

Imaging Challenges in a Producing Mideast carbonate platform environment

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Summary

This paper summarizes some of the seismic imaging challenges associated with a producing field in the Arabian Gulf. Overburden effects and their impact on the seismic data quality are discussed. We describe an approach which partially compensates for these effects in the time domain, thereby increasing the utility of this seismic dataset.

Introduction

Carbonate platforms in the Mideast continue to represent an important source of hydrocarbon reserves. Interpretation and attribute extraction from time-based seismic imaging products has been successful for numerous decades as the base seismic products for Exploration, Development and Production Geophysics.

With the continuing advances in seismic imaging, there is an obvious interest in applying new algorithms in these settings. However, many of these carbonate reservoirs have accompanying imaging challenges that cannot be addressed solely through the application of the most current seismic imaging technology. Alternative processing strategies must be considered; either to replace more conventional approaches and/or to prepare the data so that they conform to the limitations of the imaging algorithm.

For example, small-scale distortions in the near surface and overburden often result in structural and amplitude artifacts at the reservoir level that are of the same scale as the production well spacing. This is particularly problematic in this mature Production (thin bedded) carbonate reservoir environment. This is because of the dense well control. In order for seismic images to add full value, they must be at their resolution limit.

This paper discusses the basic geological factors affecting the seismic imaging in these settings and their physical impact on the seismic wavefield. We also describe an alternative processing strategy to compensate for these effects. This abstract focuses on the correction of time-delay effects. The actual presentation will include a discussion of amplitude effects and the imaging characteristics of the individual (geophone and hydrophone) sensor types.

Case History

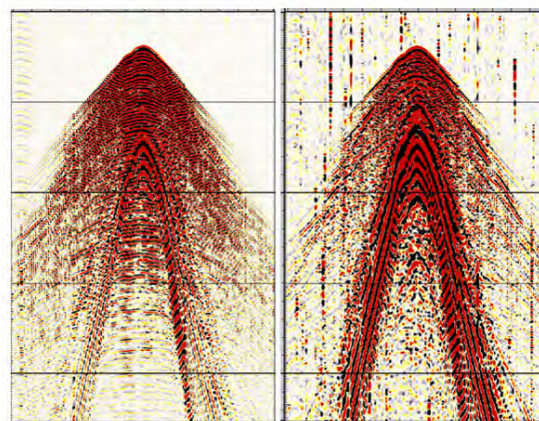
The seismic data is from a major producing field in the Arabian Gulf. Structural dip at the reservoir level is generally one to two degrees and only occasionally reaches five degrees. Structural relief over the entire structure is approximately 300 meters and the scales of the structural artifacts we will discuss generally have less than 30 meters of apparent vertical relief.

A 3-D 2C OBC survey was acquired in water depths varying from less than 7 to over 25 meters. Living reefs are scattered throughout, resulting in significant variations in water depth, seabed reflectivity and geophone coupling.

The data exhibit a variety of noises, including

- “trapped-mode” water-borne energy
- water-bottom-interface surface waves (“mud-roll”)
- short-period “reverberation” multiples, with periodicity varying with water depth
- diffractions from reefs
- interference from existing production facilities
- ambient “random” noise.

The “noise field” exhibits different character on hydrophone and geophone data (Figure 1). The results of the surface-wave noise attenuation for this project were previously published (Reilly et al 2008).



a) hydrophone

b) geophone

Figure 1: Example data quality: OBC field records

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Once near-surface effects have been sufficiently mitigated, it becomes apparent that overburden effects cause significant deformation of the horizon surfaces at the reservoir level (Figure 2). These overburden effects are typically observed throughout the region.

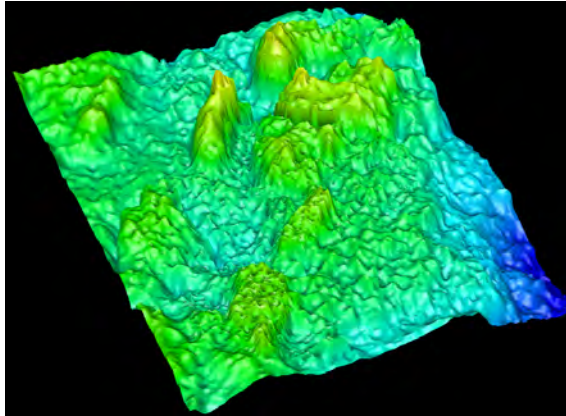


Figure 2: Horizon time surface at target level. Although the large-scale structure is visible, many of the small-scale "crenulations" on this surface are due to overburden effects (as demonstrated by well data).

This phenomenon becomes particularly problematic when one attempts to integrate the seismic structural information in the geologic model (Figure 3). The initial result is an overly complex model which clearly contains many non-geologic features at the reservoir level. This ultimately reduces the overall credibility of the seismic dataset.

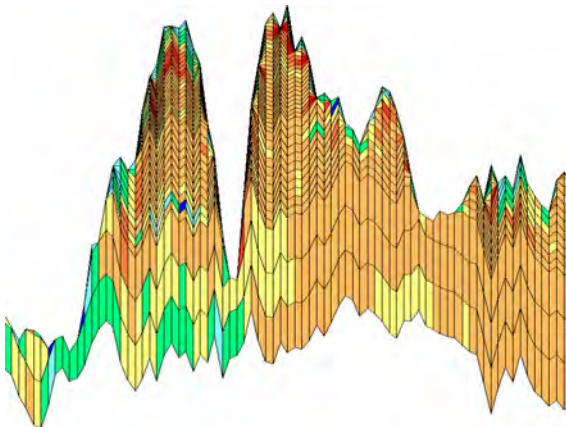


Figure 3: Cross section through an initial geologic model that incorporates the seismic horizon surfaces. Again, many of the small-scale crenulations on this model are due to overburden effects and do not reflect the true structure at the reservoir levels.

In order to understand the cause of these perturbations, it is necessary to investigate the overburden geology. Figure 4a is a simple synthetic model which represents the known vertical velocity field from the surface to target levels. The velocity variation observed from well data spans the entire range of sedimentary velocities (e.g. <2000 m/s to over 6200 m/s) and is further complicated by numerous cyclical velocity inversions. As a result, the presence of very small faults result in significant distortions to conventionally processed data after (pre- or post-stack) time imaging.

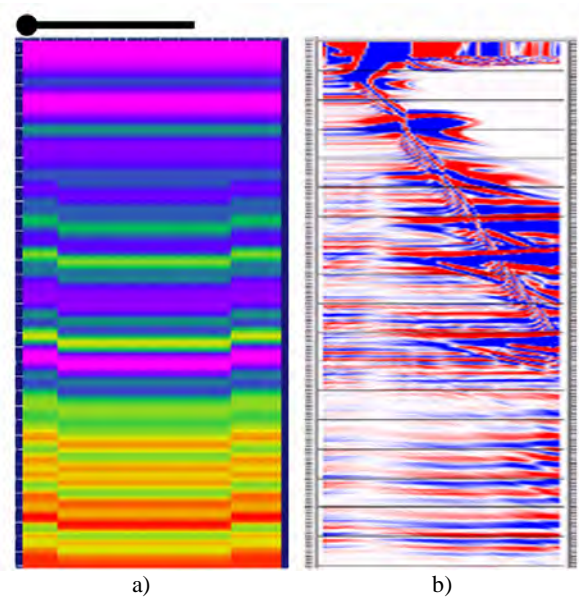


Figure 4: Synthetic model showing:
a) velocity model (purple 2000m/s, red 6200 m/s)
b) NMO corrected shot record that spans the small fault

The problem becomes even more complex when other well-known stratigraphic and diagenetic features in the overburden are considered; e.g. stratigraphic truncations, channels, karstification and related diagenetic phenomena (Figure 5).

The logical approach to removing these effects would be to attempt depth imaging. Where the causative anomaly can be clearly identified, anomalies can be partially mitigated using conventional technology (Takanashi et al, 2008). However; there are fundamental challenges with utilizing current depth-imaging technology:

- the bulk of the velocity perturbations are not directly imaged on the seismic data and,
- the scale length of these perturbations is often less than <200m, or significantly below the resolution scale of current velocity model building technology, and

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- even if an accurate velocity model could be constructed, accurate imaging at these scale lengths would likely require a full 3D implementation of reverse-time migration..

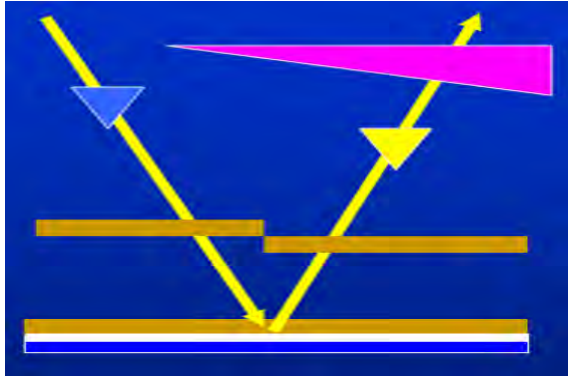


Figure 5: Illustration of geologic features within the overburden that cause distortion at the reservoir level.

Examination of the actual seismic data substantiates the modeling work. Figure 6a is a NMO corrected CMP gather after the application of all surface-wave attenuation, random-noise attenuation, and near surface refraction and reflection statics processes have been applied. Even though this gather is approximately 300 fold, there is apparently little coherent reflectivity. Data of the quality shown in this figure is typically used to justify new data acquisition with ever higher requirements for trace density.

Further analysis of these data reveals evidence that both azimuthal anisotropy (Luo et al, 2005) and the effects of residual acquisition noise are also partially responsible for traveltimes delays. However, as shown by the horizon time surfaces (Figure 2), small-scale overburden effects appear to dominate the trace-to-trace variation within a CDP gather, even after azimuthal sort. This “jitter” is generally less than 10 ms; but it significantly degrades the retention of frequencies above 50Hz after stacking.

Figure 6b is the same gather after a 3D dynamic correction process has been applied. This process attempts to correct for small scale distortions on the scale length of 200 m or less, leaving the larger scale features for later depth imaging processes. After this correction has been applied, valid reflection information becomes visible in this gather.

The conventional approach to improving stack response is to increase the effort in the RMS velocity analysis phase (post DMO or post PreSTM) however, during this study we observed that this can actually result in an increase in the

non-structural time distortion without any significant improvement in the overall stack response.



Figure 6a: NMO corrected CMP gather



Figure 6b: NMO corrected CMP gather after 3D dynamic correction has been applied.

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Figure 7a is an image at target level from a stack utilizing a velocity field that was picked using a conventional RMS velocity workflow. In an effort to improve the stacking response, a much higher picking effort was attempted. The results are shown in Figure 7b. What becomes immediately apparent in Figure 7b is the introduction of a time distortion that exactly matches the picking interval (blue arrow). This is an excellent example of what can occur when a 1D approach is utilized to solve a 3D problem (as described in Figure 5).

Figure 8 shows the same data after the 3D dynamic correction process is applied after NMO and prior to stack. It is quite apparent from this figure that this approach is effective at improving data resolution without causing additional structural artifacts in the output stack. Furthermore, it does not create, or remove, time structure generated by the RMS velocity field.

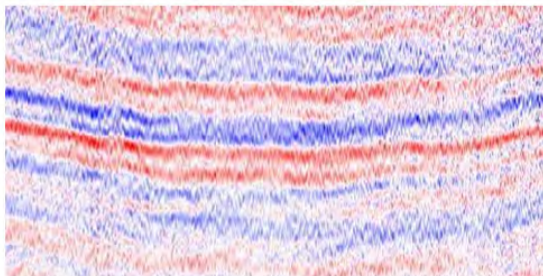
Of course, in this environment, a full solution still requires transformation into the depth domain. However, successful imaging in the depth domain must recognize the limitations of the selected depth migration algorithm. The 3D dynamic correction process discussed in this paper is specifically designed to complement follow-on depth imaging work.

Conclusions

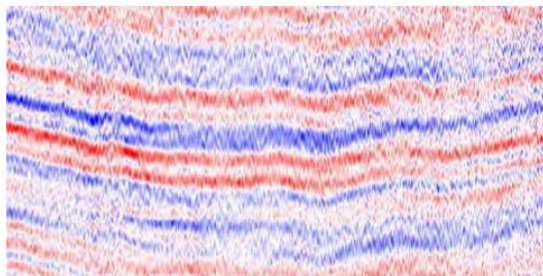
A processing strategy that focuses on addressing the fundamental factors impacting seismic data quality can result in significant improvement in the final dataset. Application of advanced imaging techniques that cannot accommodate the known geologic problem will likely fail to provide significant additional value unless the processes similar to those discussed in this abstract are applied prior to the imaging step. This not only impacts structural mapping, but also the subsequent attribute (amplitude) and inversion workflows.

Acknowledgments

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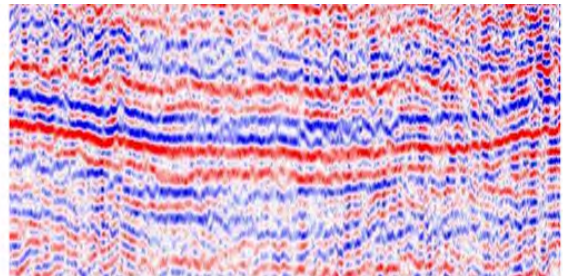


a)

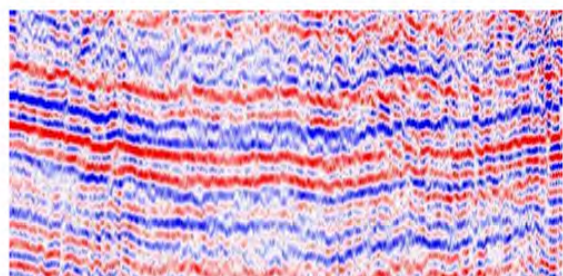


b)

Figure 7: Stack section
a) following conventional seismic picking workflow and
b) after "high effort" closely spaced velocity analysis



a)



b)

Figure 8: Stack section after 3D dynamic correction
a) using the seismic velocity field from 7a
b) using the seismic velocity field used in 7b

EDITED REFERENCES

Note: This reference list is a copy-edited version of the reference list submitted by the author. Reference lists for the 2009 SEG Technical Program Expanded Abstracts have been copy edited so that references provided with the online metadata for each paper will achieve a high degree of linking to cited sources that appear on the Web.

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