Unification of geological phenomena associated with geohazards in the Persian Gulf

(A case study using 2D seismic data)

Abstract

This study has been made due to the problems aroused from a challenging gasfield drilled by two wells, one nearly prone to eruption. A pronounced gas chimney located in the north of the Persian Gulf has motivated this study orienting toward a new approach in geohazards study.

The prime task was to investigate geological features liable to hazards while drilling, specifically gas chimney aimed at pursuing its evolution and its interaction with faults. The interpretation was initiated by making use of 2D marine seismic data resulted mapping a number of key horizons, followed by fault interpretation, gas chimney prediction and seismic attribute study.

In the present paper, an ample attention was paid to investigate a geodynamic mechanism manifested by characters such as so called A, V, U shapes, Micro-deformed zones and buckle folds, leading eventually to certain geological features, notably geohazards. Observations led to contemplate of different encountered geohazards, would have been originated by a unique processes. Hence, the subsequent features have been termed as the unified geological forms. We classified and mapped the hazardous geological features (geohazards) on each key horizon to be considered as a basis for ulterior drilling forecast.

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Introduction

Gas Chimney Detection and Geohazards Study on a challenging gas field were conducted by Dana Geophysics Company with collaboration of dGB in 2010. As geohazards may pose serious problems in drilling (human life, costs and time), Iranian Offshore Oil Company (IOOC) offered this study to Dana Geophysics in order to investigate hazards while drilling. This study was emphasized on identification of the probable geological features prone to hazards in an area of about 261sq. km. in the Persian Gulf.

The Persian Gulf Basin is located within the regional tectonic frame of Arabian and Iranian plates. In the present times, Persian Gulf is a shallow depression tectonically evolved during the Late Tertiary. The steep slope on the Iranian side is related to the folding of the Zagros Orogeny, whereas the low dipping on the Arabian side is due to the gentler tectonic movements (Ghazban, 2007). The northern part of the Persian Gulf (study area) is controlled by structural procedures: initial basement activities associated with Zagros tectonics and ultimate salt movements. The main hydrocarbon producers in the Persian Gulf are Kangan and Upper Dalan Formations of Permo-Triassic. Secondary reservoirs such as Surmeh, Fahliyan, Dariyan and Intra Sarvak mostly contain non commercial oil or heavy oil in the study area.

Methodology

In this study, altogether 62 lines of 2D seismic (totally about 1261Km) and two drilled wells have been investigated to locate potential geohazards in the north of the Persian Gulf. Conditioning of 2D seismic lines in order to improve data quality was the first step which has been taken by using structure based filtering, the so called SteeringCube Technology[4]. Therefore detail structural interpretation of 10 seismic horizons was completed and fault interpretation was done precisely. Accordingly, structural evolution model including of fault pattern was determined.

In order to map geohazards, all seismic profiles aimed at geohazards investigation were observed. In this regard, seismic attribute analysis as a powerful device to bring up geological features has been performed during the extraction from the enhanced seismic data (both on 2D seismic sections and on the interpolated time slices). Average frequency content, RMS energy and similarity as the most and critical seismic attributes were studied the most. In addition, two main neural network based technologies the so called Unsupervised Waveform Segmentation and Supervised ChimneyCube were used to facilitate object detection such as gas chimneys and to delineate subtle geological features like micro deformations. During the chimney cube generation, probable chimney paths were picked on key seismic sections and validated by well data (e.g. gas kick) (**Figure 4**).

Finally, all interpreted data, geological features and geohazards elements were integrated so as to be presented for drilling forecast, not only that but also having ensemble of the findings on hand, will permit to visualize them and permits contemplate their common points or mechanism responsible building them. Within this frame, all risk elements were classified in the study area and projected onto the key horizons. Gas chimney model was built and its relation with faults and different geohazards was evaluated.

Potential Geologic Risk Elements and Interpretation

Associated with interpretation of the key horizons, flattening technique permitted to pursuit structural evolution specifically within different reservoirs during the time. Also interpreted faults were led to place majority of them in the context of normal faults exerted within the crestal position of the structure producing pathways for eventual vertical fluid migration. According to structural interpretation it was concluded that structural growth has been initiated from Permian and attained its maximum peak in Upper

[4] Developed by dGB Earth Sciences in OpendTect Software

Cretaceous, associated with high density faulting and probably favorable space and time for hydrocarbon migration. **Figure 1** displays structural growth in the structure goes along with major faulting in the crestal position.

From the geohazards standpoint, all 2D seismic sections were investigated aiming at identifying geological features posing drilling risks and classified them in the context of geohazards elements. We tried to tackle mechanism responsible building these features as well. Attaining this, would lead to predict eventual zones or layers prone to risk. This initiated by paying attention to reflection seismic characters specifically those related to geohazards. Classification of hazards emphasizing their occurrence in the study area is as follows:

1. High Pressure Zone (A-Shaped Features, Intra-formational folds (Buckle folds), Micro-deformed zones, Channel fills, Gas pockets (or Bright spots), Gas Chimneys (Fault related)
2. Karstification and gas chimneys
3. Collapsing (V-shape & U-shape)
4. Slope failure/stability
5. Seabed relief
6. Fault

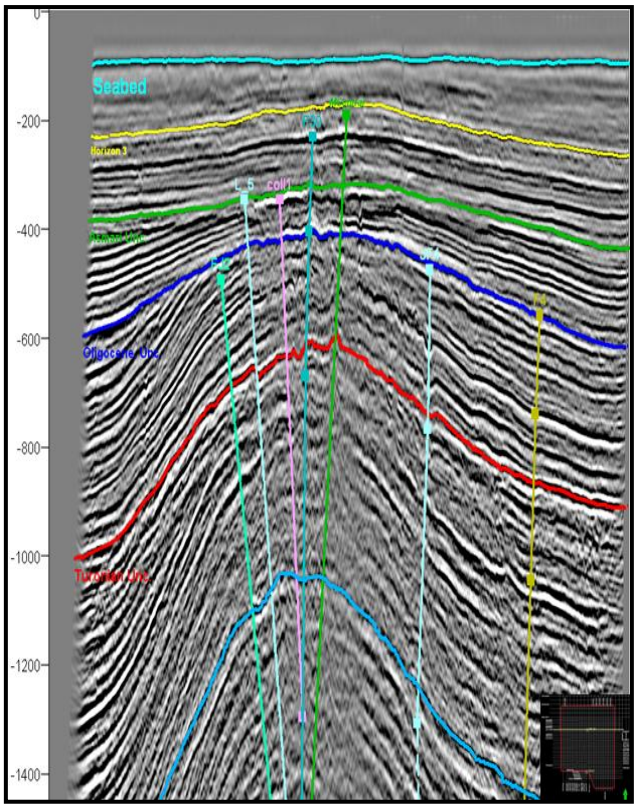

Figure 1 *structural growth with major faulting in the crest of structure*

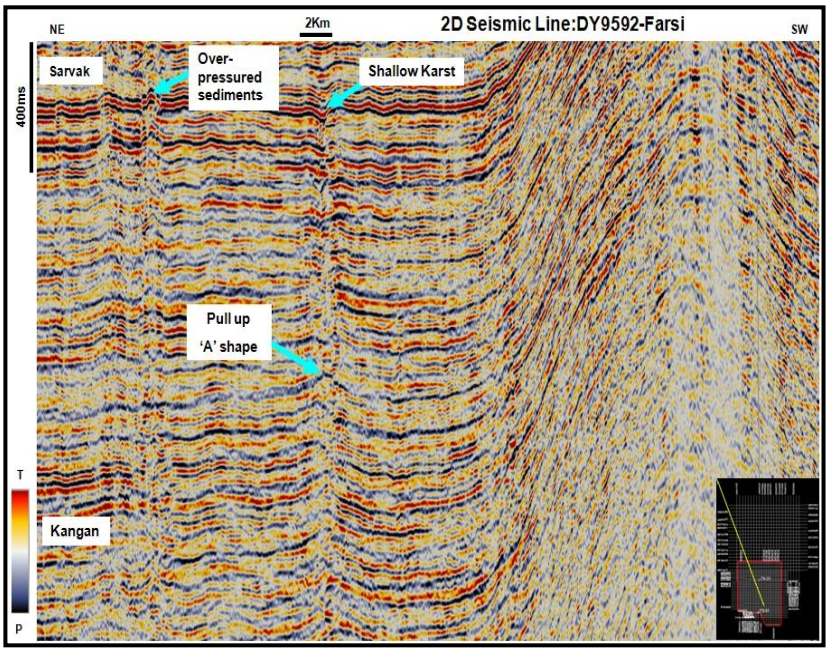

Figure 2 *Revealed Over pressured and shallow Karst on 2D seismic*

Figure 2 displays typical revealed seismic A-shape features which in most of the time, can be observed within gas chimney regions and overpressure zones. Also V- and U-shapes characters associated with Karstification and subsequent collapsing can be seen on this figure. Other important seismic reflector characters like intra formational fold which can be thought of as a manifestation of upward movement mostly exerted by fluid flow (or fluid pressure) and micro deformed zone built as a consequence of gas injected within unconsolidated sediments, notably, clay, marl or possibly sandstone were distinguished. These features could be considered as over-pressured zone, as it may be bounded by fault or trapped by facies change. According

to a number of collapsing phenomena encountered in a columnar form (within this Field or its peripheral), we concluded that they should be complied by a unified mechanism. These columnar phenomenon having uniformity in their architecture, that is from bottom to top an uplift, generally associated with fault, above that, A-shape reflector character , overlain by collapsing structure, generally demonstrated by disrupted reflector character, and on top of that, V- or U-shapes.

Gas Chimney Prediction

As stated earlier, a considerable volume within the core of the study structure has been invaded by gas chimney phenomena. Seismic data investigation using seismic attribute technology showed that hydrocarbon related fluid migration via gas chimneys has been existed in this Field (**Figure 3**) and gas chimney paths were predicted using a standard workflow proposed by dGB. We utilized supervised neural network technique along with seismic attribute technology. Interpretation of predicted chimney cube resulted that gas chimney in this area is fault related and an ample attention was paid to profoundly study it. We found that the field is a gas prone structure, along which a series of faults have been exerted. These faults have particularly been distributed within the crestal position where major gas chimney has been developed. Also mapping seafloor, demonstrated that the raised seabed is caused by materials produced by gas chimney migration upward.

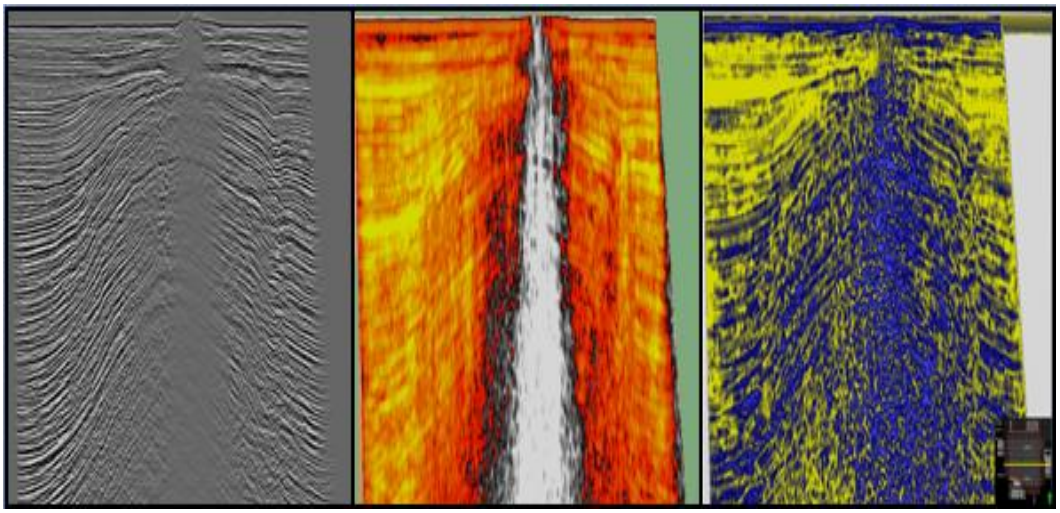

Figure 3 *Raw data (left), Ln Energy (middle) and Average Frequency (right) of a 2D seismic section*

On the seismic profiles, some geological evidences attracted our attention that could be led to relate charge and leakage mechanism. This has been specifically interpreted on **Figure 5**, where the shallow seal is breached permitting fluid to migrate upward resulted brightening at shallow levels. In order to follow charge and leakage mechanism, so called average chimney predicted was calculated above and below certain horizons. This permits to evaluate relative fluid flow, calculated below a horizon, would be interpreted as charge, and calculated above a horizon, would be interpreted as leakage.

Predicted above chimney at Kangan level (main gas reserve) shows that sealing is punctured and this is consistent with faulting most probably originated from Kangan or deeper part as fold geometry imposes. At Turonian level in the shallower depths, among the projected faults, four major faults with north-south trending play a crucial role in hydrocarbon migration. In **Figure 6** the predicted gas chimneys, below the Turonian level, shows that the area is compartmentalized by these major faults. It is interpreted that these major faults are responsible for hydrocarbon charge, and control migration paths in vertical direction. On the other hand this indicates relationship of faults and gas chimney.

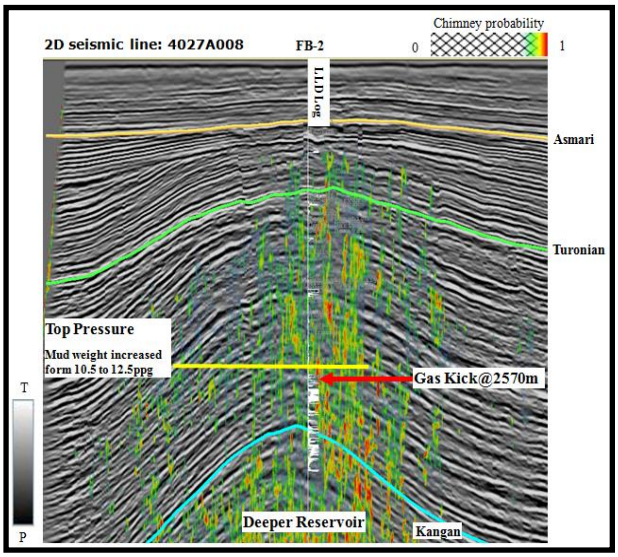

Figure 4 *Validation of predicted Chimney at well*

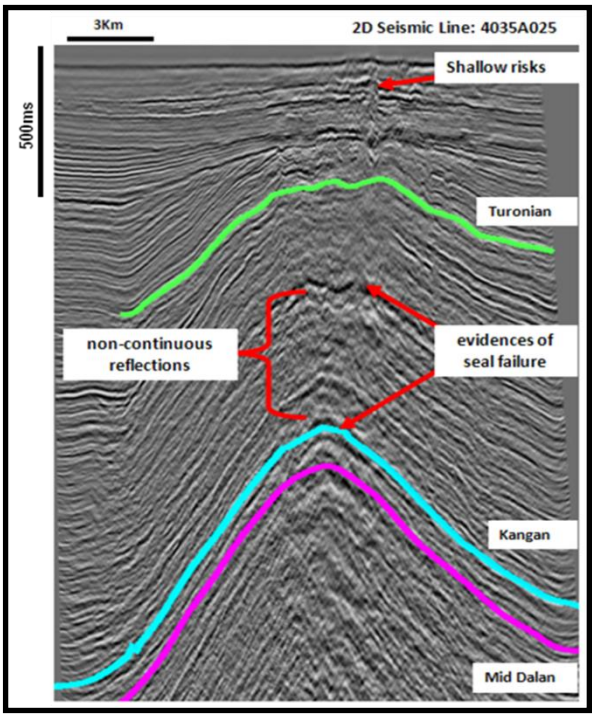

Figure 5 *Evidences of seal failure on 2D seismic*

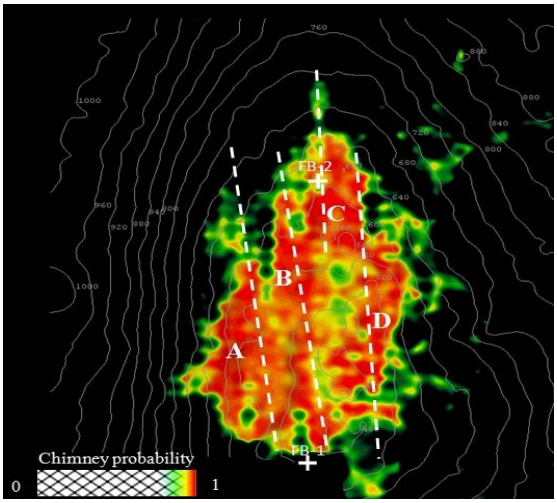

Figure 6 *Predicted chimney below Turonian*

Conclusion

In this paper, it was briefly shown that different physical and chemical conditions exerted within sedimentary column, imposes seismic characters to be shaped in a sense that they may represent geohazards. During the advanced seismic data interpretation, different potential geologic risk elements such as A-shape and V-shape features, gas chimney, buckle folds and micro deformations were identified and mechanism responsible building them were studied. Among geohazards identified in the study area, gas chimney is considered as major feature reigning within the gasfied, hence, an ample attention was paid to delineate it. Gas chimney model was built and its relation with faults and different geohazards was evaluated. We found out a unified mechanism constructing quite numerous geohazards, notably, columnar collapsing features that have been controlled by gas chimney and faults. Parallel to this objective, we concluded that there would have been other aspects of geohazards such as micro-deformed zones, buckle folds and DHI would be thought of as prospect potential as well.

Acknowledgements

We would like to express our gratitude to Iranian Offshore Oil Company (IOOC) for authorizing the present work and also we appreciate DANA Geophysics Company (DGC) for supporting this study.

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