



Application of 4D Seismic Data Matching Technique to the Merging of Overlapping 3-D Survey Volumes at Mangala Field, Barmer Basin

Rajesh Soni, Kondal Reddy
Cairn Oil & Gas, Vedanta Limited*

Rajesh.soni@cairnindia.com

Keywords

Seismic merging, Cross-equalization, Barmer Basin, Mangala field, Seismic shaping

Summary

The Mangala field, located in Barmer Basin, Rajasthan, India is covered by 3D seismic data from two vintages. The first survey, the NR3D was acquired and processed during 2005 and again reprocessed in 2010. Another high-density 3D seismic survey, the HD3D, was acquired in 2007 with a different orientation and processed to support field development. Vertical and lateral resolution of the HD3D data is superior whereas image quality of the NR3D data is significantly better along the main trapping fault. These datasets have amplitude and phase spectrum mismatches due to different acquisition and processing parameters which complicate their simultaneous interpretation. This abstract describes the workflow to merge these datasets, focusing on minimizing attribute mismatches. This modified 4D workflow involves regriding of NR3D data to reconcile orientation differences, applying a global phase and time matching to reconcile the time and phase differences, applying a shaping filter for bandwidth and energy matching and then merging the two datasets. This post-stack merging process preserved the better quality of NR3D data at the crestal part of the field, and good quality of HD3D data in the structural flank areas.

Introduction

The Mangala field is in the northern part of the onshore Barmer Basin in Rajasthan, India. Hydrocarbons in the field are trapped within a south-east dipping tilted fault block structure formed during the Tertiary rifting episode that created the Barmer Basin. The primary reservoir is the Fatehgarh Formation deposited during the Late Cretaceous to Early Paleocene.

The field is covered by 3D seismic data from two vintages of acquisition. The first survey, the NR3D was acquired and processed during 2005 and subsequently reprocessed in 2010. Data from this survey was used to support early appraisal well drilling in the field and initial field development plan. Another high-density 3D seismic survey, the HD3D, was acquired in 2007 with a different orientation and processed to support field development (Figure 1). Acquisition and processing parameters differ for both vintages. Both vertical and lateral resolution of the HD3D data is superior compared to the NR3D data, with better definition of intra-field faults and continuity of reflections within Fatehgarh formation. However, image quality of the NR3D data is significantly better than that of the HD3D data along the main trapping fault at the crest of the structure (Figure 1). Consequently, reliable reservoir modeling and infill well placement near the crest using the HD3D data alone is challenging.

Given the relative advantages and disadvantages of the two seismic datasets, interpreters are currently using both datasets to support field development activity. While the long-term plan is to perform full reprocessing by combining data from both surveys, a short-term answer was needed to improve interpretation efficiency and accuracy. This abstract describes the deterministic workflow we used to merge the two datasets, with a focus on minimizing attribute mismatches. We used a modified 4D workflow for the merge process, preserving the better quality of NR3D data at the crestal part of the field, and using good quality of HD3D data in the structural flank areas. Since the previous structural interpretation for static modeling is largely based on HD3D survey, this survey was taken as the base survey and the NR3D was matched to it.

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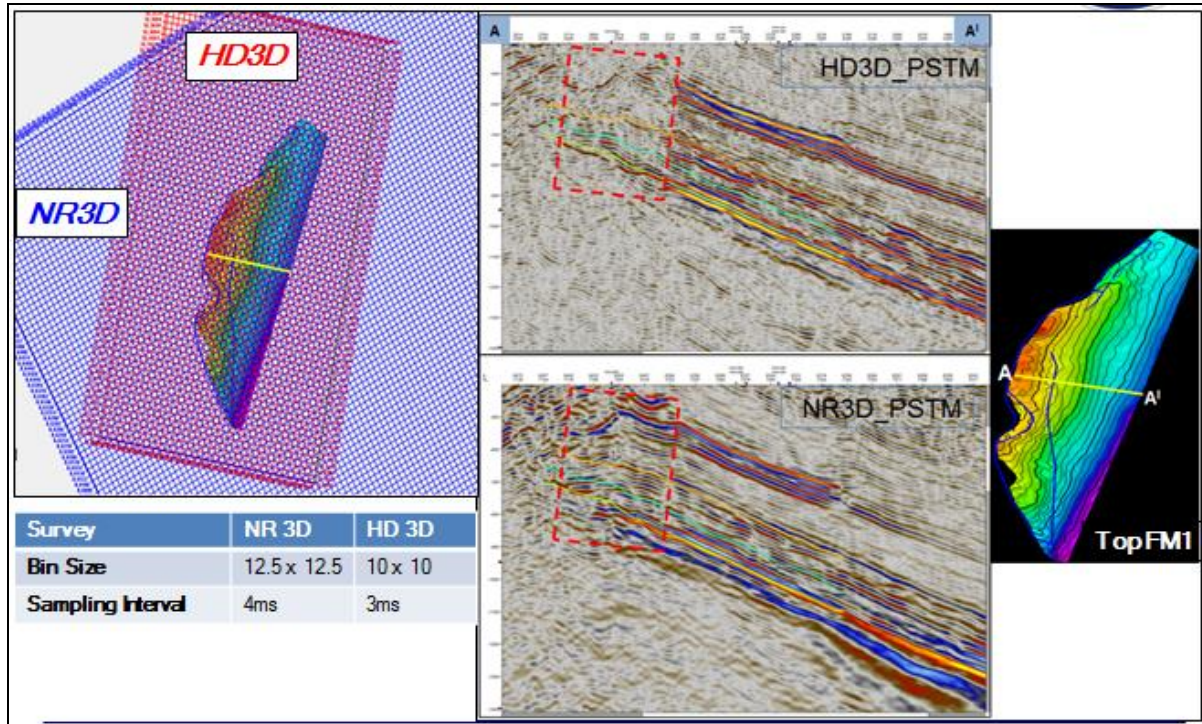


Figure 1 Difference in the orientation and imaging quality of NR3D and HD3D PSTM dataset. Isochron for Top of Fatehgarh reservoir is shown in the background.

Method

Matching the two legacy seismic datasets before deriving and interpreting a 4D anomaly is a routine exercise in a 4D project. In this study, we used a modified 4D workflow to minimize the mismatch of time, phase, frequency and signal energy between the datasets before merging. The workflow is schematically shown in Figure 2.

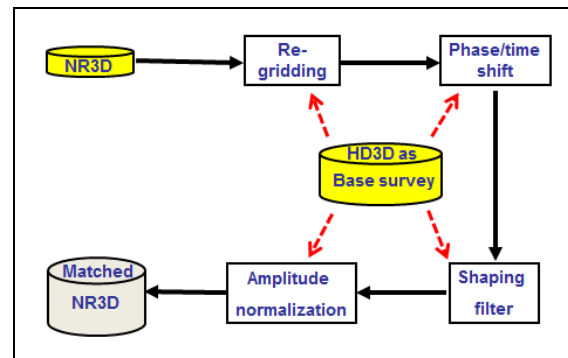


Figure 2 Modified 4D workflow used to match the NR3D and HD3D datasets.



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First NR3D survey data was re-gridded to the geometry of the HD3D to reconcile their different orientations. Re-gridded NR3D data has been checked to maintain the structural consistency with the vintage NR3D data. A well tie had been performed on vintage NR3D data using Mangala 1 well and a time-depth relation and wavelet were established. The same wavelet and time-depth relation had been used to perform seismic to well tie with re-gridded NR3D data and found that the events and correlation values are similar. This step established that the gridding process had not altered the timing of events in NR3D data.

Then, global phase and time shift differences were computed within an interval containing the primary reservoir section. This process can be thought of computing constant phase and time shift during the seismic-to-well tie process where HD3D data acts as synthetic data and NR3D is used as seismic data. This estimated phase and time shifts can be applied using trace-by-trace sense, running average method with overlapping windows or as a Global time and phase shift. In this project, the estimated phase and time shifts had been applied using Global time and phase shift.

The next step is to design a matching filter for the two datasets. The process derives a transfer function between the two datasets to match their frequency content, phase, time shifts and average power. This step is very crucial and required stringent QC to assure the quality of shaping filter. Amplitudes for NR3D data were normalized to match the dynamic range of amplitudes in both datasets (Figure 3). To QC the quality of shaping procedure, seismic to well tie had been performed for HD3D data using Mangala 1 and a time-depth relation and wavelet were established. The same wavelet and time-depth relation had been used to perform seismic to well tie with NR3D data before and after shaping procedure (Figure 4). The correlation has increased after shaping the NR3D data which confirmed that time-depth and wavelet characteristic of NR3D data after shaping application resembled more with HD3D dataset. The cross-correlation had been computed between HD3D and NR3D for primary reservoir interval before and after shaping and a significant improvement was observed in the correlation value

after the shaping (Figure 5). Improved image quality is clearly visible in the section view (Figure 6) as well as in map view (Figure 7).

The result of this workflow is a correction of the NR3D dataset so that attributes of reflection time, phase and amplitude were matched to those of the HD3D dataset.

Conclusion

Reliable reservoir modeling and infill well placement near the crest in Mangala Field using the existing seismic datasets is challenging due to mismatches of time, phase, frequency and signal energy between the datasets. The co-interpretation process using these seismic vintages is also inefficient and prone to errors. In this study, we have demonstrated, how a fit for purpose solution of modifying 4D workflow can increase the efficiency of seismic data interpretation and support development activity at the Mangala field. We generated a new NR3D product which has been matched to HD3D and then generated a single dataset by deterministic merging of HD3D and matched NR3D datasets. The merged product preserved the better qualities of data in the two individual datasets.

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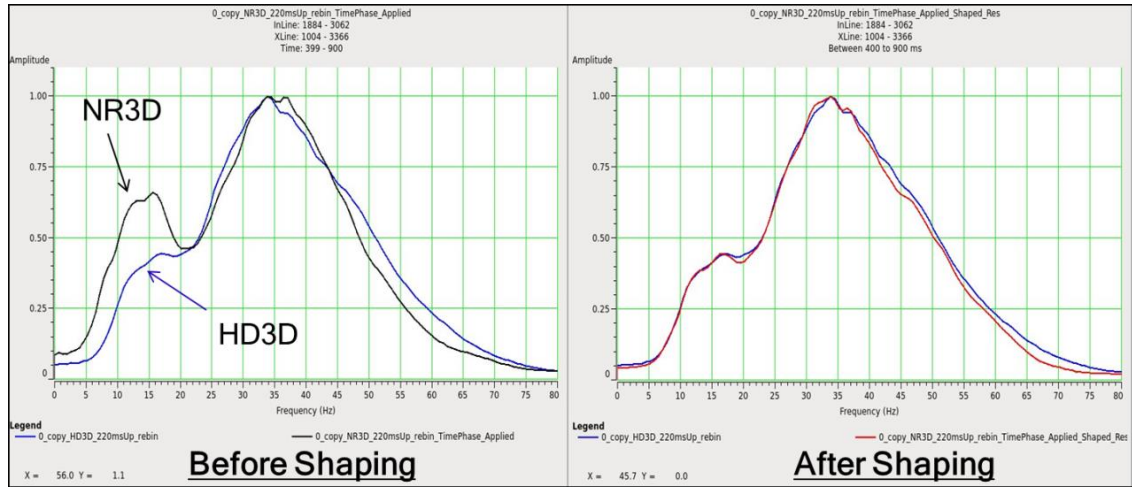


Figure 3 Frequency spectra of HD3D and NR3D before (left) and after shaping (right)

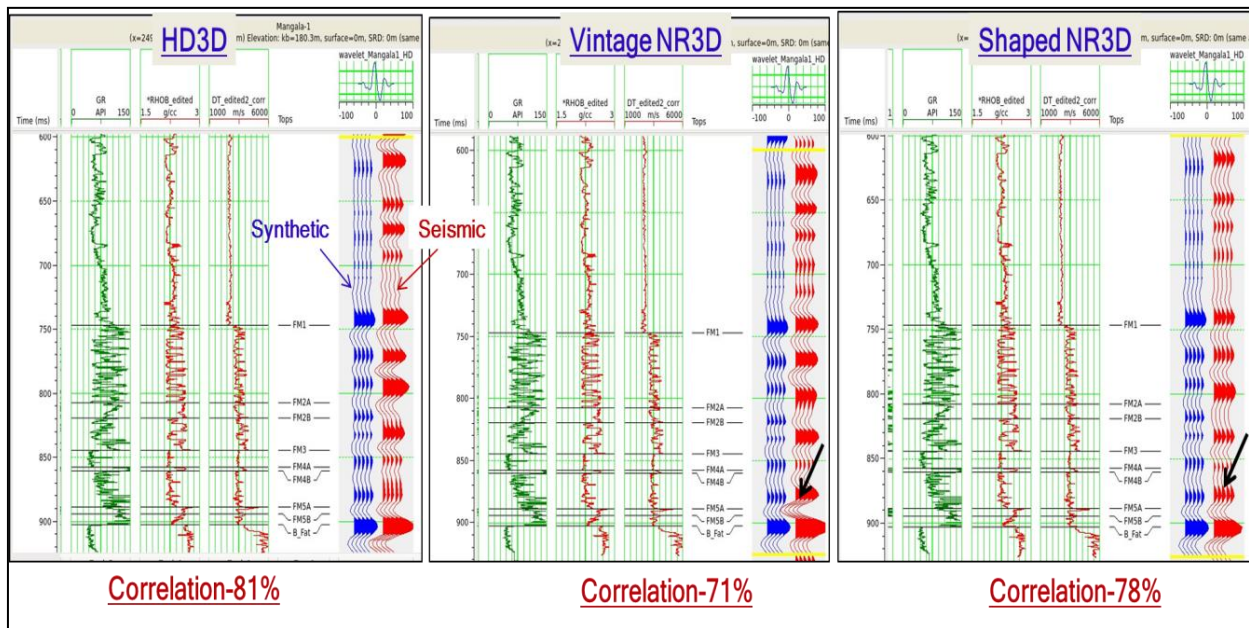


Figure 4 Seismic to well tie of different seismic dataset with Mangala 1 well using the wavelet and time-depth derived from HD3D data. This clearly indicates that time-depth and wavelet characteristic of NR3D data after shaping application resembles more with HD3D dataset

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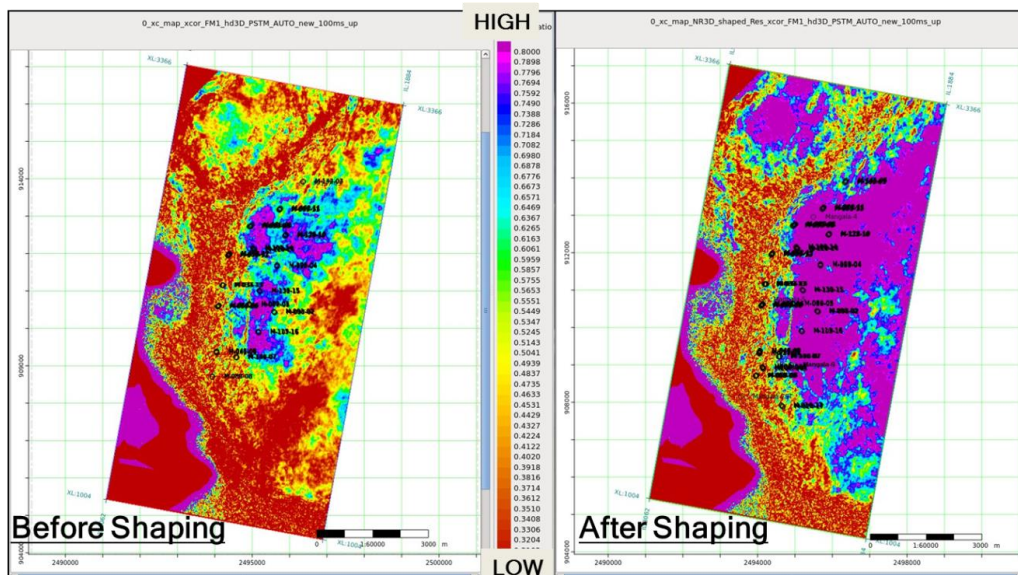


Figure 5 Cross-correlation between HD3D and NR3D for primary reservoir interval before and after shaping indicating a significant improvement in correlation value after the shaping.

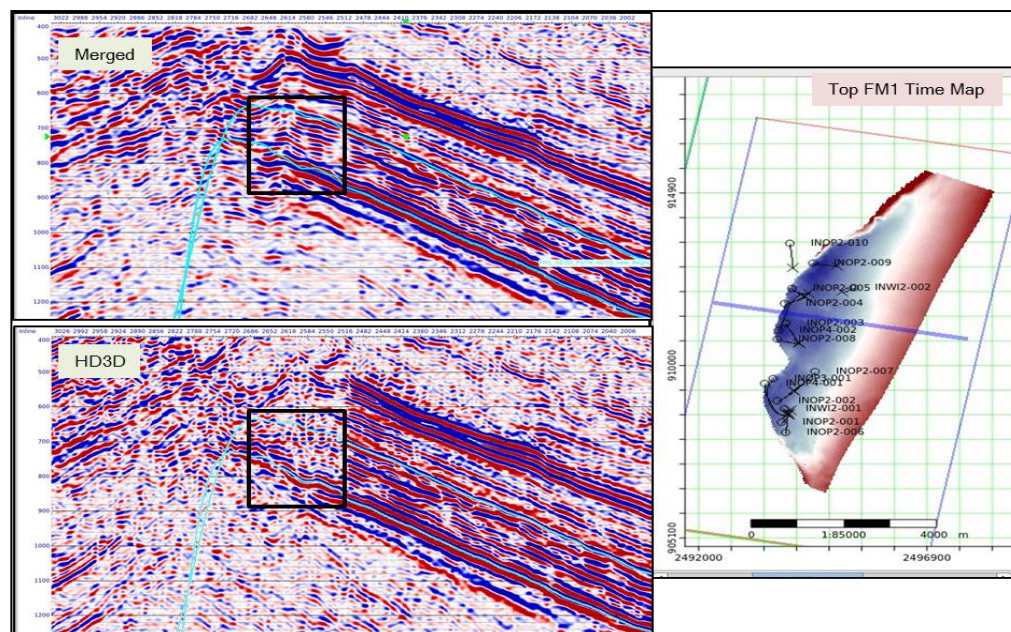


Figure 6 Improvement in image quality at the crest of Mangala structure after merging the two datasets.

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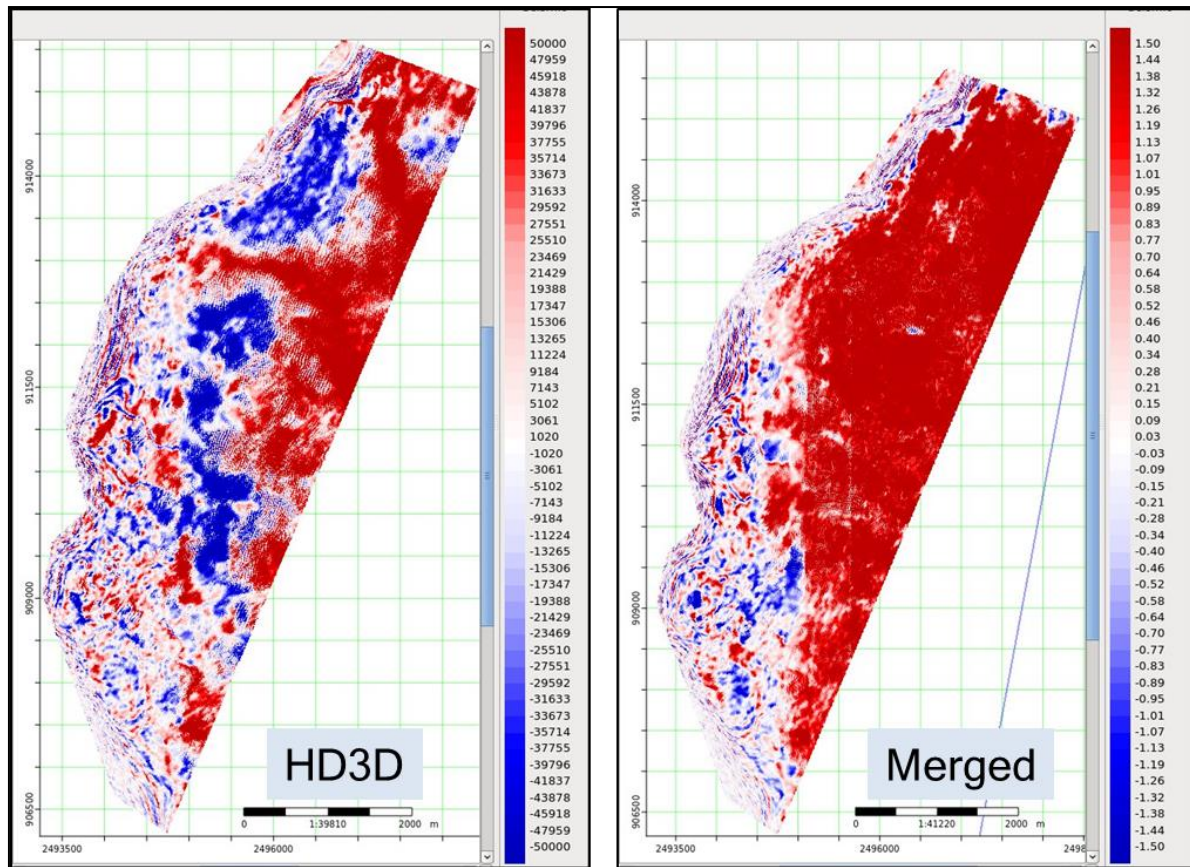


Figure 7 Seismic amplitude at the top of FM1 horizon extracted from HD3D and Merged data. FM1 horizon is a seismic peak event and expected to have positive amplitude throughout (red colour) which is more true for merged dataset than for HD3D data.