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High porosity anomaly with good reservoir properties in the lower Fahliyan formation (Neocomian) of Darquain Field (SW Iran) by 3D seismic

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Abstract

Seismic data from the onshore area of Iran over the Darquain structure is used to investigate stratigraphic and structural seismic anomalies inside the Fahliyan formation (Neocomian). The data consists of a 3D grid seismic cube, acquired in the late 1990's. An integrated seismic interpretation and inversion revealed an outstanding feature in the lower part of the Fahliyan formation. This anomaly has N-S trend, parallel to Darquain structure and the results of seismic studies predict high porosity for the observed anomaly in the lower part of Fahliyan as a major oil reservoir. Recent drillings based on the results of seismic interpretation proved its potential.

Keywords: Reservoir properties, Acoustic impedance, Seismic inversion, Fahliyan formation, 3D seismic, Darquain field

1 INTRODUCTION

The Darquain structure with N-S trend is located in SW Iran (figure 1). This structure was discovered in the mid 1970's by 2D reflection survey. The first exploration well did not penetrate the Fahliyan formation but considerable oil column was discovered in the second well. The results of the third well showed there is a combination of structural and stratigraphic traps.

The Darquain structure is part of the Mesopotamian-Persian Gulf lowland (Berberian, 1995) and structurally belongs to the stable shelf of the Arabian Platform. Its trend is in contradiction to the Zagros type structures (NW-SE) and it is supposed that it is an Arabian type structure. It is parallel to a N-trending anticline which extends from Saudi Arabia to Kuwait’s Burgan field (Al-Husseini, 2000). Also Iraqi Zubair and Nahr Umr fields and Iranian Azadegan field are in the northern extension of the Burgan field (Burgan paleo-high). Major basement N-trending basement fault systems are supposed for such paleo-highs. These N-trending basement fault systems appear to have been formed during the Precambrian after the Amar Collision between about 640 and 620 million years ago (Al-Husseini, 2000) and relevant structures were formed by their reactivation especially during Cretaceous time.

Motiei (1995) proposed the Darquain structure as part of the Abadan Plain geological zone. This zone is not seismically active and also there is no evidence of geological outcrops for subsurface structures, therefore their exploration is based on geophysical activities. In the Darquain structure as in other structures on the Abadan Plain, there is no structural closure at the Asmari (Oligo-Miocene) level.

The National Iranian Oil Company covered the Darquain structure with 3D seismic in 1999. The 3D data is of excellent quality, showing very high signal-to-noise ratios, and having stable phase and amplitude characteristics. The interpretation of 3D data indicates laterally variable seismic character of the Lower Fahliyan reflectors as main pay zone.

2 GEOLOGICAL SETTING OF LOWER FAHLIYAN

The Early Cretaceous 'Garau intra-shelf basin' inherited much of the differential topography from the earlier Jurassic Gotnia intra-shelf basin (Sharland et al., 2001) in the Abadan Plain and Dezful embayment. Later on progressive uplift of the western Arabian plate area (including Abadan Plain) commenced, possibly as a result of the opening of the south and central Atlantic Ocean (Sharland, et al., 2001) and most of the area was dominated by shallow water deposition of carbonate ramp (Fahliyan formation). At the beginning of the Cretaceous period, SW Iran was located just north of the Equator, and the large scale basin configuration had just changed from one of a differentiated passive-margin of shallow shelves and deeper, intra-shelf basins which characterized the Jurassic (Murris, 1980) to that of a very low relief passive-margin ramp setting, with the stable Arabian shelf passing northeastwards into the deeper water realm of the Mesopotamian-Northern Gulf Basin (Al-Fares, et al., 1998).

The Neocomian Fahliyan formation is subdivided into two parts in SW Iran. The lower part is equivalent to the Yamama-Minagish in Kuwait and SE Iraq. The Berriasian-Valanginian Minagish Formation in an oilfield in north Kuwait was deposited on a homoclinal carbonate ramp (Davis, et al., 1997). The same depositional setting is supposed for the lower Fahliyan in the study area (Davis, 2001, Personal communication). Ziegler (2001) suggested a shelf platform of the Arabian plate that was covered by shallow-water carbonates Yamama during the Berriasian to Valanginian (144-132 Ma). Also Sadooni (1997) proposed sedimentation of Yamama formation in SE Iraq on a leeward ramp on the gentle slope of the Arabian Platform.

3 METHOD OF STUDY

3.1 SEISMIC INTERPRETATION

Well logs were correlated and sub-layer tops were identified. 3D seismic cube and other relevant data such as well data and geological markers were loaded into the seismic interpretation software. The 3D data set has been interpreted using state-of-the-art interpretation and visualization UNIX workstation software at the National Iranian Oil Company.

The phase of the seismic data was established by deterministic wavelet extraction techniques and horizon identification using synthetic seismograms on the workstation. Therefore, there was enough confidence regarding compatibility between seismic and well data.

Autotracking techniques were used to obtain basic interpretation of time surfaces, but much painstaking manual interpretation was necessary for interpretation of the Top Upper Fahliyan discontinues reflector. The time picking of pay zone (top Lower Fahliyan) was almost easier especially on the western flank. Detection of Garau formation (between Gotnia & Fahliyan) on seismic data was difficult due to poor contrast between Garau and Lower Fahliyan. Also Garau formation in the Darquain structure is relatively thin. Therefore, interpretation of top Gotnia formation was decided as a basis for upper horizons. Then other sub-horizons were added to the interpretation. Special care was needed in order to minimize the effect of multiple interference.

The Fahliyan formation is predominately carbonate with lateral facies changes and the result acquired from 3D seismic interpretation supports this idea. Organic buildups or ecological reefs that are composed of a substantial amount of calcium carbonate framework (Wilson, 1997) with high porosity. Also results of drilling approved presence of reefal buildup in this structure. Therefore more efforts were concentrated on the reflection character of the pay zone from a stratigraphic point of view. Figure 2 exhibits six parallel E-W trending seismic sections, on which a possible buildup anomaly is shown.

After completion of interpretation, many surface and volumetric seismic attributes have been tested (figure 3). Different seismic attributes for the Fahliyan pay zone, show an oval form trending N-S. In-lines (E-W direction) indicate predominant amplitude changes in both sides (figure 2). These changes are detectable by seismic attributes. Onlap features, above the pay zone reflector, show erosional surface on the western flank. That oval feature is clearer on frequency attribute (figure 3A) and it probably reflects increment of frequency content due to thinning zone because of top pay zone and sub horizontal oil-water contact. This feature may indicate a paleo-island (because of reefal buildup) and fringing reefs around it. In addition, volumetric attributes such as reflection intensity from the Fahliyan pay zone indicate a similar ellipse anomaly at the western part of the Darquain structure (e.g. figure 4).

3.2 INVERSION

A key step in this study was a 3D seismic inversion of the seismic data. Sonic inversion method was checked and model based constrain method was selected for final inversion (better correlation with well data). The initial model consisted of source-interpreted horizons which were exported from seismic interpretation software to the inversion software.

A pseudo acoustic impedance (Z) was calculated in a wide time window (including top Upper Fahliyan and pay zone). Therefore, by selected method and based on initial acoustic impedance model and extracted wavelet in the well site the whole 3D cube converted to impedance volume. Cross-plot of Z versus porosity clearly shows the inverse trend with more than 95% correlation factor (figure 5).

figure 6 shows an impedance profile and aerial distribution of Z at pay zone.

4 DISCUSSIONS

High degree heterogeneity within the Fahliyan reservoir is indicated by the impedance data. In addition, other seismic attributes (figures 3 and 4) present such heterogeneity. In fact, frequency attribute tends to be noisy (Brown, 1996) but instantaneous frequency (figure 3) offers a good indicator for lateral changes here as subtle buildups. Referring to Macurda (1997) subtle buildups can often be differentiated by frequency. Apparent polarity (figure 3) reveals an oval form in the western flank of the structure. Furthermore, other attributes (e.g. figure 4) show more or less the same feature. Erosion and sub-aerial exposure of the top Fahliyan pay zone is evidence of a very shallow sedimentation environment.

Seismic interpretation and inversion results envoy evidence for the formation of an atoll (N-S trend) in the crestal part and western limb of present structure. Atolls not only occur within major barrier complexes, but also generate areas of shallow-water carbonate deposition in the open sea (Sellwood, 1986).

Tectonic activities affect sedimentation by governing the broad distribution of high land and basins (Reading 1986); it seems formation of an atoll was due to activity of a deep seated basement fault zone. The activity of this fault zone during sedimentation of the Lower Fahliyan prepared a suitable environment for deposition of carbonate buildups as such fault zones were considered active during the Cretaceous period (Sharland, et al., 2001). The Deep Darquain fault system is suggested as a subsidiary of the major N-S Burgan high in Saudi Arabia, Kuwait and SE Iraq (figure 1).

Sadooni (1997) supposed the contemporaneous growth of giant structures as one of the major factors that controlled the deposition of the Cretaceous sediments in southern Iraq. The same idea is applicable for the growth of the Darquain structure and it seems fault activity changed the topography of the Fahliyan ramp and locally a rimmed platform was formed at that time. Probably around that platform fringing reefs were deposited. In such environment, Carbonate sediment can be affected by shallow marine depositional diagnesis or ground water diagenesis in vadose and phreatic zones (Wilson, 1997). Fresh water leaching could be a major element for the increase of porosity.

5 CONCLUSIONS

Based on integrated structural and stratigraphic seismic interpretation and inversion, an anomaly as good the Lower Fahliyan reservoir with high potential of porosity was detected on the western limb. The available evidence supports a local shallow part in the sedimentary basin during the Lower Cretaceous for sedimentation of high porosity the Lower Fahliyan in the Darquain structure. This atoll type sediment is hard to believe for such a gentle lower cretaceous basin, but it is possible by supposing a deep fault system. Therefore, more concentration on this part is suggested for production purposes. The result of drilling recent wells (based on 3D seismic interpretation) proves this idea.

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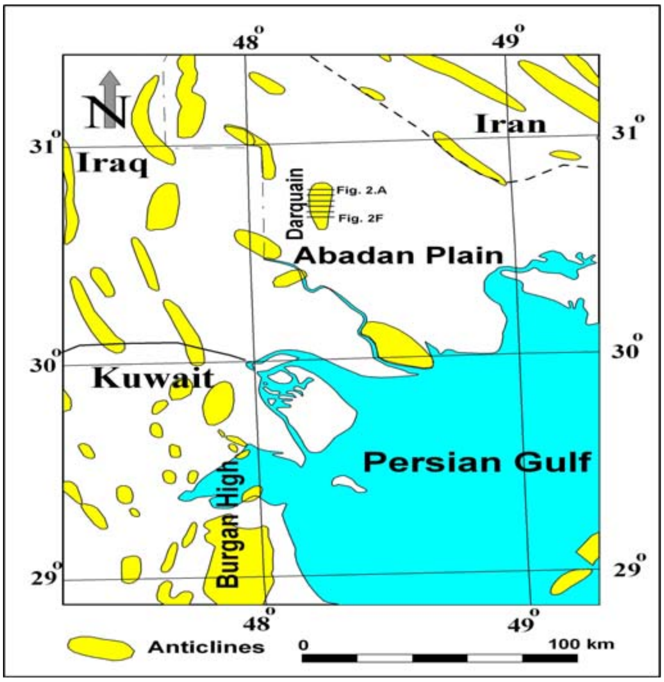

Figure 1. Location of the N-S trending Darquain anticline in SW Iran. Main N-S anticlinal trend in SW of the study area is known as Burgan High.

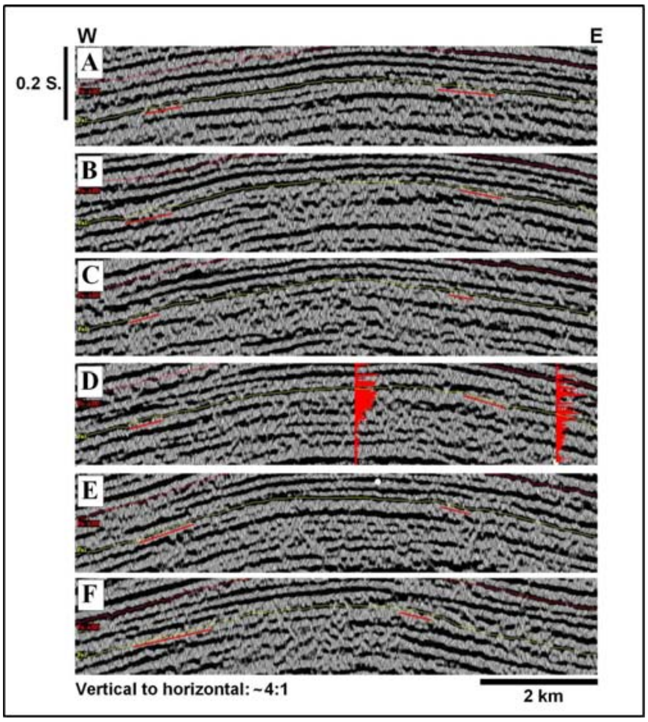

Figure 2. In-line seismic sections in E-W trend Darquain structure show a probable reefal buildup in pay zone (inside Fahliyan formation). Straight lines indicate possible fringing reef or indication of oil-water contact around the proposed feature. Porosity log is shown in the fourth section (Section D). Locations are shown in Figure 1.

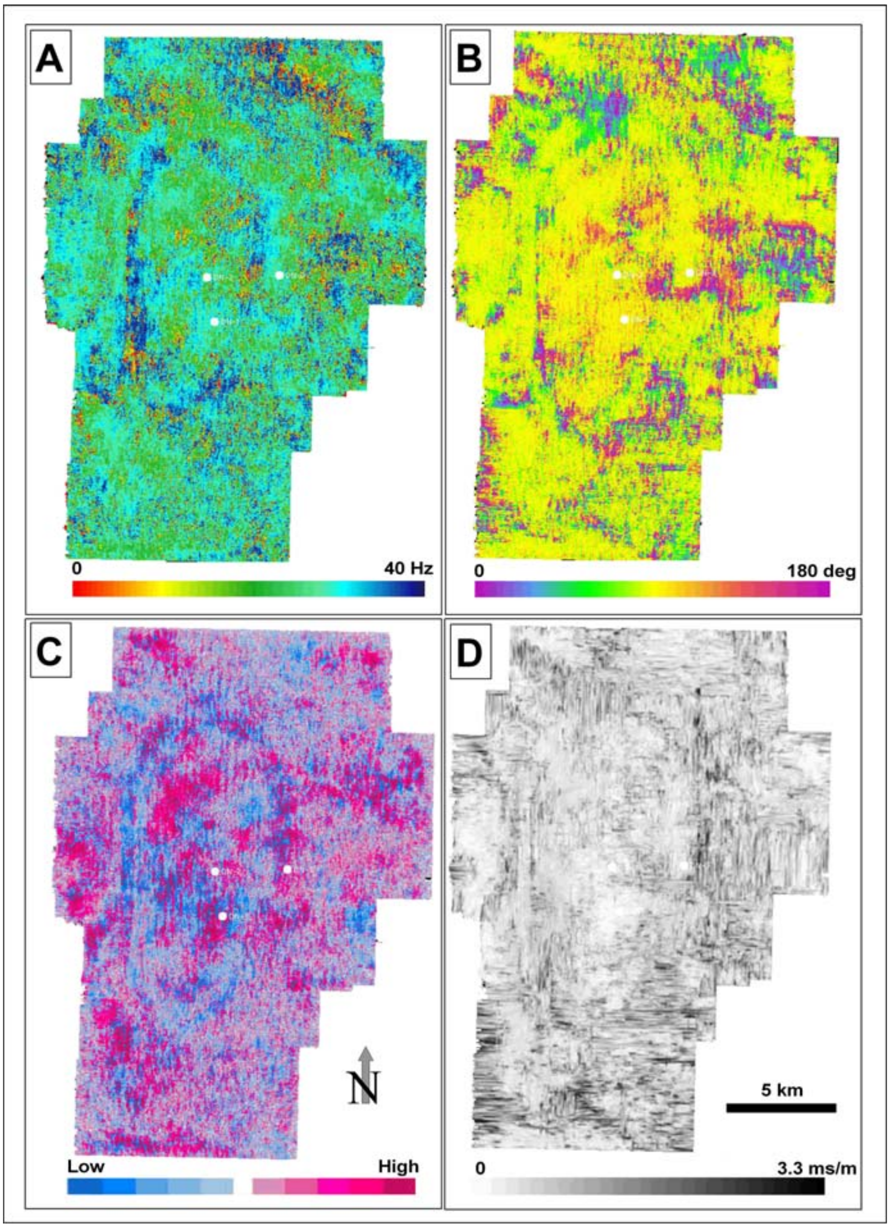

Figure 3. Seismic attributes in pay zone which show an oval shape N-S trending feature. These seismic attributes reflects variations due to sub horizontal oil-water contact or they possibly represent reefal buildups around a paleo-island. (A) Instantaneous frequency, (B) Instantaneous polarity, (C) Apparent polarity and (D) Time dip.

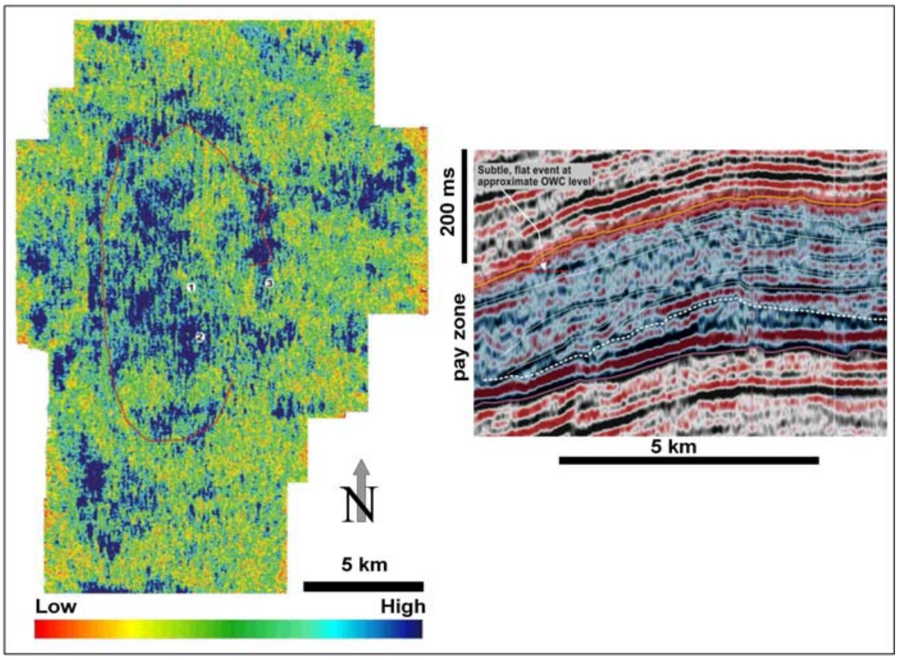

Figure 4. Left: Reflection intensity attribute from Fahliyan pay zone (Volumetric attribute, top Lower Fahliyan-12ms+24ms) represents an oval feature. Right: Seismic section across the Darquain anticline which shows reflectors of the Fahliyan pay zone.

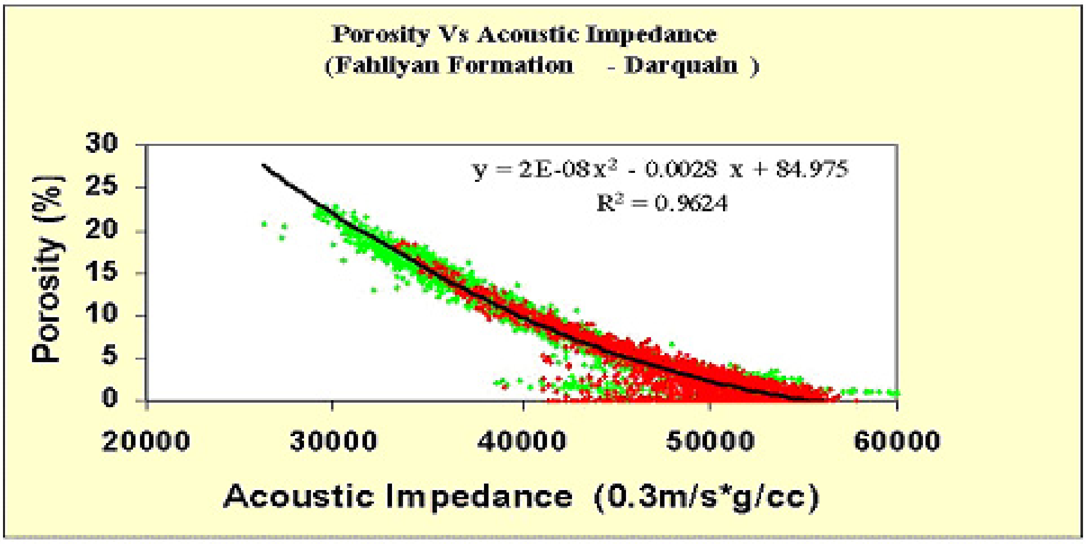

Figure 5. Relationship between porosity and Z (green and red circles represent data related to Darquain wells 2 and 3, respectively).

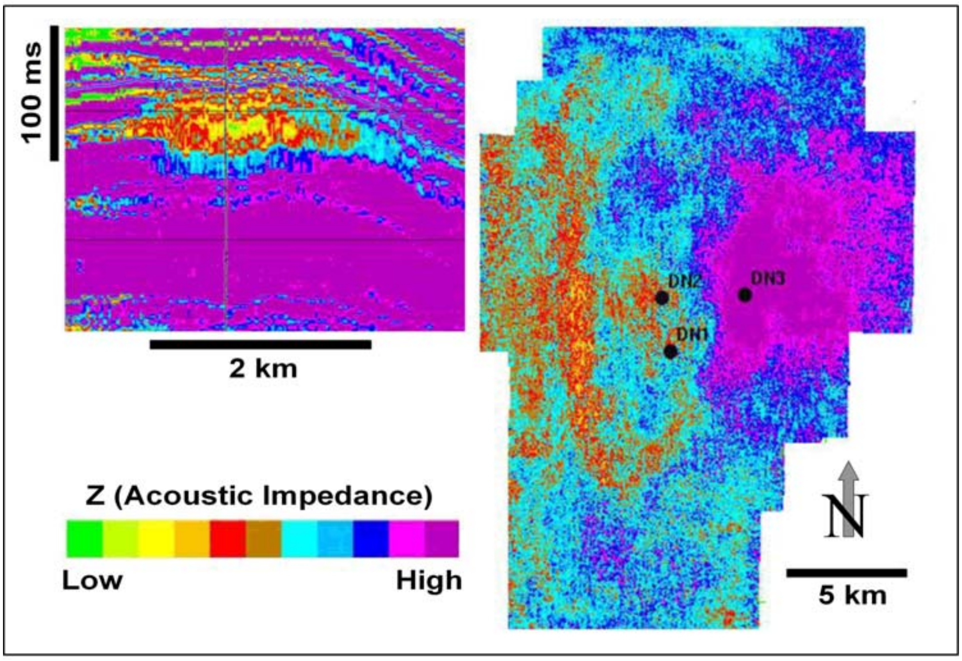

Figure 6. Left: An impedance profile with low Z in pay zone, Right- Aerial distribution of Z over pay zone (Maleki, 2002).

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