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Fracture Modeling in Asmari Reservoir of Rag-e Sefid Oil-Field by using Multiwell Image Log (FMS/FMI)

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Abstract

The Asmari Formation (Oligo-Miocene) is the major oil reservoir in Iran, and is mainly composed of carbonate entities (Limestone and Dolomite). The Asmari Formation produces almost 85 percent of total Iranian crude oil and it is one of the main known reservoirs in the world. Therefore, the study of this rock unit has been a critical subject in the past and present time. This formation is well developed in the Zagros basin, southern Iran as well as in the Persian Gulf. It is believed that the Asmari Formation has a good fracturing system, which is resulted from the Red Sea opening and movement of Arabian Plate toward Iranian platform in the Neogene geological time.

At the time being, these tectonic activities might be continued and create some seismicity and earthquakes in this area, affecting shortening strata in the edge of Arabian plate as well as the whole Zagros basin. One of the main products of this process is fractures. These fractures are very important in the Zagros basin for their effects in the production rate of Asmari reservoir (eg. Rag-e Sefid oilfield).

The majority of studied wells of this oil-field have enough geological and petrophysical data. Among studied wells, eight of them have Formation Micro Scanner, FMS log data.

The purpose of this paper is to find out relation between Curvature of Asmari Formation and fracturing system by using the FMS logs. Fortunately, this method resulted in a good conclusion, which can be applied for the Zagros basin especially, for Asmari Formation, having consistent with those of fracturing system in Kuh-e Khaviz, Kuh-e Pahn and Kuh-e Asmari.

Keywords: *Analytic minimum information, seismic reflection, synthetic seismogram, random noise, Moho phase detection.*

Introduction

The openhole image logs such as Formation Micro Scanner (FMS), Formation Micro Imaging (FMI) and Acoustic Tele-viewer (ATV) are widely used for detecting fractures in many oilfields. The oriented cores define reliable fracture data, and main efforts are to integrate the data from cores and different imaging tools for validate image interpretation.

A three-dimensional (3D) method is useful for interpretation of fracture system in the reservoirs. Borehole image logs in comparison to fullset openhole logs are costly, but it reveals important subseismic images. Unfortunately, image logs have not fully exploited in the Iranian oilfields. Therefore, the FMS interpretation for fracture study was used in the Rag-e Sefid oilfield.

In the field scale application of multiwells image logs gives scattered fracture intensity for every well location. Mapping or griding these limited data points is not reliable. Therefore, we have to use a strong tool for reservoir fracture evaluation. In this respect, we used FMS method, which gives strong correlation between the curvature and strain from the 3D model, since it represents the distribution, degree of development of folds, faults and fractures. As a result, this method can easily determine the structural interpretation and properties of a reservoir.

In this study image logs were utilized for fracture study of Rag-e-Sefid oilfield and the results were compared with outcrops of Kuh-e-Pahn, Kuh-e-Asmari and Kuh-e-Khaviz (McQuillan, 1973; Charchi, 1994). The FMS tool can define fracture spacing and length for explaining of block size for reservoir modeling.

Previous Investigation

So far, many papers have been written to the effectiveness of rock fracture systems as a production mechanism of the limestone reservoirs. In this kind of reservoir, the fracture spacing in fracture modeling is very important input for feeding the reservoir simulation software. All these papers can be categorized in three classes. (1) papers which focus on outcrop, fracture measurement and finding relationship between fracture intensity and bed thickness, grain size, porosity and structural setting; (2) papers that focus on borehole

Image logs and mostly are single well interpretation; and (3) papers which present a method for detecting zones of anomalously high strain in oilfield structures from curvature analysis of natural structures. Herein, the above-mentioned categorizes are more discussed in below:

1- McQuillan (1973) was one of the first person who published a paper on fracture study in Iran. His paper is focused in outcrops of three structures, namely Kuh-e-Pahn, Kuh-e-Asmari and Kuh-e-Pabdeh-Gurpi. In the paper, he showed an empirical relationship between bed thickness and fracture intensity. For this purpose, the outcrop of every structure was divided in different parts (north flank, south flank, crest, north and south nose of structures). He measured all the open fractures in different traverses along the structure and ultimately presented an empirical relation between the "Bed Thickness" and "Average Fracture Density". Later, the McQuillan's method was applied in another outcrop in Kuh-e-Khaviz by Charchi (1994). Likewise, this method has been used in the other parts of the world, as it has been mentioned by Nelson (1985). This method is not a completely qualitative study, but it represents a quantitative fracture study in Iran for the first time. The results of these papers help to understand the use of subsurface fracture modeling for the Asmari Formation reservoir.

2- In the second category, the use of image logs have been discussed in details by Wu & Pollard (2002). These workers extend the normal Image logs from one dimension in boreholes to 3D in the surrounding rocks. Recently, the image logs study has been carried out in western part of Asia countries (UAE, Qatar and Iran) by Akbar and Sapru (1994).

3- In the third category, the Gauss's theorem has been applied by Lisle (1994). This method provides a technique for indicating regions on a folded surface which have suffered anomalously high strains. Likewise, this technique predicts that area with high curvature should contain more fractures. This mathematical method is programmed in many of the modeling software products and it calculates second partial derivative from any surface grid, representing the Iso-Curvature map. This method was testified by Hennings et al., (2000), in order to find out the imperial relation between curvature and fracture intensity. Although in this category, they applied this method

on outcrop, but also they suggested using this method for subsurface image logs.
This paper is an integrated study from these three methods. It uses multi-borehole image logs with extending surface method of McQuillan in subsurface and create a 3D model of fracture systems in Rag-e-Sefid oilfield.

Geology of Rag-e-Sefid Oilfield

The Rag-e Sefid Field is located in Khuzestan province, approximately 6 Km in nearest distance from the Persian Gulf, southwest Iran. The Rag-e-Sefid structure was initially recognized by surface geologists (Wily and Habibi, 1978), and later on, geophysical processes was carried out on this structure for its dimensions, by department of geophysical exploration and drilling was conducted on this structure (Wily and Habibi, 1978). As a result, Rag-e-Sefid structure was defined as an accurate asymmetrical anticline. This structure is boomerang shape and it is surrounded by other adjacent structures such as Bibi-Hakimeh, Pazanan, Agha-Jari, Ramshir, Tangu, Zageh and Hendijan (Fig. 1). This structure has 45 Km length and 5-9 Km width and geographical coordination of Eastern Longitude 49° 40’ to 50° 25’ and Northern Latitude 30° 10’ to 30° 30’ (Fig. 1). In the Rag-e-Sefid structure, the Asmari Formation on the North flank has an average of 19° dip (ranges: 15°-23°) and on the South flank an average 36° dip (ranges: 18°-60°). However, base on the position of the well at entry point, the average dip is 45° away from the hinge line (Wily and Habibi, 1978).

The Rag-e-Sefid structure has two culminations (Northwest and East), respectively the trend of the Northwest culmination is parallel to the Safania-Noruz-Bahregansar-Tangu-Bangestan paleo-high or in north-south direction (Arabian trend) and the trend of east culmination is parallel to the Zagros trend or in Northwest-Southeast direction (Rezaie, 2003). The crest line has bending between these two trends with 130°. This structure has three-horizon reservoirs, which in ascending stratigraphical order are Khami Group (Gas bearing), Bangestan group and Asmari Formation (Oil/Gas bearing) (Fig. 2).

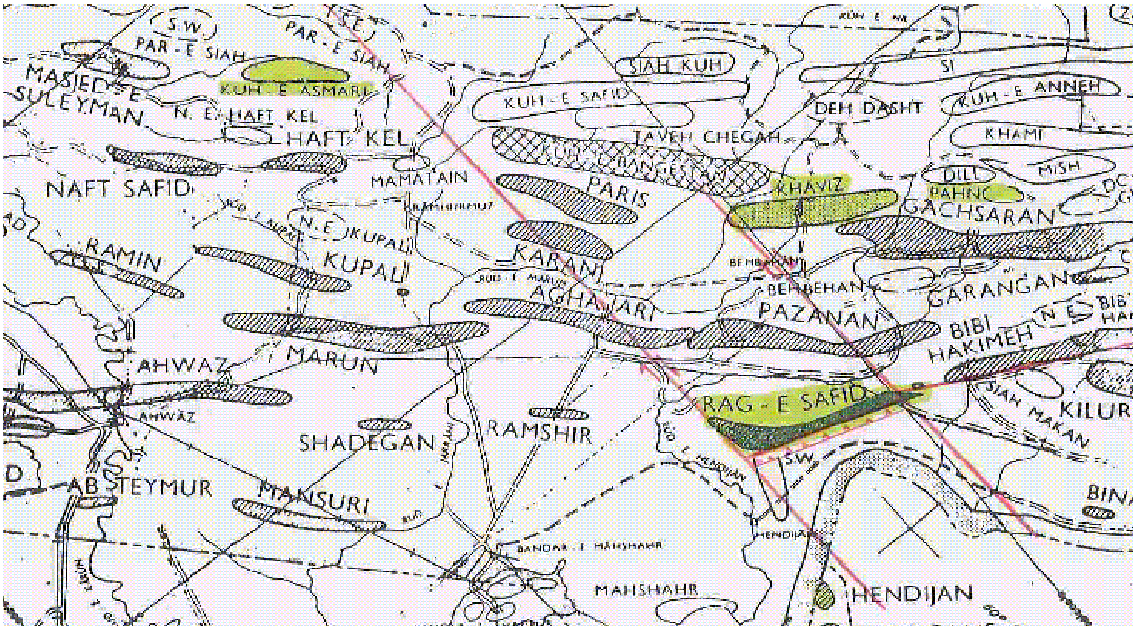

Figure 1- Location map of Rag-e Sefid structure and adjacent areas

Based on biostratigraphical data, there is a hiatus between the Pabdeh and Sarvak Formation. This hiatus encompasses Gurpi, Ilam, Lafan and even upper Sarvak Formations, suggesting a paleo-high in the Rag-e-Sefid Area (Figure 2).

The first exploration well was drilled in the Rag-e-Sefid structure (RS-01) and reached to the Asmari Formation in 1963. The second well drilled on this structure for evaluation of the Bangestan and Khami groups (RS-02) in 1964. This field has produced 199000 BOPD (total 512.76 Million Barrels oil) since 1966 to 1979. The estimated hydrocarbon of this reservoir is 2.4 Billion Barrel oil and 20 Trillion Cubic Feet gas (Motiei, 1995).

The Asmari oil reservoir is characterized by 30° API and low sulfur, whereas the Bangestan Oil reservoir is marked by 25° API and 3.5% sulfur. Based on data from oil production, it has been indicated that the amount of sulfur increases in crude oil of Asmari Formation by production. This phenomenon suggests that the oil of Asmari and Bangestan Reservoirs are connected by fractures and faults. It should be mentioned that, more than 118 wells have drilled in this structure up to now. 95 out of 118 wells drilled in the Asmari reservoir, 11 in the Bangestan reservoir and the rest for the Khami reservoir.

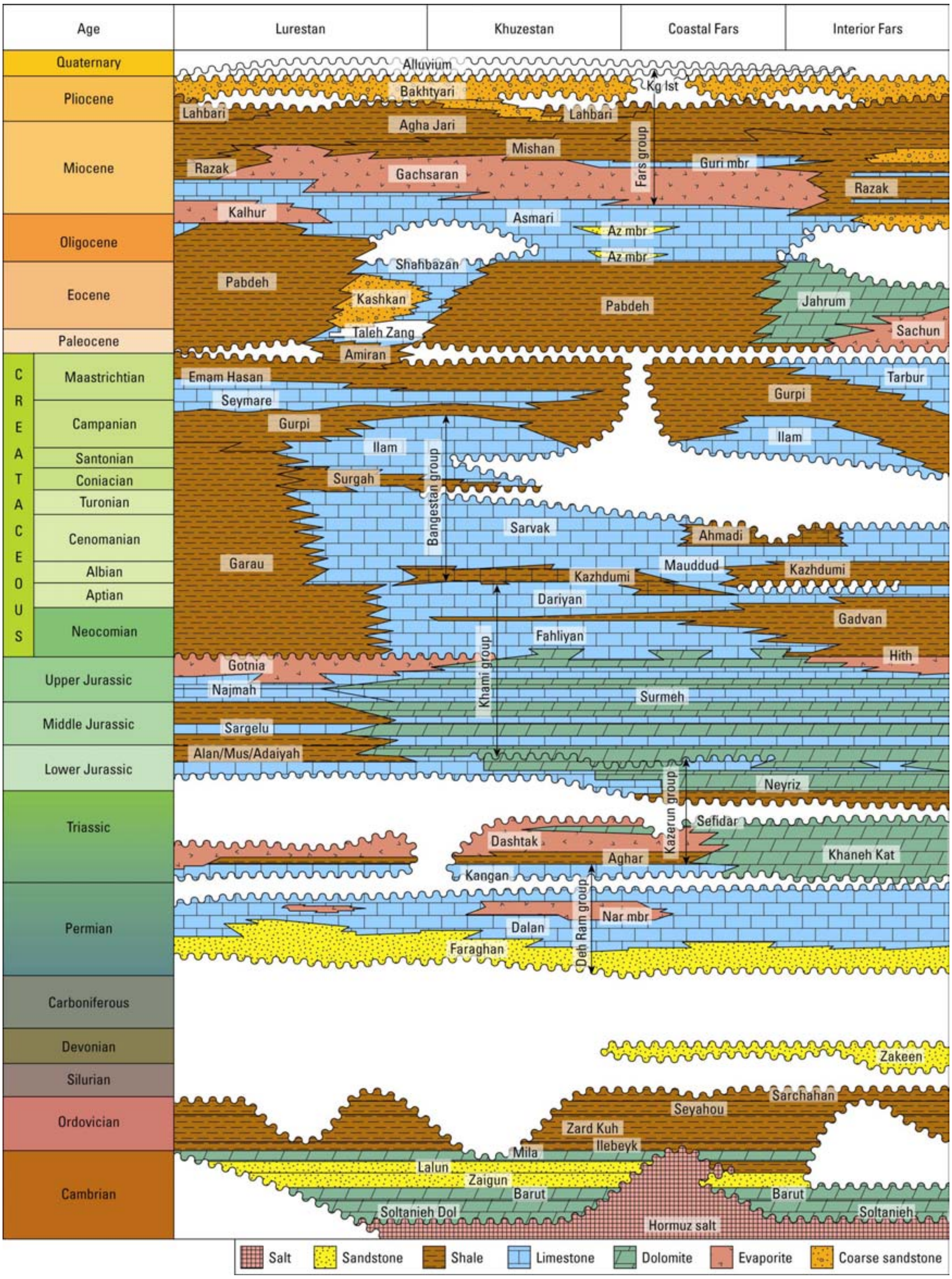

Figure 2. Stratigraphic nomenclature of rock units and age relationships in the Zagros basin

Fracture Data

In this study, eight wells from the Rag-e-Sefid oilfield were selected to investigate their image log (FMS). RS-74, RS-63 and RS-64 wells are located on the north nose and flank, well RS-71 on the south nose, and RS-61, RS-52, RS-67 and RS-70 are located on high deep and faulted of south flank (Fig. 3).

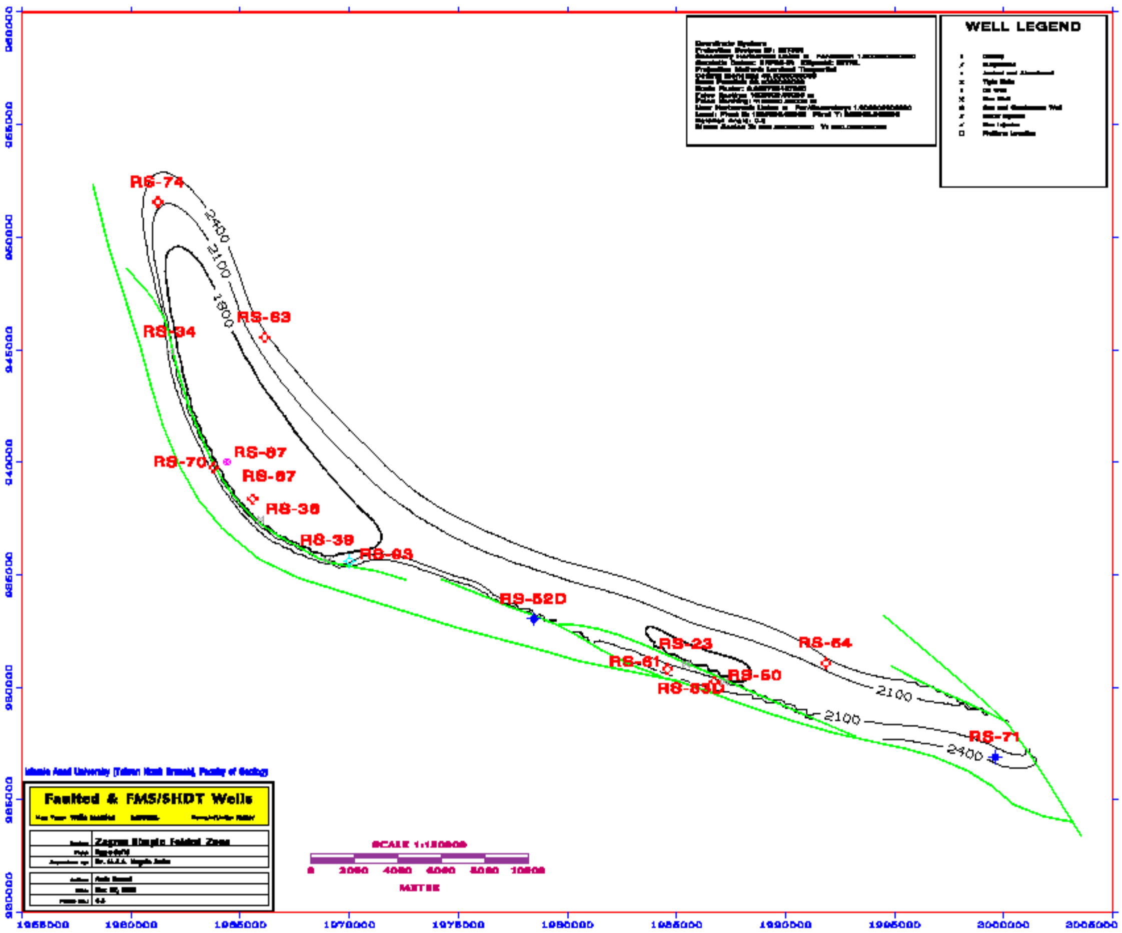

Figure 3. The FMS bearing wells location on the Asmari UGC map

The FMS log does not cover all the Asmari intervals of these wells and it only includes the uppermost zone of the Asmari Formation. Therefore the FMS log application was focused for processing and interpretation this part of formation, consistent with previous workers (McQuillan, 1973 and Charchi, 1994). In this study, all the FMS data were processed and the main geological features such as; fractures, bedding and faults were interpreted. In each well, 3 to 7 beds with different thickness were chosen and their fractures were counted.

Subsequently the “Average Fracture Frequency” was computed for each bed. The result was plotted on a log-log graph. As it can see on Figure 4, the horizontal axis shows the reverse of bed thickness and vertical axis represents the “Fracture Frequency”.

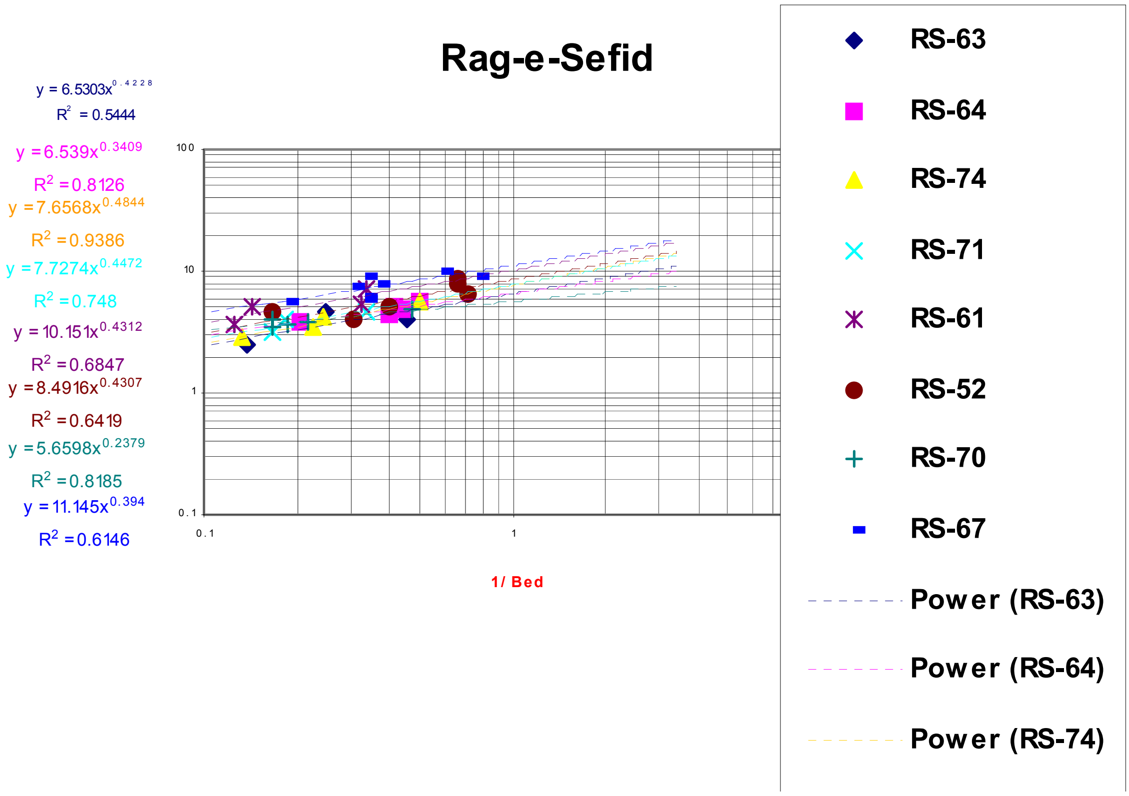

Figure 4- Log-Log Graph showing relationship between reverse of bed thickness and “Fracture Frequency” in the studied wells of Rag-e Sefid structure

Some critical points of this investigation can be summarized as the followings:

1- South flank wells (RS-67, RS-52, RS-61 and RS-70) due to high folding and faulting have higher fracture frequency in comparison with those of north flank wells (RS-63, RS-64 and RS-74).

2- As it can be seen on the left side of graph, an empirical formula has calculated for each well. Base on these formulas, fracture frequencies can be given for any thickness, which is the best quantitative parameter for fracture spacing in the reservoir modeling. By using these formulas one can reach to easy calculation, map-able and reasonable interpretation in the structural features. Likewise, the obtained properties can be used to correlate the fracture frequencies, structural geometry and other reservoir properties.

Curvature Data

All carbonate rocks have elastic behavior in normal stress regime. These types of rocks are stretched or compressed and created anticline and syncline structures during the folding processes. Likewise, the continuity of these processes will be resulted in reverse fault, trust fault and imbricated structures as well as subduction blocks during the geologic time. Based on geological investigations in southwestern Iran, The Zagros basin has undergone intensive folding, faulting and subduction during its geological history. Moreover, the Arabian platform has subducted under the Iranian platform at the time of collision of these two paleoplates (Nogole-Sadat, 1985). It is believed that the stretching process has resulted in broken of the outer layers during the extension stress/strain. Therefore, the high curved area of each structure contains more fractures rather than low curved area.

In this study, for calculation of curvature area the formula of $C = 1 / R_{curvature}$ was used (C = Curvature and R = radius of curvature). An advanced mapping and girding software was used in this study, in order to interpret the curvature of Rag-e-Sefid structure. The calculation was resulted in first and second partials derivatives. The first partial derivative is “rate of maximum dip change” and the second partial derivative is “curvature”. As it can be seen on Figure 5, the obtained data from underground contour map (UGC map) were used to produce Iso-Curvature map. The Iso-Curvature map of Figure 5, has different colors to interpret the fracture anomalous of Rag-e-Sefid structure, for instance, the red and yellow colored contours represent the high curved surface with high fractured area, whereas the green and blue colored contours represent low curved surface with less fractured area. As it has been shown on Figure 5, the high curved areas locate on the wells of south flank of Rag-e-Sefid structure, whereas the low curved areas are related to the wells of northern flank.

Therefore, the wells of southern flank of Rag-e-Sefid structure are more productive than those of northern flank. The obtained data was used to draw Iso-Fracture Intensity map since this map is one of the best guide maps for purposes of correlation, edition and production. It should be mentioned that, we cannot reach good technical points if one use to plot the obtain data of 8 wells, therefore, both Curvature and Fracture Intensity were plotted to solve the problem (Fig. 6).

Modeling Iso-Fracture from Iso-Curvature

As it can be seen on Figure 6, the numbers of studied wells are on the horizontal axis (1 = RS-74, 2 = RS-63, 3 = RS-64, 4 = RS-71, 5 = RS-61, 6 = RS-52, 7 = RS-67 and 8 = RS-70) and the vertical axis shows the geometrical parameters of Curvature and Fracture Intensity for the studied wells of Rag-e-Sefid structure. As it can be seen in Figure 6, the Curvature and Fracture Intensity have excellent correlation with each other. However, the well of RS-52 does not match with others, since this well locates exactly on the highly faulted area of the structure.

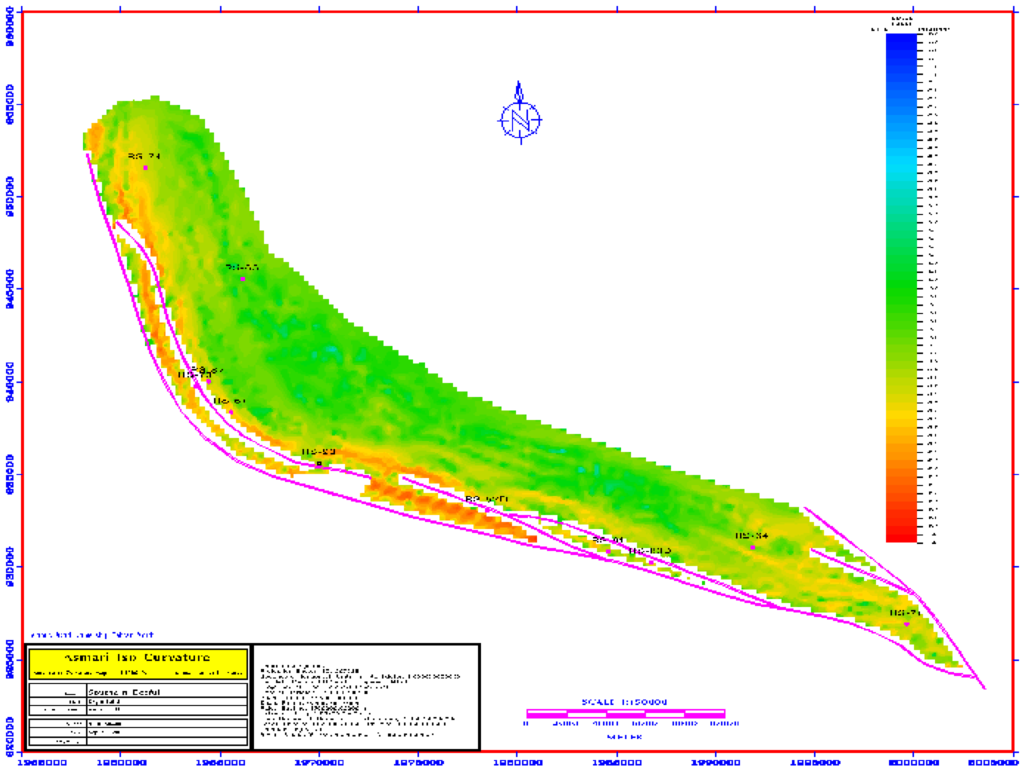

Figure 5. The Rag-e Sefid, Iso-Curvature map

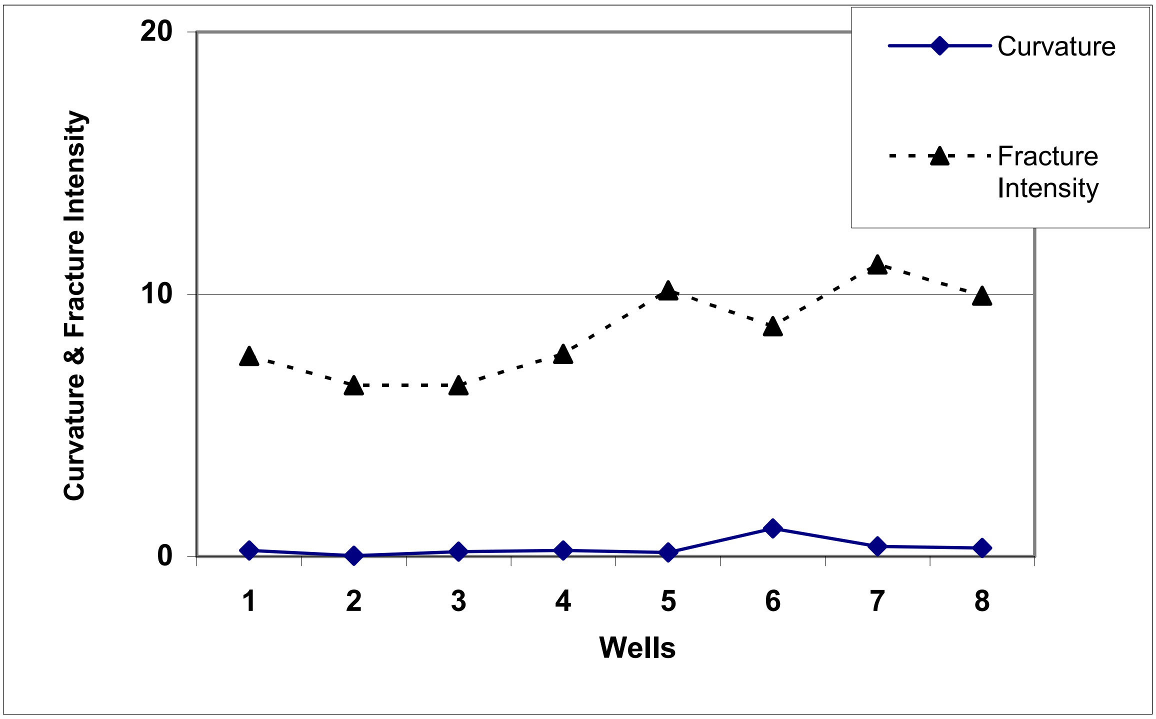

Figure 6. The graph of Curvature and Fracture Intensity in the studied wells of Rag-e Sefid structure (Well 1-3 in north flank and 4-8 in south flank).

As it can be seen on Figure 6, there is a good correlation between the Curvature and Fracture Frequency for editing inter/extrapolating of Iso-Fracture density, but there are some ambiguities on this graph. Therefore, the Figure 7 was drawn by decimal number of Curvature for more understanding relation between the Curvature and Fracture Intensity of the Rag-e-Sefid structure. For drawing this graph the small value of Curvature was multiplied by 1000. The interpolations of data were resulted in two parallel lines. The upper line (dotted line) is related for the wells of southern flank of Rag-e-Sefid structure, representing high Curvature and faulting. The lower line (continuous line) is concerned to wells of northern flank with normal curvature. Moreover, another graph was created based on the Northing and the Easting of studied wells of Rag-e-Sefid structure (Fig. 8). In this graph, the coordinates of Easting and Northing have been plotted, respectively on the horizontal and vertical axis. As it can be observed on Figure 8, there is also a good correlation between Fracture Intensity of southern and northern flanks of Rag-e-Sefid structure.

The data combination of Figures 7 and 8 were resulted to graph of Figure 9, which represent the Iso-Fracture Density map of Rag-e-

Sefid structure. This map can be easily used for evaluation of reservoir modeling not only for Rag-e-Sefid but also for other oilfields of the Zagros basin.

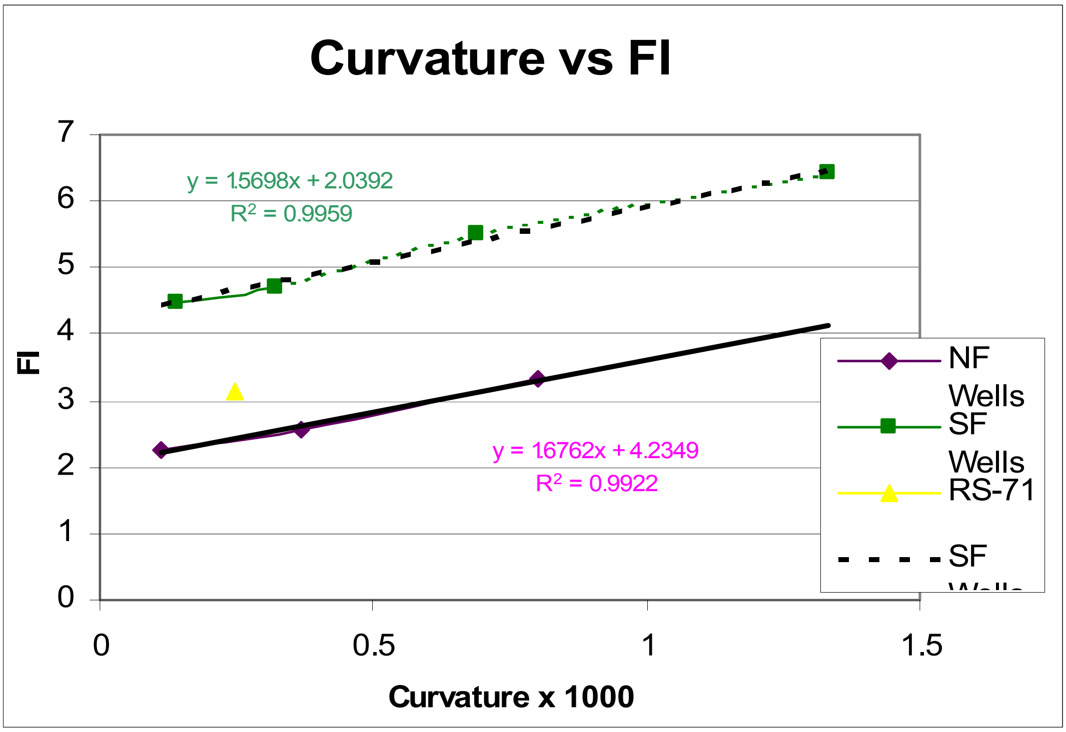

Figure 7: The graph of Curvature and Fracture Intensity in Rag-e Sefid structure (upper line for southern and lower for northern flank wells)

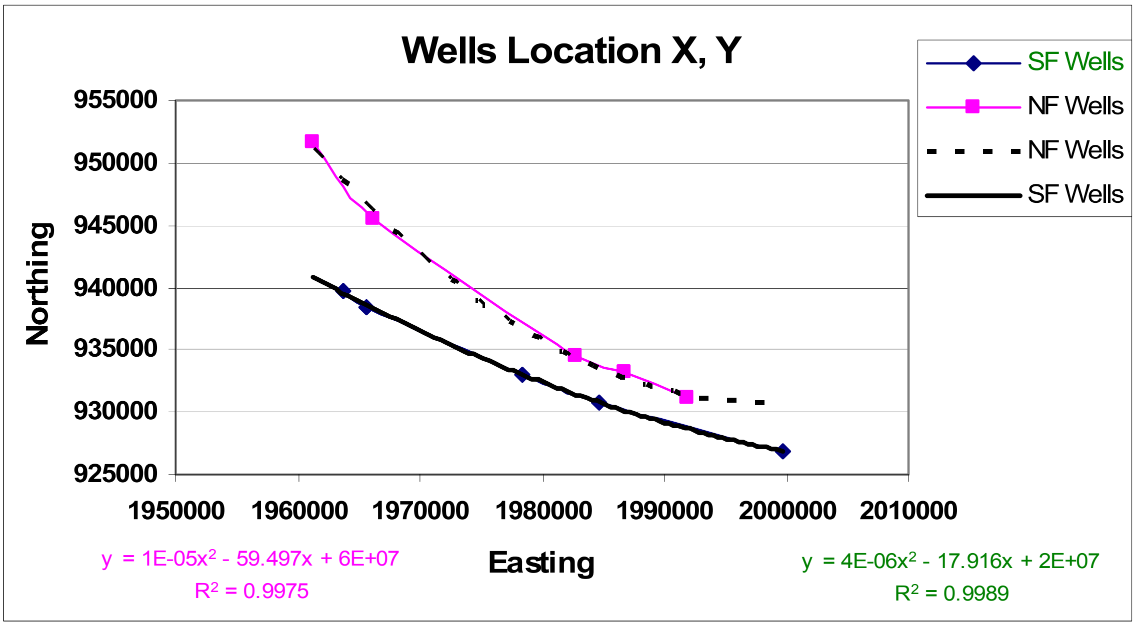

Figure 8. Data combination of figures 6 and 7 in Rag-e Sefid structure (upper line for northern and lower line for southern flank wells)

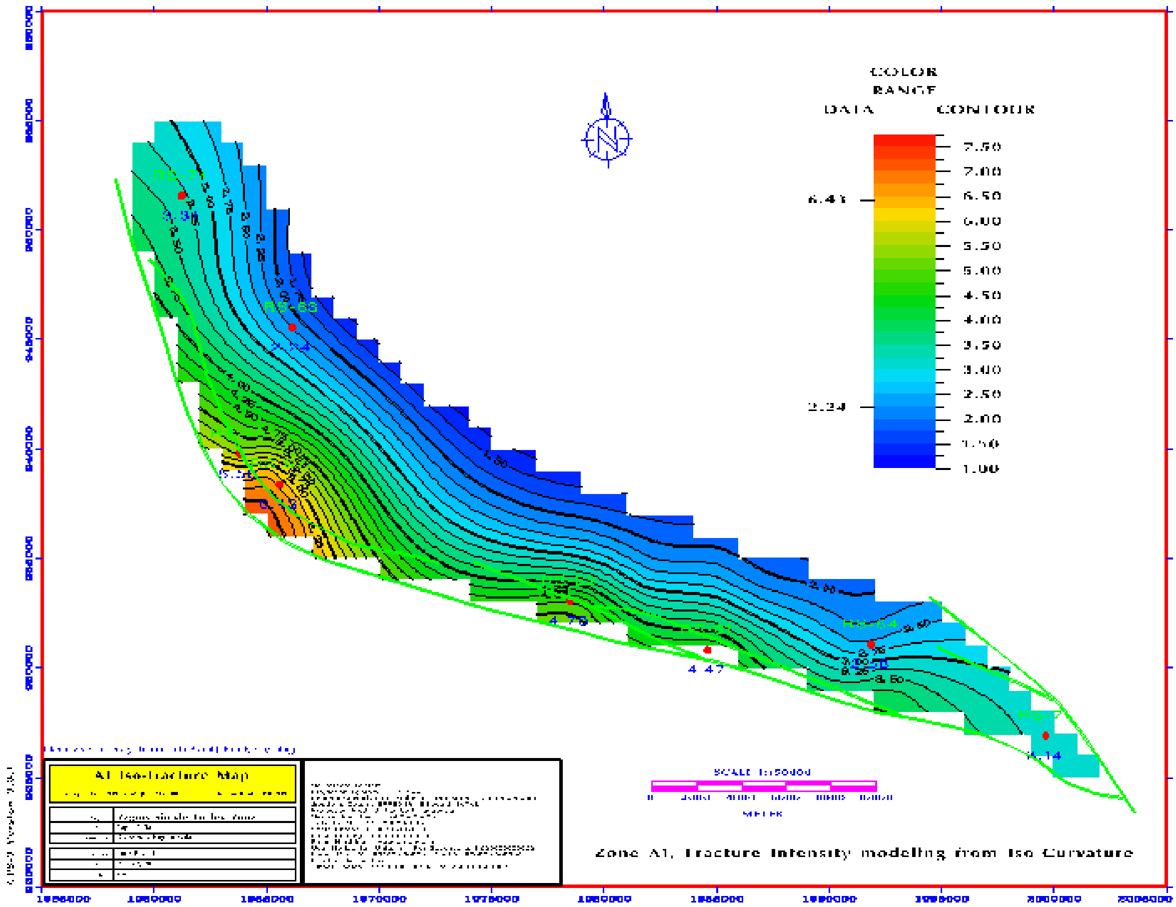

Figure 9. Iso-Fracture map of Rag-e Sefid structure

Conclusions

The study of Rag-e-Sefid structure was resulted in the following conclusions:

1- The investigation on fracture system of Asmari Formation of studied wells in the Rag-e-Sefid structure can match with the results of surface fracture study of this formation in Kuh-e Pahn, Kuh-e Asmari (McQuillan, 1973) and Kuh-e Khaviz (Charchi, 1994).

2- The similarity between the Fracture Intensity and Curvature of the Rag-e-Sefid structure suggest the same origin for these two parameters (compressional stress).

3- The Iso-Curvature map is a good guidance for preparation of Iso-Fracture Intensity map.

Here it is recommended that the multiwell image logs which was carried out for fracture modeling in the Rag-e-Sefid wells can be applied for other oil-fields in the Zagros basin.

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