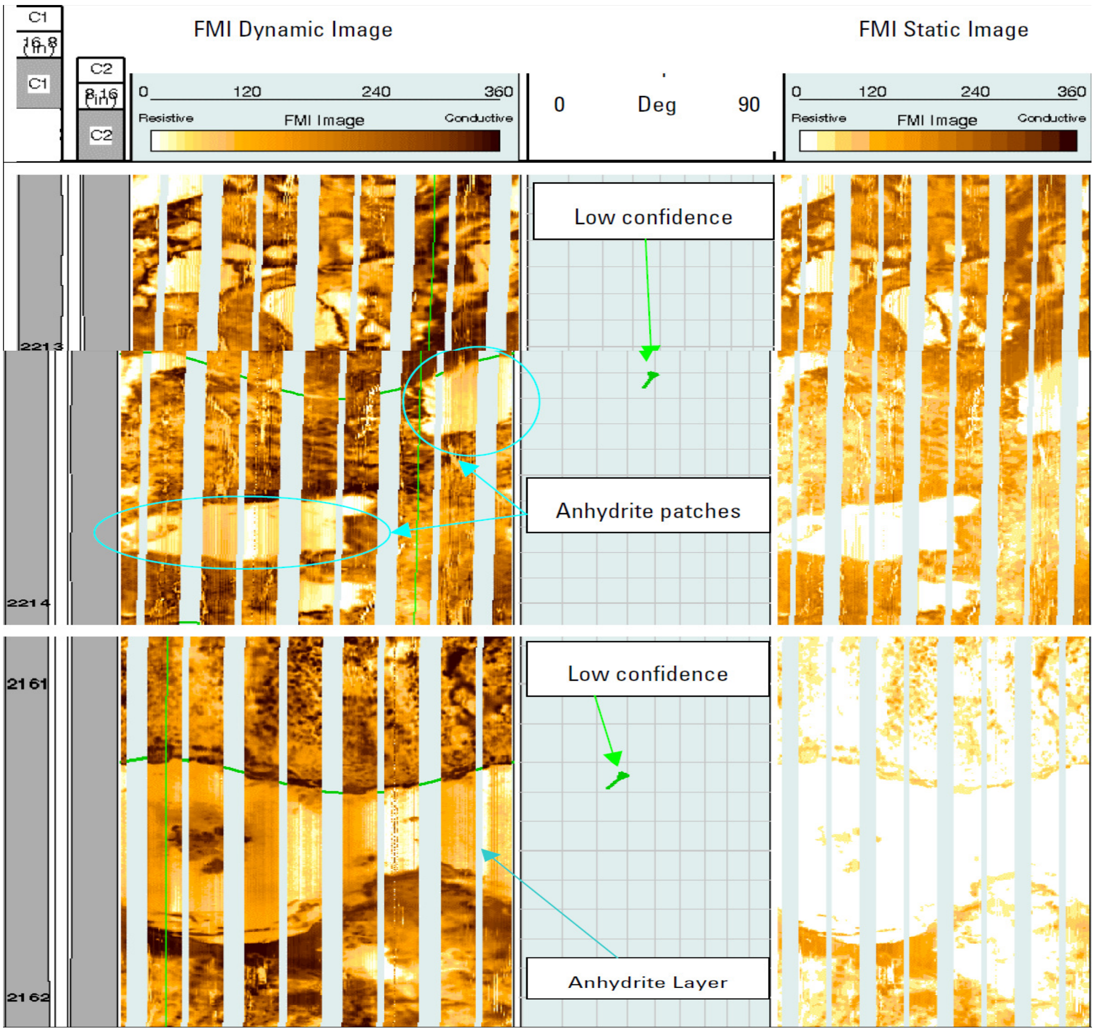

Figure 7: Example of different form of anhydrite (patches and layer) in Asmari formation

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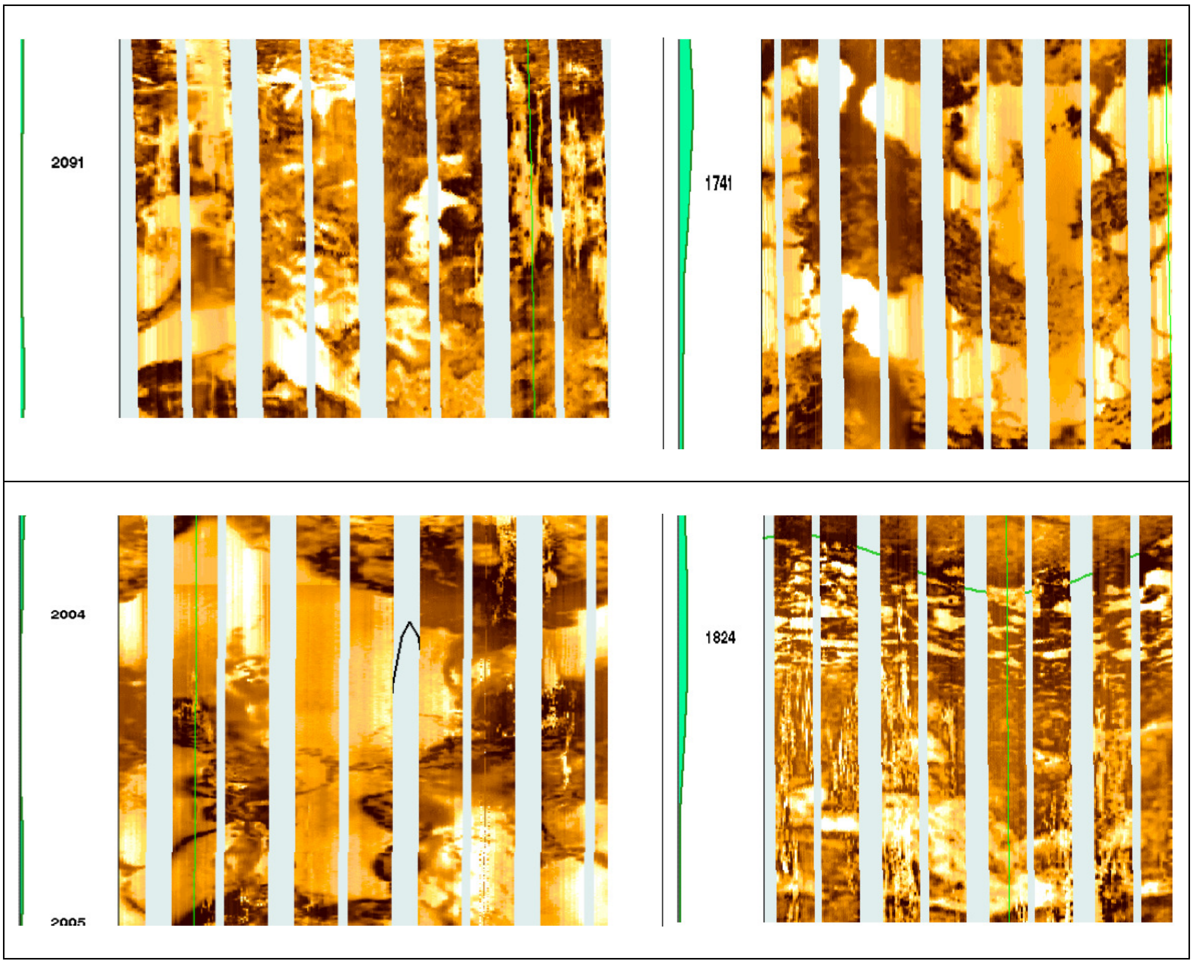
3.3 Reservoir Heterogeneity Analysis for the Well Number GS-C:

The FMI images from GS-C revealed varying amount of heterogeneity in the form of conductive and resistive (dense) areas across the whole 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 size, shape and conductivity. 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 formations heterogeneities due to dense and conductive anomalies, the rather 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 are comprised 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).



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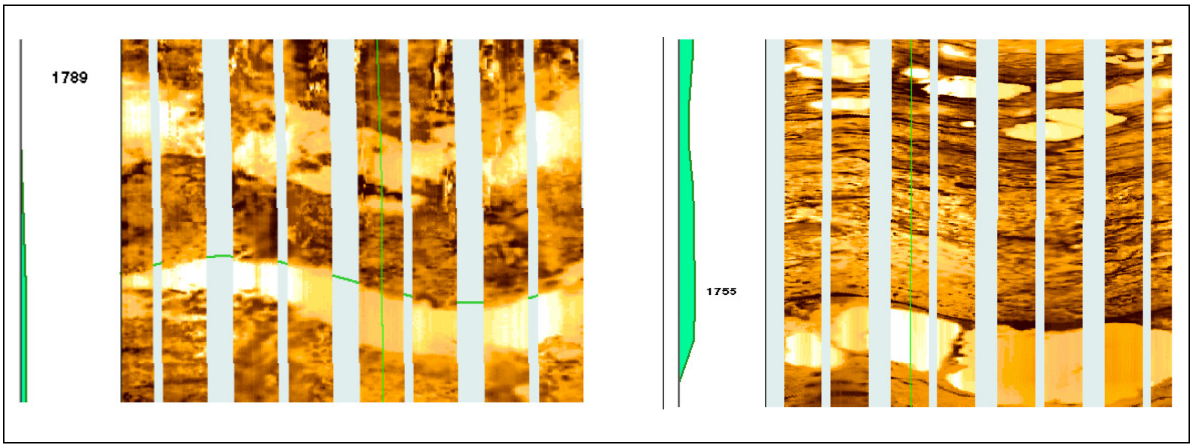

Figure 8: Example of different types of anhydrite occurrences in Asmari formation

4.0 CONCLUSION

This work shows how image log technology can be used to do the reservoir heterogeneity analysis in oil and gas reservoirs. It is an example of reservoir heterogeneity analysis that we did in Gachsaran field, located in south of Iran. In this paper, we describe the method in which we can find out detailed information about the reservoir heterogeneity system in oil and gas reservoirs.

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