Tu P05 06

Duplex Wave Migration Case Study in Yemen

G. Markarova* (Calvalley Petroleum Inc), I. Blumentsvaig (TetraSeis Inc.), A. Kostyukevych (TetraSeis Inc.) & N. Marmalyevskyy (TetraSeis Inc.)

SUMMARY

Duplex Wave Migration Method has been used to update Hiswah model in order to effectively locate future production and injection wells because as the data changes so does the framework of the model, specifically, the seismic re-interpretation of surfaces, faults and fractures. The goal of DWM was to add a value to already standard processed data with attempt to delineate sub-vertical fractures in reservoir body.

Introduction

Duplex Wave Migration Method (Marmalyevskyy et al., 2006, Khromova et al., 2010) has been used to update Hiswah model in order to effectively locate future production and injection wells because as the data changes so does the framework of the model, specifically, the seismic re-interpretation of surfaces, faults and fractures. The goal of DWM was to add a value to already standard processed data with attempt to delineate sub-vertical fractures in reservoir body.

Area Geology

The Saar Naifa oil pool is associated with an anticline structure split by faults into two parts, Hiswah South and Hiswah North as shown in Figure 1.

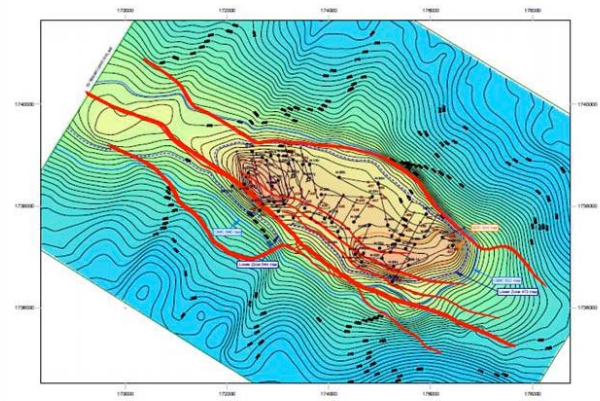

Figure 1, The main northwest southeast fault separating the oil accumulation into a North and South pool and contains a number of smaller throw faults as well.

All of the production wells are located in the North Hiswah pool and only one well was drilled in the Hiswah South pool. The Saar-Naifa Formation consists of shallow marine carbonates, predominantly limestone with smaller amounts of deeper marine argillaceous limestone and shale. These rocks were deposited during the rift phase of the basin development on the pro-grading shelf margin. The seal is formed by a regional Saar calcareous shale interval. There is a main northwest southeast fault separating the oil accumulation into a North and South pool as well as numerous smaller throw faults as shown in Figure 1. The primary porosity appears to vary across the field, likely due to facies changes. Secondary fracture porosity likely exists, particularly near the faults.

The main Saar – Naifa carbonate reservoir was split into the Upper and Lower zones. The Upper zone has higher oil saturation and a higher net to gross ratio than the Lower. The difference in the water saturation of these two zones is likely due to a very thick oil water transition zone but it could also be partially caused by two different stages of oil migration into the structure. The Lower zone could have been filled out recently and has not fully mixed with the oil which migrated into the structure at an earlier time. The top of the Saar Naifa Formation was correlatable on all of the logs. A structure map on the top of the Saar Naifa Formation was presented in Figure 1.

The Saar Naifa pool also contains a gas cap in the southeastern part of the field. The presence of this gas cap is somewhat unusual because the central area of the field is higher structurally yet no gas cap was encountered. Also most of the oil samples indicate that the oil in the main area of the field is under saturated. This may be due to two different migrations of oil into the area or that gas that may have initially been present in the central area of the field has leaked through the faults.

The key uncertainty for the Hiswah Saar Naifa oil pool is the productivity of the Lower zone. All of the existing horizontal production wells are positioned only in the Upper zone thus determination of the productivity of the Lower zone is difficult.

Data Processing Results.

Conventional 3D anisotropic pre-stack depth migration (PSDM) provides accurate structural boundary information for events with dips from 0 to about 60 degrees. Duplex Wave Migration (DWM) is capable of imaging only vertical events (dips from 60 to 90 degrees) and it does not require either a large recording aperture or a velocity model that must have strong vertical velocity heterogeneity. Conventional Kirchhoff PSDM schemes assume that the kinematics of the ray path travel time calculations are such that the seismic energy bounces off of one and only one reflector before returning to the surface. TTI's Kirchhoff type implementation of DWM assumes that the seismic energy undergoes two bounces off of primary reflectors during its wave front travel path before it returns to the surface. This secondary bounce energy appears (on a raw seismic record) to be some form of coherent noise, or offline artifact on the seismic record. Consequently it is stacked out when conventional imaging criteria are used. This scheme differentiates the capability of the DWM technology from that of conventional migrations. On the left, each geophone on the ground surface records seismic waves reflected from subsurface geological layers (shown in this case as perfectly horizontal). However, single-reflection waves hitting sub-vertical surfaces cannot reach the surface. They must reflect a second time off a sub-vertical surface as shown on the right (Figure 2).

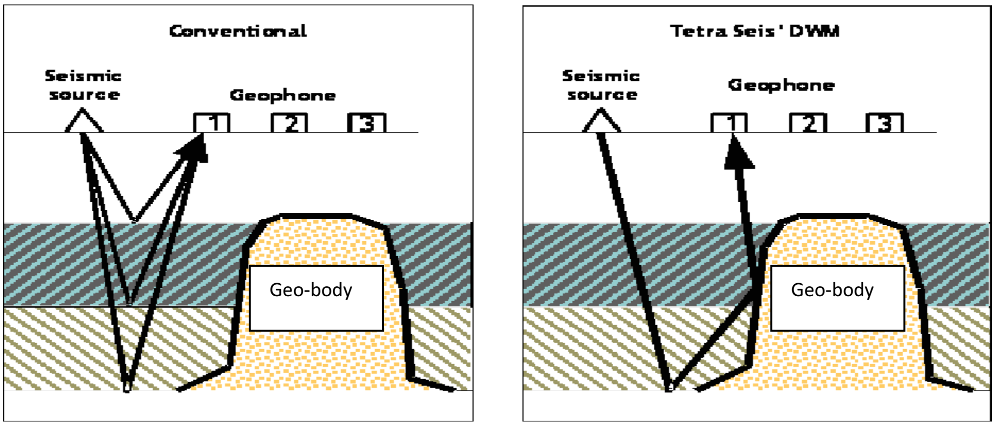

Figure 2, Direction of wave propagation which is used in conventional and Duplex Wave Migration Method.

However, if we re-define the kinematics of the problem we can stack (or image) the data in such way that this duplex wave energy (DWE) is re-enforced and the conventional single bounce energy is stacked out. When we impose this re-definition of the basic kinematics of the migration process on the seismic data the resulting 3D data cube will contain vertical or near vertical boundary information only. Therefore, through the use of DWM we can fill in the very information (dips from 60 to 90 degrees) that is missing from convention pre-stack depth migration results.

As a result of using this technique on Hiswah data-set we can compare structural depth slices of 3D PSDM, final result (Figure 3) and 3D DWM, raw result (Figure 4):

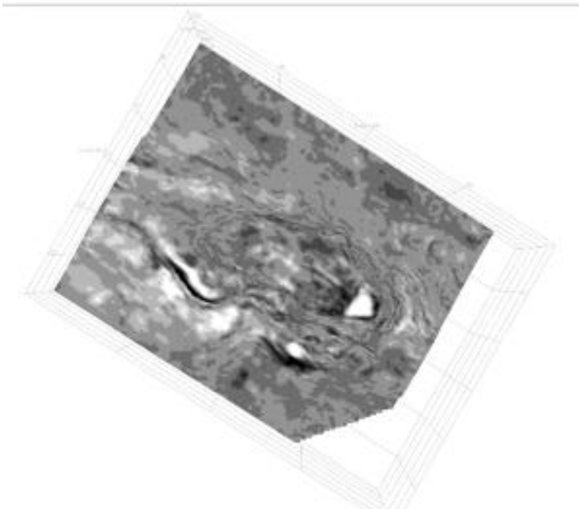

Figure 3, 3D PSDM structural depth slice 20 m above of Saar – Naifa surface.

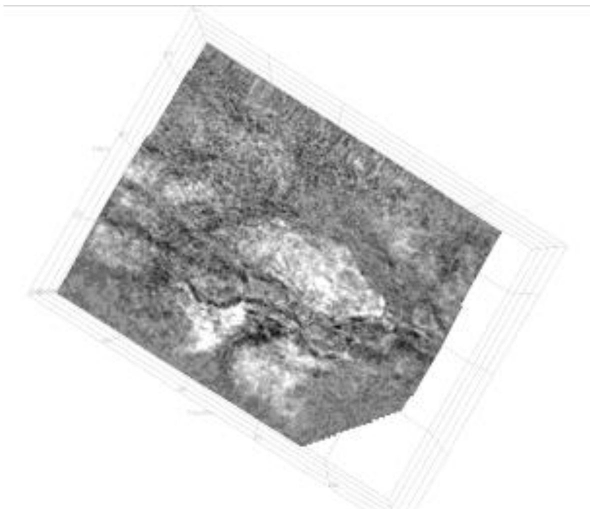

Figure 4, 3D Raw DWM structural depth slice 20 m above of Saar – Naifa surface.

We can clearly see that even raw 3D DWM result bring us new additional information which we couldn't see on final 3D PSDM. Following a number of post-processing operations such as removal of a low-frequency component which is tied with regional geology and applying voxel connectivity technique we delineated local sub-vertical anomalies (Figure 5):

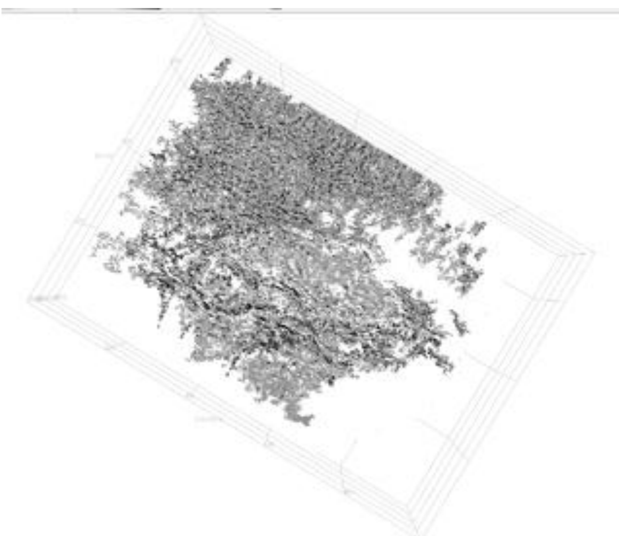

Figure 5, 3D Post-Processed DWM structural depth slice 20 m above of Saar – Naifa surface.

Based on these processed results a new injector well was planned, drilled and well logging was performed during progression. In the end of drilling process a massive water loss was encountered because well reached an open fracture as it was predicted in DWM results. Below you can see well's position and Slowness well log (Figure 6):

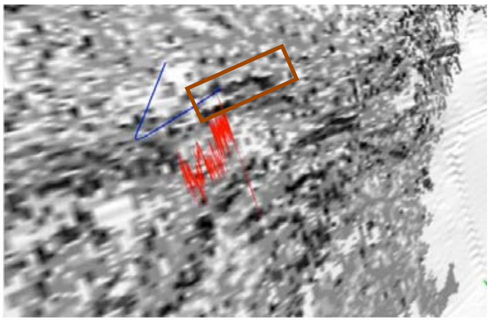

Figure 6, Injector well position entering into delineated by DWM fracturing zone. It is clearly seen velocity loss.

Conclusion

As a conclusion, we can definitely say that DWM method brought additional information to a conventional seismic data which allows updating Hiswah model, and we recommend continues combined study of DWM lineaments, wells production and all available drilling information including wells production intervals to collect maximum information which will be beneficial for reservoir study.

Acknowledgements

We would like to thank Calvalley Petroleum Inc. for allowing us to publish this information.

References

1. Marmalyevskyy, N., Gornyak, Z., Kostyukevych, A., Mershchiy, V., Roganov, Y., [2006]. Method, systemandapparatus for interpreting seismic data using duplex waves, Patent US 7,110,323 B2

2. Khromova, I., Link, B. [2010]. Fracture Delineation Case History from Russia and implications for plays in North America. 80th Ann. Internat. Mtg., SEG. Expanded Abstract, 297-301.