Qualitative and Quantitative Analysis of a reservoir by Waveform Classification – A case study, Aishwariya field, Barmer Basin

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Summary

Seismic attributes are extensively used for predicting the lithological and petro-physical properties of the reservoir, which helps in hydrocarbon exploration. The waveform classification technique uses the wave shape of these seismic attributes as a classifying parameter. In this technique, an interval of interest is defined with the help of interpreted horizons. And then a suite of waveforms is generated that best expresses the wave shapes of all the seismic traces within that interval. Upon classification into these classifiers, self-organized maps are generated which may depict depositional and structural patterns which thereby infer reservoir properties.

The Aishwariya Field, situated within the RJ-ON-90/1 Contract Area, was discovered in March 2004. It is currently the third largest onshore field discovered in the Barmer Basin of Rajasthan, India. In the present study, waveform classification is carried out within the interval of interest defined by two horizons picked in the field. The high density 3D seismic data is being represented through low density self-organized maps which are generated through Neural Network Training of the wave shapes. These maps are then utilized to estimate the geology of the area as a different wave-shape can mean a different geology. Waveform maps often unravel the depositional environment. It is demonstrated that once a geological understanding of the seismic signatures is achieved, the semi-quantitative or quantitative interpretation of seismic facies is conceivable with the help of supervised waveform classification. The Net/Gross of the reservoir is calibrated with the shape of the seismic signature and hence NtG model is inferred in Aishwariya Field using this technique.

Keywords: Net/Gross (NtG), Waveform Classification (WFC), Self-Organized maps (SOM), Neural Network Training

Introduction

The figure below shows the location of the RJ-ON-90/1 Contract Area and within that the location of Aishwariya Field.

Figure-1: Location of Aishwariya field in the Barmer Basin

3D seismic data over the field was acquired in 2004. The data quality varies from good at the flank to poor at the crest of. Structurally, Aishwariya Field is a relatively simple fault block footwall high, with a major block bounding fault system to the west and north-west. The database used for the field seismic interpretation includes PSTM seismic and available well information. The PSTM seismic dataset is zerophase with SEG normal polarity convention i.e. an increase in acoustic impedance was maintained throughout the interpretation. Processing of the seismic data has been undertaken twice, once in 2004 and once in 2010. In this study the 2010 processed data has been used.

Aim of the study:
• Qualitative Interpretation of the color-coded maps generated by WFC to locate regional trends representing the depositional environments and the geology of the area.
• Supervised Waveform Classification in the same intervals using seismic traces from the wells and...
knowledge of Net/Gross values for each well, for the quantitative interpretation.

- Calibration of Net/Gross with the seismic trace shape and verifying these results by taking one well with known Net/Gross as a blind well and checking the correlation of the seismic trace shape in that well with its Net/Gross.

Methodology

Unsupervised Waveform Classification

Figure-2 depicts the workflow of the unsupervised waveform classification technique. 3D seismic volumes, interpreted horizons at two levels (Upper Fatehgarh and Lower Fatehgarh) and attribute maps namely P-impedance, Variance etc. are used as inputs to the waveform analysis. The next step is to classify the classifier using Neural Network and finally self-organized maps are created with the defined classes. The key to the success of a waveform analysis work is a well interpreted horizon that mimics the subsurface. As a result it is desirable that the horizon should snap to peak, trough or zero crossing.

Figure-3: Interval Definition for waveform

Table 1: Interval Definition

<table>
<thead>
<tr>
<th>Interval</th>
<th>Upper Bound</th>
<th>Lower Bound</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>R1</td>
<td>R2</td>
</tr>
<tr>
<td>2</td>
<td>R1-15ms</td>
<td>R1+40ms</td>
</tr>
<tr>
<td>3</td>
<td>R2-5ms</td>
<td>R2+38ms</td>
</tr>
<tr>
<td>4</td>
<td>R3</td>
<td>R3</td>
</tr>
</tbody>
</table>

Classifying the Classifier and Seismic

The WFC process starts with fixing the number of classes envisaged in the study area. Neurons are generated from the input seismic traces by Neural Network process and they change their wave-shapes to represent the input seismic. In this fashion the classes are formed.

To create the self-organized map from the input seismic, a trace is selected (Figure-4) and correlated with the existing classes. The best correlated class is assigned to this trace keeping the topological structure of the input data intact. This process is repeated for all the traces within the zone of interest.

Various seismic attributes have been used in combination to achieve the best classification. Figure-5 illustrates the comparison of two SOM (self-organized maps) generated by using reflectivity and a combination of reflectivity and variance. The reflectivity and variance SOM has more noise resulting in blurred definition of the structural features whereas the reflectivity SOM has properly mapped the faults at the crest and flank of the structure. Also, one can observe the apparent lateral facies variation from the crest to the flank.

Figure-2: WFC workflow

Interval Definition

The study Intervals are defined using the interpreted horizons R1 (Top Fatehgarh), R2 (Top Lower Fatehgarh) and R3 (base Fatehgarh). Table-1 summarizes the interval definitions for four intervals. Intervals 1 to 3 were used for unsupervised and 4 for supervised classification.
Figure - 4: Classification process, every trace is being classified based on the Neurons

Figure - 5: Comparison of two SOM – Reflectivity and Reflectivity & Variance.

Figure - 6: Facies variation across the field.

Comparing the two maps in Figure-5, we observe that using only reflectivity provides more apparent geological details as compared to the combination of reflectivity and variance. Hence using reflectivity attribute is desirable for waveform analysis within interval-1. Figure-6 shows an extra loop appearing near the flank which pinches out towards the crest. This is attributed to a change in facies from the crest to the flank.

Figure-7 depicts the WFC carried out for different intervals. The depositional environment and facies are changing from the Upper Fatehgarh to Lower Fatehgarh. Notice the channel feature present in interval-3 (Lower Fatehgarh) representative of fluvial deposition. Interval-2 is mainly deposited as marginal lake formation.

Figure-7: Comparison of final maps of all intervals
Supervised Waveform Classification and Estimation of Net/Gross

Supervised waveform analysis is carried out to estimate the Net/Gross (NtG) in Aishwarya Field. NtG values at well locations and un-supervised SOM are the main inputs for this analysis. Usually the number of classes are fixed one less than the number of wells to test the results on a blind well. Subsequently, the classes are replaced from actual traces from well. This incorporates the wells’ NtG data into the classes. Finally the seismic is classified into these classes.

Table 2 provides the NtG values in Interval-4 for five wells in the field. For estimation of NtG in this interval, the number of classes considered is four, which are indexed to the traces from four of the wells. Classification run generates an SOM in which the blind well is assigned the class to which it best correlates. It was consistently observed that this waveform class represented NtG values closest to the blind well. All wells were used in turn as blind wells, with good results. Consider the example illustrated by Figure-9 in which Well A-6z is a blind well. The wave-shape and NtG values corresponding to the blind well are best correlated to Well A-5 (refer Table-2). This indicates that wave shapes do relate to NtG. This facilitates the estimation of NtG away from the Wells.

Table 2: Net/Gross values for Interval 4

<table>
<thead>
<tr>
<th>Well</th>
<th>Net (m)</th>
<th>Gross (m)</th>
<th>Net/Gross (fraction)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-1z</td>
<td>38</td>
<td>96</td>
<td>0.39</td>
</tr>
<tr>
<td>A-2z</td>
<td>29</td>
<td>81</td>
<td>0.36</td>
</tr>
<tr>
<td>A-3</td>
<td>24</td>
<td>79</td>
<td>0.31</td>
</tr>
<tr>
<td>A-5</td>
<td>42</td>
<td>95</td>
<td>0.45</td>
</tr>
<tr>
<td>A-6z</td>
<td>34</td>
<td>57</td>
<td>0.6</td>
</tr>
</tbody>
</table>

The unsupervised waveform classification is also carried out within this interval (Figure-10). It is observed that wells A-5 and A-6z lie in the same class (dark red color) with high NtG. Similarly, A-2z and A-3 lie in the same class (red color) with low NtG. Whereas Well A-1z with medium NtG falls in a different class (light blue color).

To validate the WFC model, the wave shapes versus NtG of two new Wells (A-10 and A-12) are analyzed. The Wells A-10 and A-12 have NtG values 0.50 and 0.49 respectively. Notice that these Wells lie in the same class (dark red color) representing the high NtG (Figure-10). The classes from the SOM maps and NtG measurements within the blind wells are converging. The depositional environment at this interval is fluviatile.
faults, facies changes across the horizon, some channel features etc. Although there are imaging issues at the crest of the field, WFC provides a reasonable framework to help understand varying depositional features in the field.

Unsupervised and supervised waveform classifications can be used for the qualitative and quantitative analysis of the reservoir to locate the regions of high NtG. The good NtG values encountered by the blind wells A-10 and A-12 validate the WFC model. Hence, SOM maps can be used as an effective tool to map the NtG regions during well planning and reservoir model building. WFC analysis should be used as additional evidence along with other geophysical and geological measurements, and not in isolation.

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