Improving Structural Interpretation Using Modern Techniques For Solving Complex Problems: From Near Surface Anomalies to Pre Stack Depth Migration- Block 32, Yemen

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Summary

TransGlobe Energy Corporation along with its partner DNO-ASA have been working on Block 32, Yemen, since 1997 (see figure 1 for location) The Tasour structure was 'discovered' in 1995 and has been producing since late 2000. A total of 18 wells have been drilled in the area, which is immediately north of the prolific Masila Block operated by Nexen. Older 2D seismic could not provide accurate interpretation due to noise, low fold, surface/static issues, crooked line and fault shadow effects. The extremes of topography and near-surface velocity anomalies could only be corrected through an accurate geological near surface model. Noise, predominantly in the form of ground-roll and ringing generated by the steep-walled canyons, was attenuated with a customized shot-receiver array and modern noise attenuation techniques. 2D pre-stack migration (PSDM) went a long way toward mitigating the above issues resulting in redefined interpretation decreasing the drilling risks. In 2004, a 3D seismic program was shot and Pre Stack Depth Migrated to further resolve structural/static issues, refine interpretation and find additional reserves and deeper drilling targets.

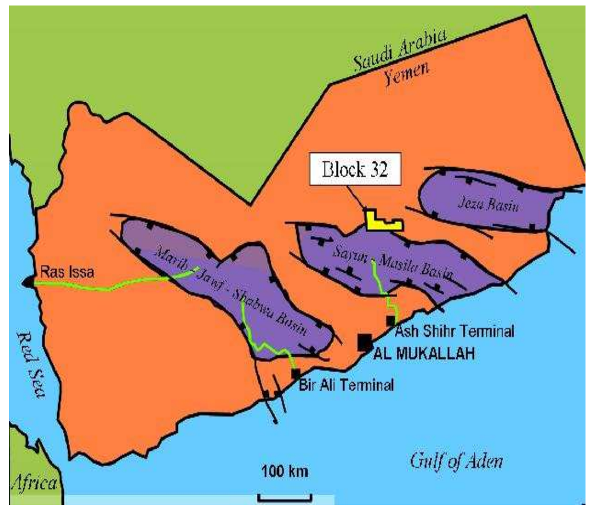

Figure 1: Location of Block 32 Yemen

Geology and Structure

Tasour field is located on the northern flank of the Masila basin containing the billion barrels Block 14 operated by Nexen. Sediments range from Jurassic to early Tertiary with production predominantly from early Cretaceous Qishn shelf sands. Structurally, the basin is carved into a system of horsts and grabens controlled by Jurassic reactivation of underlying Precambrian fault trends. At the individual field level, structure is simple normal faulting (see figure 2). Displacement greater than approx. 50 msecs breaches the reservoir sands overlain by sealing carbonates. Reservoir risk is nearly absent with porosity/permeability typically greater than 20%/2 darcies respectively. Hydrocarbon migration is also critical and typically only older structures, characterized by isochron thinning (between Qishn and younger events), are viable commercial targets. Multiple secondary reservoirs have been discovered in deeper early Cretaceous and Jurassic carbonates, clastics and fractured crystalline basement. Although the geology is relatively straightforward, topography and surface conditions present unique imaging challenges requiring unique solutions. Of particular interest with respect to structural definition and hydrocarbon reserves is the degree to which fault-related imaging anomalies can be resolved. Earlier on the Tasour structure was defined using a grid of 2D seismic lines. The newly acquired 3D dataset provided significant enhancements to the overall structural interpretation (see figure 2 for a typical prospect on block32).

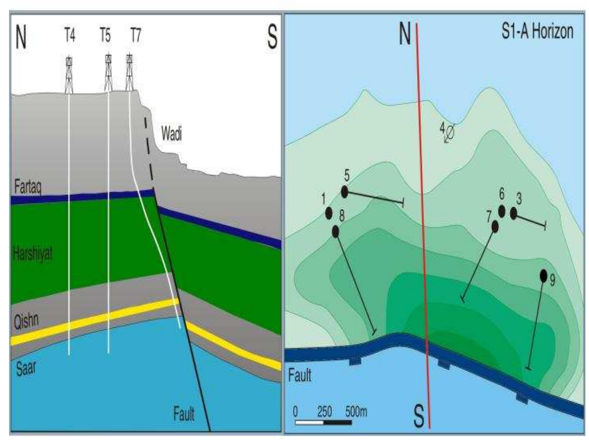

Figure 2: Prospect model

Data Processing Challenges

I Near Surface

Topography (valleys or wadis and plateaus or jebels) and near surface velocity anomalies including the velocity inversions cause large changes in the travel times of the seismic rays and create artificial structures. Typically, refraction statics are derived from the picking of first breaks. These refraction methods can fail when there is a velocity inversion at the near surface and all other cases when refractor information is not recorded on the seismic data. In the Tasour area, refraction statics are not an option. CGG has developed a unique way of creating a weathering model based on the combination of all available information at the time of processing. The geological information (outcrops), the stratigraphic data, satellite images, up holes, check shots, fault and well information were all used to create an accurate geological model of the near surface. High-resolution satellite images were used to construct the digital elevation model (DEM), which was then used to construct a structure map of the top of the UER Fm. (base of static model). The upper layers are constructed in a similar fashion. For each formation a 3D velocity model was created based on up-holes and check shot information. The result was a highly accurate 3D geological of model of the near surface, which was then used to compute the primary statics (figure 3 represents the stratigraphic information and figure 4 the near surface model).

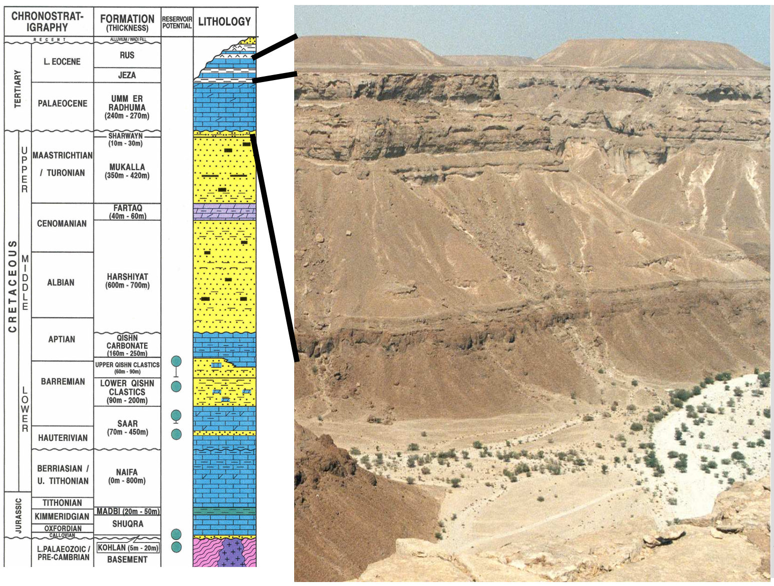

Figure 3: Topography and Stratigraphy

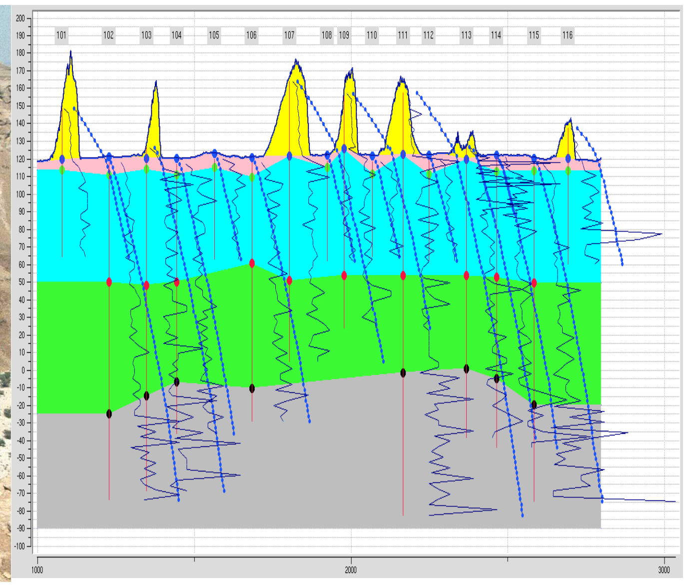

Figure 4: Geological model of near surface

II Noise

The 3D program was acquired using a heliportable dynamite program. The rapid changes of topography (100+ m. vertical cliffs) combined with the presence of high velocity surface layers, poor geophone coupling together with the presence of fractured and karsted lithology created a very low signal penetration and the generation of strong ground roll and back scattered noise. Field records typically show no reflectors and are of low frequency (< 50 Hz., see figure 5 for a raw shot from 2D data). In 1998 a customized shot/receiver array was developed to attenuate much of this coherent noise. The processing sequence was designed to attenuate such strong noise without affecting the primaries. After the tests we decided to not use the FK Filters as such of filters tend to smear the data and remove some of the diffractions. CGG's new program of Noise Attenuation called FSFIL was used together with the F-X projection filtering programs on different modes. Known as "frequency slice filtering" FSFIL provides a powerful method of noise attenuation targeting a precise part of frequency spectrum. Figure 6a and 6b represent respectively an Inline Stack before and after Noise Attenuation. As result of this processing flow we obtained a migrated volume where several geological horizons were imaged properly. For the first time the basement was imaged with a high accuracy. This was considered important because of recent deep basement discoveries on

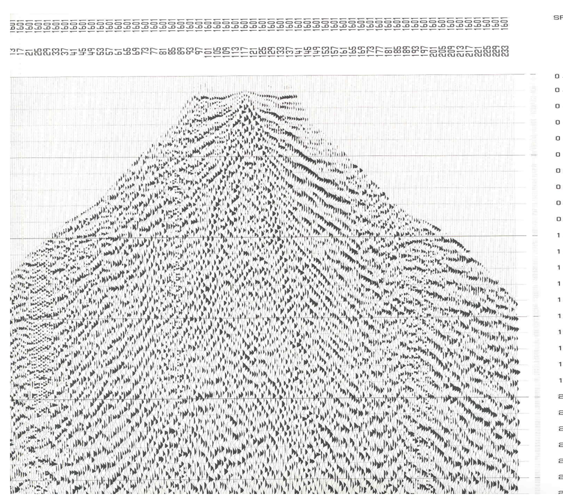

Figure 5: Typical 2D Shot

Masila Block. The True Amplitude Processing of this seismic volume wasn't required at this time, although the noise attenuation programs used for this dataset preserve the true amplitudes of the data.

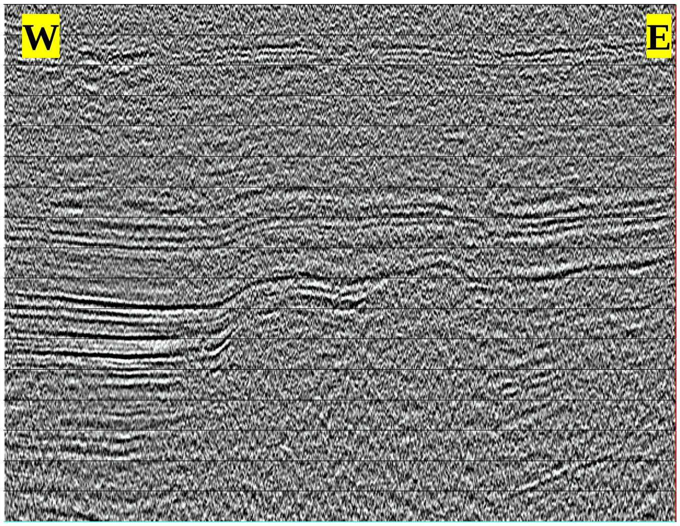

Figure 6a: Stack before Noise Attenuation

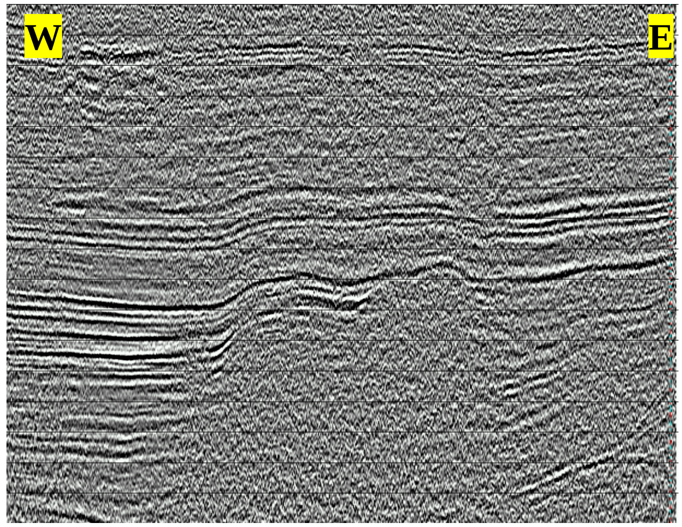

Figure 6b: Stack after Noise Attenuation

III Pre Stack Depth Migration

Poor data in fault shadow zones is common in seismic exploration. Although the faulting and resulting structures are quite straightforward, serious anomalies in the seismic resolution result from the 'fault-shadow effect' (Fagan, 1996, see figure 7). The fault shadow typically results whenever layers of differing velocity are juxtaposed by faulting. The triangular area under the fault (hanging-wall side) shows distorted/chaotic seismic events that are generally depressed in time. At Tasour the fault-shadow is seen as a pronounced roll over of seismic events near the fault apex. The throw of faults on the field is on the range of 20-70 meters and most of them do not extend to the surface. To complicate matters, Tasour wadi (with low-velocity fill) partly overlies the fault-shadow zone. Fault shadow effects cannot be solved by time migration. Near surface anomalies and velocity contrast associated with them are major sources of uncertainty and contribute to the poor data. Early maps on the Tasour field, based on simple 2D time processing, showed a pronounced roll over of the reservoir near the fault (see figure 8a). The structure was considered to be a faulted anticline with much lesser recoverable reserves and no wells were drilled near the fault. In 1999 CGG carried out an extensive program of 2D Kirchhoff

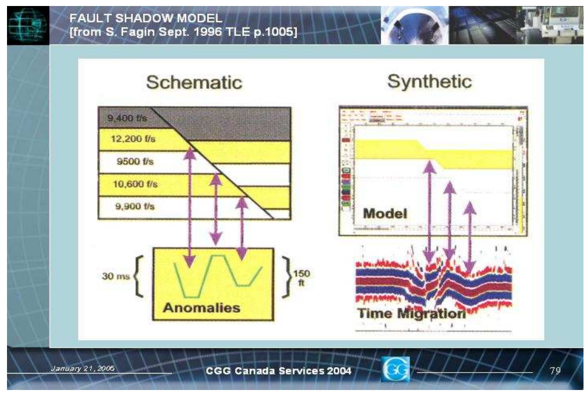

Figure 7: Fault Shadow

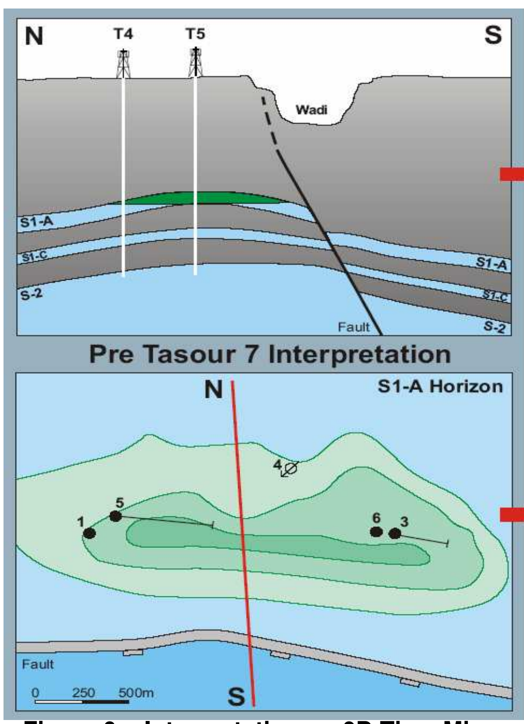

Figure 8a: Interpretation on 2D Time Mig

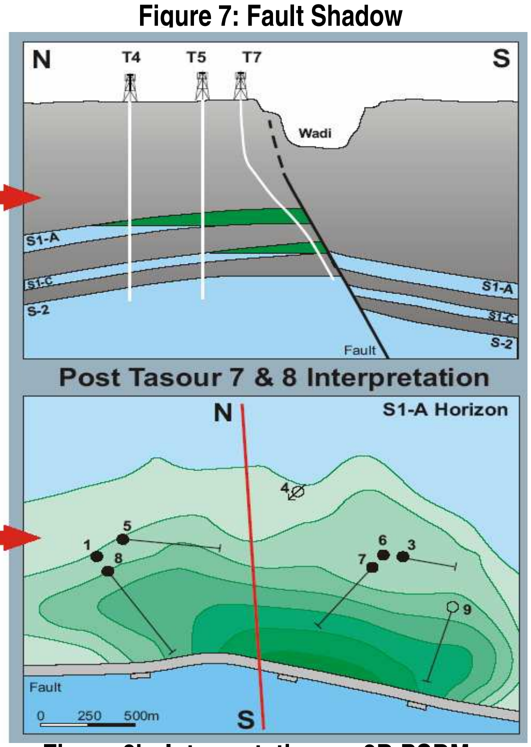

Figure 8b: Interpretation on 2D PSDM

PSDM in order to correct for these problems. PSDM processing consistently indicated that seismic events dipped upward to the fault apex with no roll over (see figure 8b). Subsequent wells confirmed this and allowed for a considerable increase in field boundary and projected recoverable reserves. Encouraged by these results, the 3D shot in 2004 was processed utilizing a highly accurate evolved static model and 3D PSDM. Results have further increased the field size and resolved attractive deeper prospects. The 3D PSDM volume further indicated that no roll over was present and subsequent wells became excellent crestal producers close to the fault. Figure 9a illustrates the "roll" situation toward the faults on the time migration, which is in strong conflict with "no roll" situation of the current structure. Figure 9b illustrates the results of PSDM, which reflects the real structure. PSDM also created a more accurate image of deeper events and the basement.

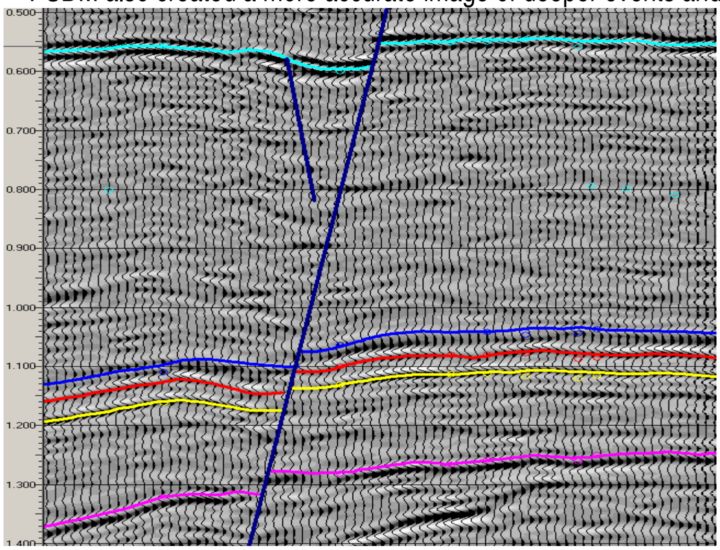

Figure 9a: Time Migration

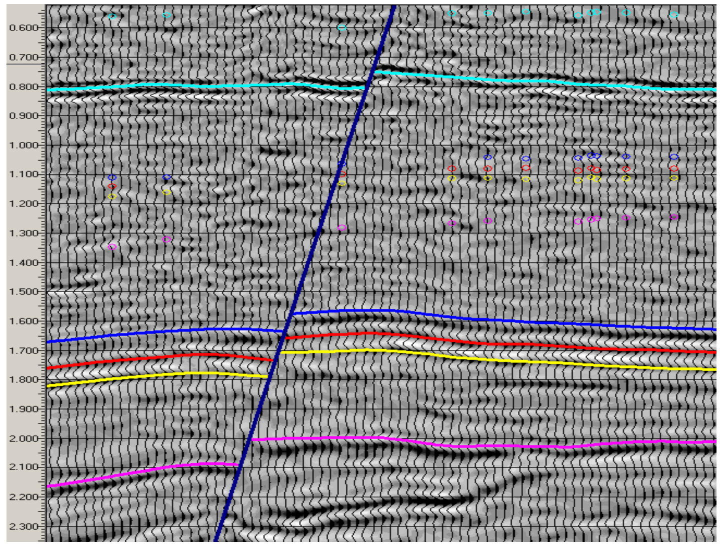

Figure 9b: Pre Stack Depth Migration

Future work

18 wells have already been drilled. The interpretation of 3D PSDM volume has extended the size of the field and the current development plan includes an aggressive drilling program. Exploration wells for deeper prospects have been planed. The 3D program has revealed the potential extension of the field in an easterly direction and a new 3D program is in planning stage. CGG is testing the new statics workstation called Geostar for better statics correction. In the future the true amplitude processing might be considered in order to use attributes as AVO, inversion and fracture characterization. Wave Equation Pre Stack Depth migration might be used in order to improve the basement and obtain depth migrated angle gathers for true AVO analysis.

Conclusions

3D volume has given better results and better understanding of the structures on Tasour field. Modern techniques for modeling of near surface anomalies, noise attenuation and imaging have improved the quality of the seismic data. PSDM gave better resolution, clearer fault definition, better horizon continuity, correct positioning, and changed the interpretation. The recent well results have confirmed that PSDM was necessary in solving the fault shadow effects present on this dataset. The limits of the field have been extended and the volume of proven reserves increased significantly. For the first time the basement has been properly imaged and exploration wells for deeper prospects have been planed. A new 3D program, east of the current one, is now in the planning phase.

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