



Determining the structural discontinuities in fractured carbonate reservoirs using FMS and VSP logs in the one of oil fields on West of Zagros

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Article info

Original: 06.10.2015

Revised: 02.05.2016

Accepted: 19.05.2016

Published online:

15.06.2016

Key Words: *fracture carbonate reservoirs FMS log VSP log west of Zagros*

Abstract

A study is made into the structural discontinuities in an oil field to the west of the Zagros mountain range, on the border between Iran and Iraq. Many oil reservoirs in the west of Iran and in the Kurdistan Region of Iraq are of fractured carbonate type. Faults and folds can change the structure of the reservoir. In such reservoirs, the study of the structural discontinuity leads to the discovery of complex geological structures. This complexity can impact on the discovery of a path to the reservoir. In one such oil field in western Zagros the reservoir was expected to be located at a particular depth but the new drilling well did not meet the reservoir. In this paper, Formation Micro Scanner (FMS) and Vertical Seismic Profile (VSP) have been used to determine the location of the structural discontinuities. Due to the low resolution of the VSP seismic data we find that it discovers the major faults and the formations borders, but will not be able to determine the small changes and complexity of the structure. Conversely, the FMS log(?) easily recognizes these microstructures. Therefore, with a combination of large-scale VSP data and small-scale FMS data we construct a 3D model. The results show that the well has been cut by five faults that dip to the north with the exception of a first fault to the south slope. To create the faults planes, AutoCAD software was also applied and the results are shown in this study.

Introduction

Knowledge of condition layers and underground formations lithology is the one of the main concerns of geologists and petroleum engineers to explore the characteristics of the reservoir. One approach to obtain the correct information from the reservoir is drilling well (Corn Cornet, J. and Langeland, 2013). The wells can give us valuable subsurface information those are include core, bit drilling, cutting, formation fluid samples and well log (Schlumberger, 1989). Logs don't taken directly to the desired properties, but the advantage of this method is continuously information. The tools are also designed so that it's detect formation changes vertical and lateral, formation properties on an ongoing (Serra, 2003).

One of the important methods of geophysical exploration is seismic. It is based on the vibration of synthetic elastic waves near the surface using explosive sources or Non-explosive (Pereira & Jones, 2010). Waves vibrate particles in the environment that receiver convert to weak electrical signals. The signals are recorded digital (Pereira & Jones, 2010). Geophone was recorded time at ground level and with understand the depth of the horizon, can be calculated the speed in this manner. Vertical Seismic Profile (VSP) is one of the newest most important methods of oil exploration that correct layer model to the classification of surface seismic data interpretation (Wiederhold, 2001). VSP method restricts is installed and running time to high costs and rig time (Robert, 2000). In VSP, energy source is placed on the surface near the well and receivers into the well, at the surface making explosion in different parts (Hardage, 1983). generally there is 15 meter distance between receivers (figure 1). With regard to the environment, underground geological structure and purposes used various arrangements (Slim, 2005).

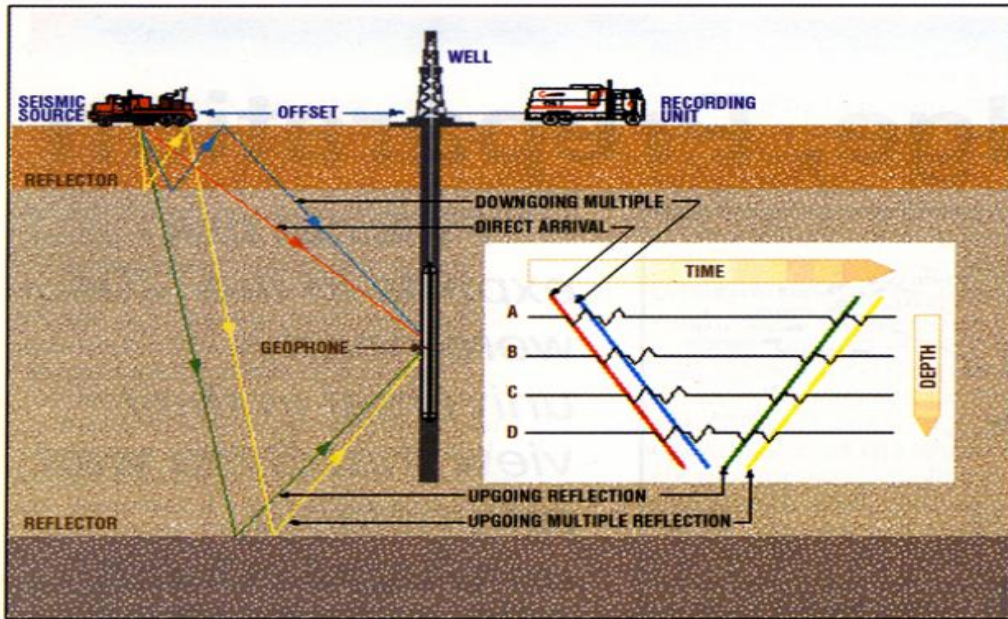


Figure 1 : Typical equipment setup and seismic ray paths in VSP (Robert, 2000)

Formation Micro Scanner (FMS) is an imaging tool in the well. It has some electrodes on two pads arranged. The flap has 24 electrical receivers in two rows (figure 2). 64 electrodes transmit waves and receiving those in the formation (Serra, 1989). More log methods such as well logging, well testing and mud loss are low resolution and don't identify small-scale fractures around well (Corn Cornet, J. and Langeland, 2013). But imager logs offer high-resolution images from the well. The main application of imager logs is identify fractures and its characteristics (Jordan & Frank, 1986). The results of FMS is similar to the results of core analysis and complete the core data (Slim, 2005). Imager logs show high resistance areas in white such as anhydrite, shale fossil or hydrocarbons in the cores and show low resistance areas in dark such as pores filled by water or shale (Serra, 1989).

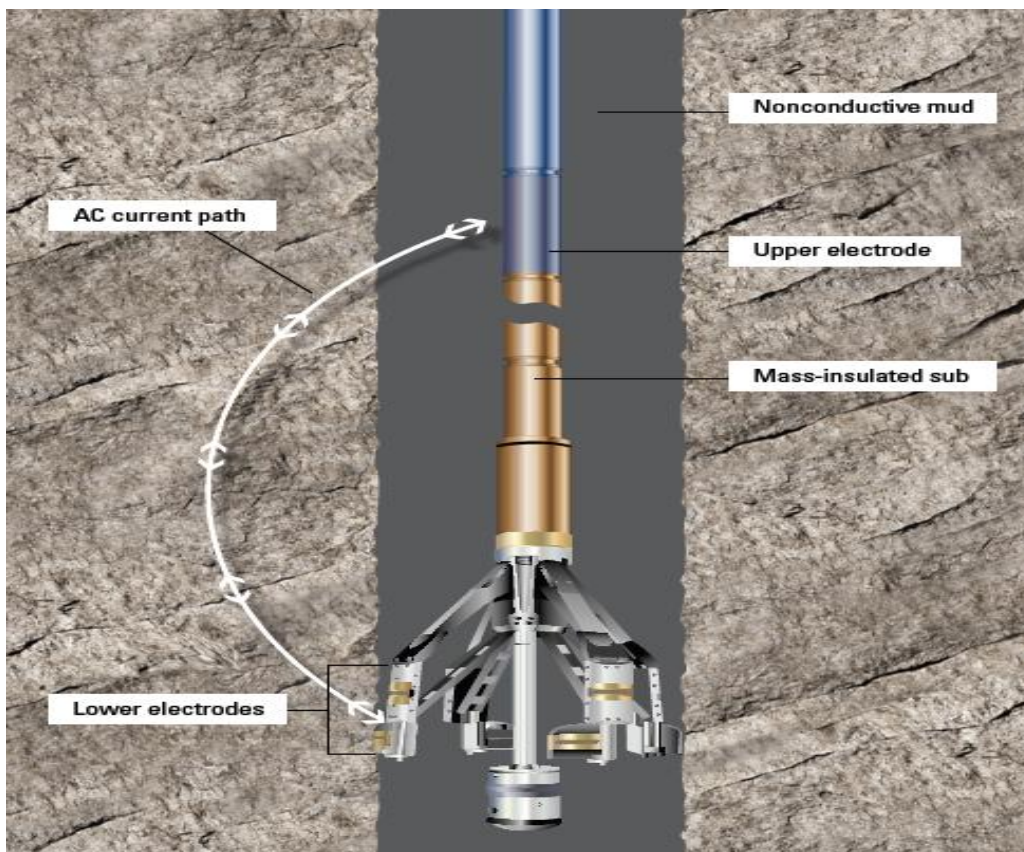


Figure 2 : FMS measuring tool Method (Schlumberger, 2013)

Case study

Company planned a deviated well A as production well about 100-150m from the south of well B. The well had been drilled southward in hoped that it would intersect the reservoir, which was assumed to be dipping SSW. Unexpectedly, the well missed the Asmari reservoir while Well B penetrated Asmari and Pabdeh reservoirs. A normal VSP surveying planned to investigate the cause of that well lead to miss the reservoir. The survey was carried out with a Combinable Seismic Imager tool (CSI) on 18th of October 2002. Also FMS log run on the same day between the intervals 773m to 2603m to study the dipping pattern along the well trajectory. Therefor using structural model information can lead us to design sidetrack trajectory to reach the Asmari reservoir.

Table1 shows the slope of the faults and blocks obtained by FMS (Moradi, 2015). That shows six faults in all other wells have been observed.

Table1 : Geological strata that well A cut them

| Block number | Interval (m) | Dip azimuth | Dip (interval) average | Explanation |
|--------------|--------------|---------------|------------------------|--|
| 1 | 800-1270 | North | (36-85)/65 | Steep multiple flexors |
| Fault 1 | 1270 | SSE | 13 | Northward drag near Fault-1 |
| 2 | 1270-1650 | North | (15-90)/45 | Multiple flexors, drag near the fault (F2) |
| Fault 2 | 1650 | North | 17 | No drag |
| 3 | 1650- 1935 | North | (42-82)/65 | Steep concave beds |
| Fault 3 | 1935 | NNW | 29 | |
| 4 | 1950- 2075 | North & South | (30-85)/75 | Overturning & drag near the fault plane |
| Fault 4 | 2075 | North | 9 | Short drag |
| 5 | 2075- 2280 | South & North | (28-51)/38 | Semi-recumbent |
| Fault 5 | 2280 | North | 18 | No drag |
| 6 | 2280-2450 | South | (25-50)/28 | drag |
| Fault 6 | 2450 | NNW | 12 | No drag |
| 7 | 2451-2600 | South & North | (45-90)/70 | Steep flexor |

Run Model

The corrected VSP image showed a number of south dipping reflectors away from the well (Figure 3). However, there is no certain dipping pattern of reflectors near the wellbore. The top-Asmari reflector, penetrated by the nearby well B at 1264m True Vertical Depth Sub-Sea (TV DSS) ,appears to be abruptly terminated cross a low angle boundary. As well as some deeper and shallow reflectors, near and farther from the well, also show abrupt terminations against low dipping features (Figure 4). These low angle features are possible reverse / thrust faults, which apparently dip to the north.

According to the formations probably those faults cross 7 blocks which were considered.

The corrected VSP image indicates that there are two significant faults (F1 & F2) intersecting the well trajectory of A. F1 crosses the well trajectory about 1000 m TV DSS and F2 about 1750 m TV DSS. The FMS results show which most formation dips are towards north above F2, with some pockets dipping toward the south. Below F2, the formation dips toward the south. These dips change indicate that the geological structure is very complex, possibly with many faults. The third fault(F3) intersecting the well A and probably this fault will not intersecting any other wells. Regarding the well B, Asmari Formation identified as a strong reflector. Following the general geology principle, a possible interpretation for the Asmari Formation is shown as two segments due to faulting. The first segment intersects the well B between F2 and F3, the Asmari Formation is fractured or faulted with high angles of dipping. The second segment below F3 is shifted towards the north.

After the seismic process, a FMS service was immediately run for the well deviation, formation dips and geological structure. During run-in-hole, a few check shot surveys were recorded in the casing section and two control points were recorded in the open hole. GR log was recorded in both down and up logging operations. At each check shot level, three fine shots were recorded and five good shots were acquired for each VSP level.

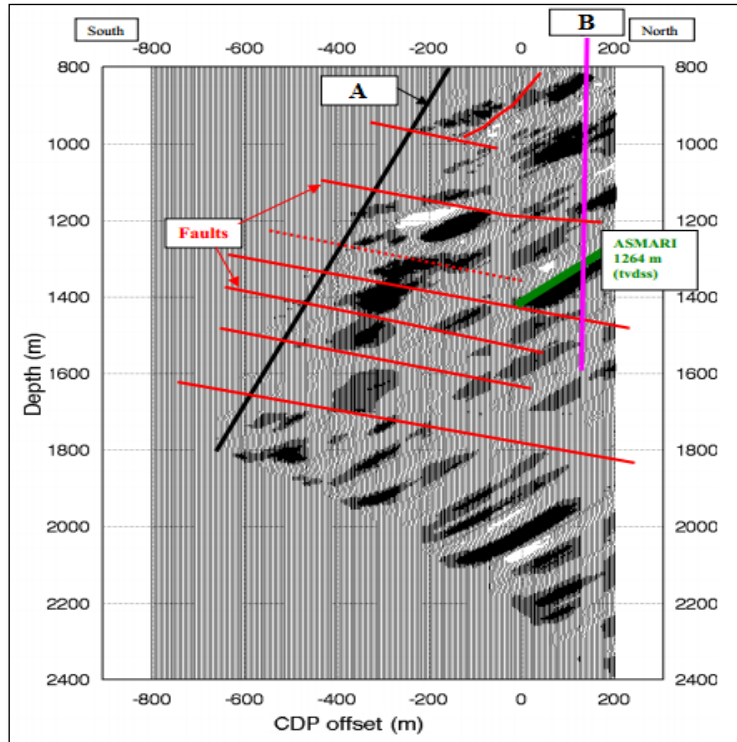


Figure 3: corrected VSP image of the subsurface with interpretation

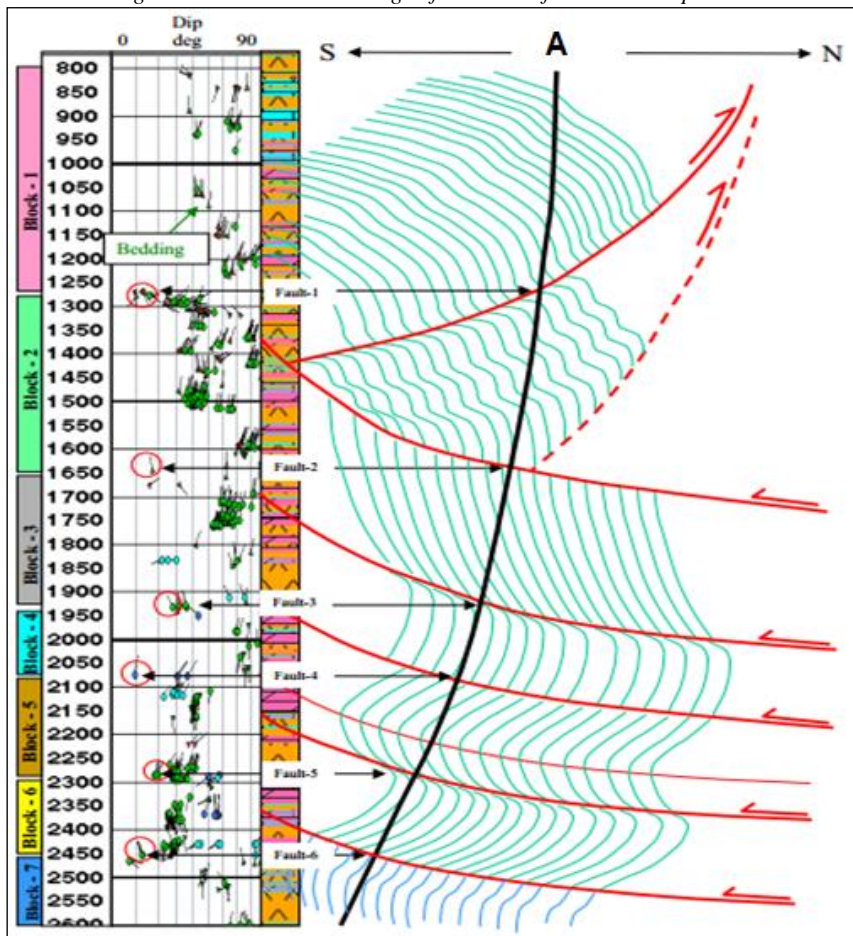


Figure 4 : Schematic structural model developed based on interactively picked dips from the FMS images

There are six faults that intersected the well. One fault dips to the South and the rest five faults dip to the north.

Due to a problem with the CT operations, we found that the depth was not accurate for the seismic operation. The problem was fixed after the seismic operation. GR log was recorded in the both down and up runs and it was applied to correlate with the FMS log for the depth determination of seismic levels.

The GR and FMS images show three possible main lithological units alternating with each other to comprise the section of Gachsaran Formation penetrated by the well A: clean anhydrite, shale / marl anhydrite and dominantly shale / marl. Layers are mainly developed in largely shale / marl intervals and least developed in clean anhydrite intervals.

Overall structure around the well looks like a high angle flank, which is faulted dominantly by northwardly dipping reverse / thrust faults. Due to plastic nature of anhydrite and marl / shale anhydrite of Gachsaran Formation, the beds / layers have assumed higher dips in the flexes formed by faulting. The non-reservoir beds / layers extended to have higher and complex dip pattern.

By using the depth of wells, we determined the coordinates of well points that fault crosses, then by using coordinates of those points plus fault slope of discontinuities and also using AutoCAD software we created a layer or a set of points.

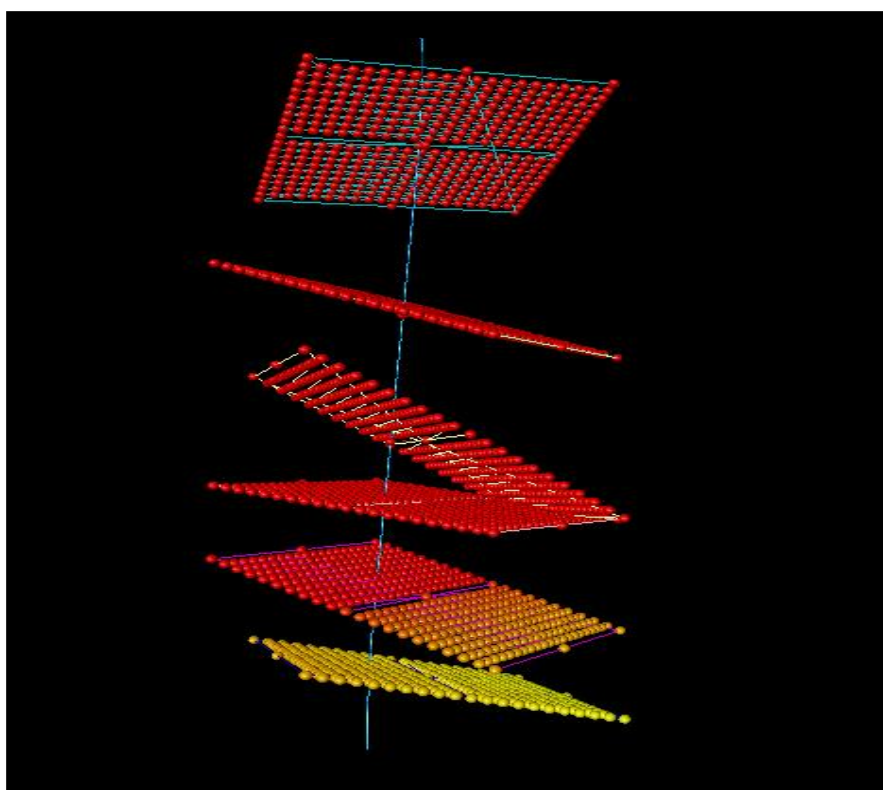


Figure 5: View of the simulated faults with AutoCAD

Except the first fault (F1) at 1270m (Measured Depth) , which has south dipping, rest five faults have dipping to the north at low angles (Figure 5). The layers and beds within Gachsaran are more tightly folded / deformed than the Asmari. The most possible locations of faulted Asmari are shown in figure 6. The faulted Asmari appears to be more than 200m away horizontally from the well trajectory of well A towards north (Figure 6). So any side-track hole drilled to the northward (and north-westward) should be able to intersect Asmari.

The results obtained from the two techniques (VSP and FMS) represent structural details at different scale. Each technique has different benefit to resolve structural details. For instance, VSP can see reflectors farther from the well, the extent of which depends upon the position of the well trajectory relative to the structure. It can also help to determine the lateral extent of the faults seen in the well provided they are within the resolution scale of the borehole-seismic. However, not all features can be recognized with that technique because it has coarser resolution and it depends on the geometrical relationship between the well trajectory and the structural features. For instance, reflections coming from high angle beds dipping in different

directions may don't reach the geophones (installed in the wellbore) to be recorded as reflectors, hence affect accurate reflection of the structure. While FMS / Formation Micro Imager (FMI) provide higher resolution picture of the structural features (i.e., their dip magnitude, dip azimuth and strike) exposed to the wellbore. We provide accurate information on dip and strike of all structural features (beds, faults and fractures), and their physical appearance and relationship with each other. Therefore integration of two techniques can help us to resolve complicated structural issues like the one encountered by well A

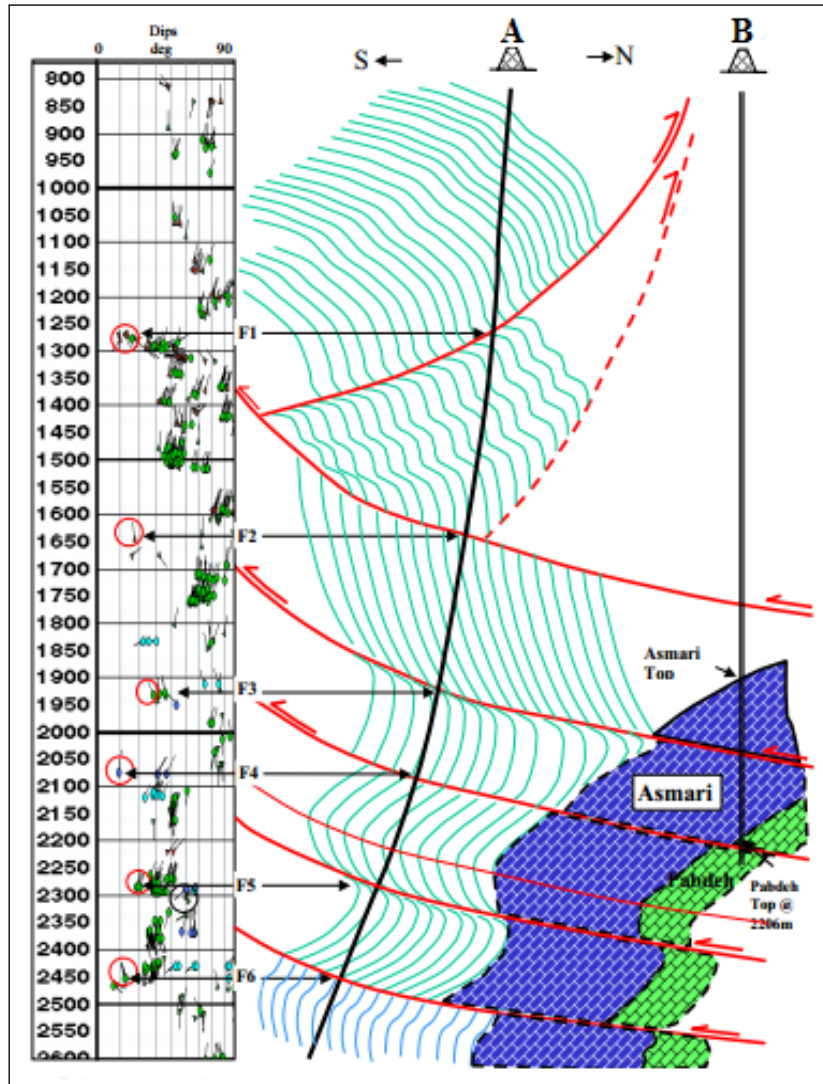


Figure 6 : Final structural model developed from FMS dips and VSP image.

Results

Although Asmari doesn't meet well A, but it is likely to close. Imager logs are proper to investigate the wells. Imager logs provide high quality images which can obtain accurate values of dip and azimuth layers and faults along well. Vertical seismic data is related to the information surrounding the wells also has shown Change in slope away from the wells as well as helped us to recognize extending the faults, but it has low resolution.

There are six faults that intersected the well A. One fault dips to the south while all other faults dip northward at lower angles. The six faults have divided the whole interval into seven blocks. Each block is separated by a low angle reverse (9°-29°) or thrust fault. The dip of each block is medium to steep (28°-75°) and reversals of dip azimuth are caused by low angle faults. Asmari reservoir is possibly not far from well A. It could be penetrated by a sidetrack hole drifted either to the north, northeast or north south.

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