Improved Advanced Reservoir Characterization through Inversion Techniques: A Comparative Study

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Summary

Seismic post stack inversion is the most popular method because of its greater robustness and simpler assumptions. There are two approaches for post stack inversion method, broad band and band limited inversion respectively (Russell, 2006). Broad band inversion is further classified into model based and sparse spike inversion.
Post stack Seismic inversion attributes are now routinely used to estimate density, impedance, and the ratios of the velocities of P and S waves also the elastic impedance from well log and seismic data. Efficiency and improved quality of inversion method make it adopt by exploration industries for extraction of rock physical properties from seismic data (Ming Li, 2014). Inversion techniques start with construction of initial geological model and match with real seismic data. Modified the model's parameters until calculated data match with observed seismic data. Finally matched geological model help for predicting distribution of physical properties of reservoir (Vecken & Da Silva, 2004). Interests on seismic inversion have grown for a couple of years and these integrated studies are used for hydrocarbons exploration (Vazquez etal., 1987). Seismic data carry rich information about lithology and reservoir physical properties. Seismic inversion transforms interface property into stratigraphic property and can be directly related with well log information. In this way geological interpretation made from seismic data and inverted data is helpful for reservoir characterization (Ming Li, 2014).

Methodology

For reservoir characterization several standard seismic post-stack inversion methods are used and compare their results. Model-based (MBI), Sparse-spike (SSI), and Band-limited (BLI) inversions are applied to the post-stack seismic data. We need to extract the wavelet to convolve with reflectivity to produce synthetic trace is not simplistic. Seismic wavelet is time varying and much complicated in shape. The various method of inversion requires more accurately the estimation of wavelet (Russell, 2006). Wavelet is not same at different locations in subsurface. Effects (geometrical spreading, attenuation) of subsurface cause wavelet more complicated (Barclay et al., 2007). Statistical wavelet is used for this study. The time window for statistical wavelet extraction is from 2150 to 2400 ms with wavelength 200 ms and taper length is 25 ms. Zero phase wavelet have been used for synthetic. The extracted wavelet with its amplitude and phase spectrum is shown in Figure 1.
For low frequency models we need know about acoustic impedance. Acoustic impedance has two types. Relative and absolute acoustic impedance. “Relative impedance does not require any initial low frequency model for its calculation” (Barclay et al., 2007), because it is relative property of layers. Relative impedance is used for qualitative seismic interpretation. Absolute impedance is the absolute property of layers, and it deals with both qualitative and quantitative seismic interpretation (Cooke and Cant, 2010). For obtaining absolute impedance (0-15 Hz) frequencies

are added in inversion algorithms (Cooke and Cant, 2010). Low frequencies act as a part of algorithm in model-based inversion but in spare spike inversion low frequency model add separately (Cooke & Schneider, 1983). A low frequency model used for inversion is shown in Figure 2. Sonic log is used for generation of low frequency model in wells vicinity in this study.

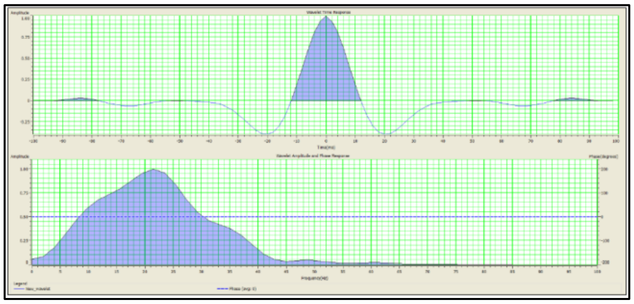

Figure 1: Extracted statistical wavelet

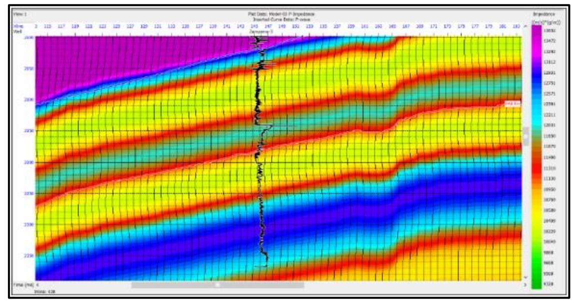

Figure 2: Low frequency model

In inversion analysis, correlation between well log impedance and seismic derived acoustic impedance is shown in Figure 3. Inverted seismic impedance (red) pick the trend of well logs impedance (blue) and the correlation coefficient between seismic trace (red) and synthetic derived from wells log (black) is 0.99 with error of 0.09 %.

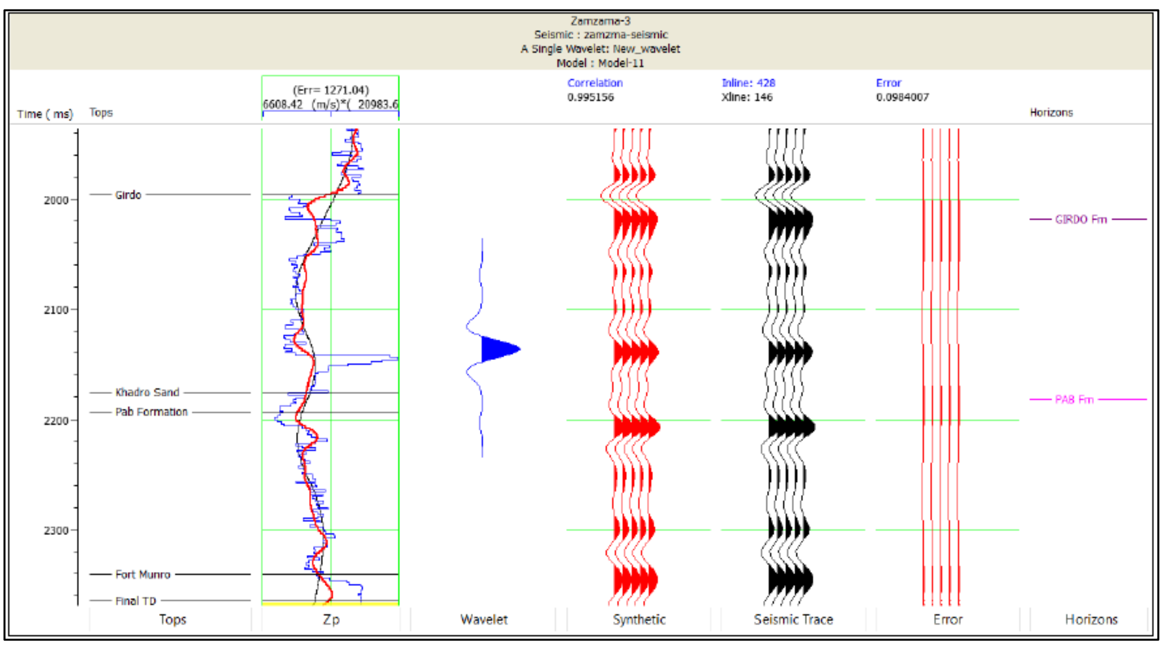

Figure 3: Inversion analysis results of model-based inversion with inverted impedance (red), log impedance (blue), low impedance model (black).

Model based inversion applied on seismic section shown in Figure 4. Model based inversion capture the lateral and vertical variation in acoustic impedance. Zone of interest (ZOI) starts at 2200 ms has low impedance and is indicative of gas saturation.

The base of ZOI has high impedance (purple), is marked by start of Fort Munro limestone. Vertical and lateral resolution of model-based inversion is greater, and it also pick impedance variation within reservoir.

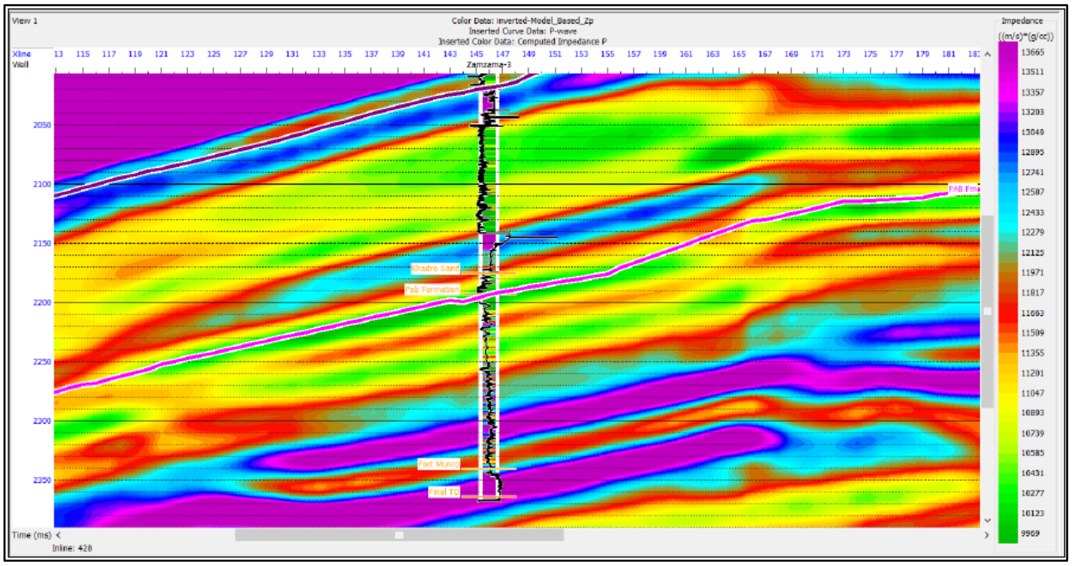

Figure 4: Inverted impedance of model-based inversion algorithm.

After inverting the data, we need to estimate its physical property like porosity. For porosity estimation we require porosity logs of two wells, in the study area we have well 03 and 05, after providing the porosity logs, we must select the inverted Zp and seismic data and define a window on which this process has to be done.

After running the process, we must select the multi attribute analysis list and select different attributes which we have to apply and run all the attributes after that we get estimated error of different attributes, so we have to select the attribute with minimum error and run that attribute to estimate the porosity. In this case I have run multi attributes with minimal training and validation error i.e. time (inverted Model Based Zp), Y coordinates (Inverted Model Based Zp), derivative instantaneous amplitude and average frequency. By Vp/Vs ratio plotting we can say that at well 03 we have high porosity of approximately 8 % and at well 06 05% and at well 05 03%. The porosities are low due to tight sand in this area as shown in Figure 5.

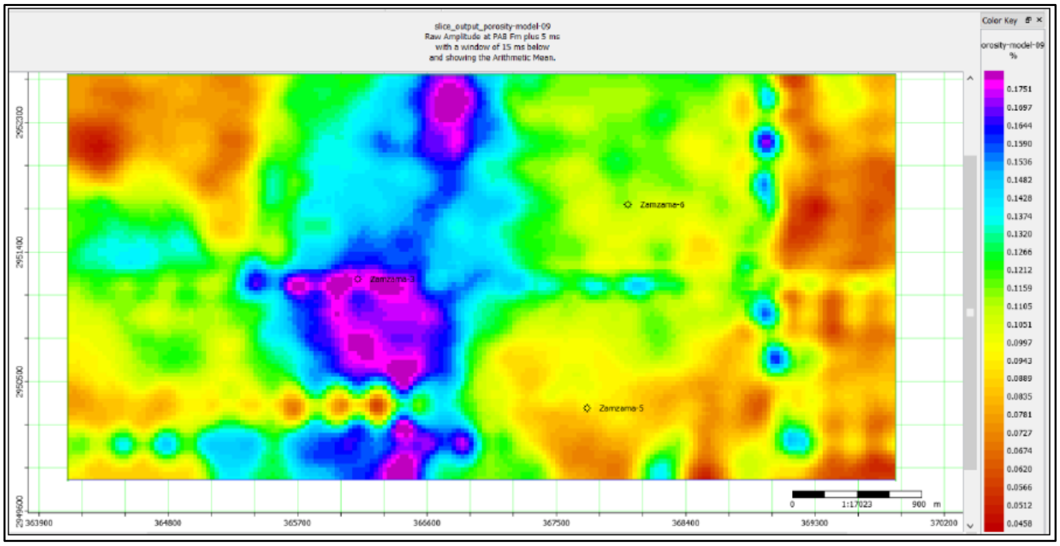

Figure 5: Porosity data slice with 17% porosity at well 03.

The same procedure has been applied for Sparse spike and bandlimited inversion and then compare their results.

Observations

In each case the data is inverted into P-impedance and density volume. The final stacked section shows high-resolution images within the time-depth ranges of 1700 to 2500ms. All inversions show mutually consistent results with low impedances within the target hydrocarbon sand. All post-stack inversion methods produce accurate and reliable results and unequivocally confirm the presence of reservoir zone. Model based inversion methods show higher correlation coefficient and least error. The geostatistical method populates the petrophysical parameters (porosity, fluid saturation, volume of shale etc.) over the entire seismic section even at those locations where well data is unavailable. Surfaces of known data points are estimated by geostatistical approach and the points lies between these surfaces are interpolated and filled by appropriate values (Haas and Dubrule, 1994).

The application of Model based inversion (MBI), Sparse spike inversion (SSI) and Bandlimited inversion (BLI) is to accurately pick low impedance zone with correlation coefficient and error. MBI has correlation coefficient of (0.99) with an error of (0.09) at reservoir level. The correlation coefficient of SSI is (0.97) and error is (0.027) while BLI also lies in acceptable ranges with correlation coefficient of (0.88). All inversion algorithm techniques resolve the reservoir very well, but MBI is better among them in the study area with maximum correlation and minimum error. Porosity of low impedance Pab formation is estimated through interpolation techniques such as probabilistic neural network (PNN) for spatially distribution. To invert porosities over seismic cube inverted impedance is used as an external attribute along with derived porosities at well location. In Figure 6 and 7 comparison has been shown on section level as well as on basemaps.

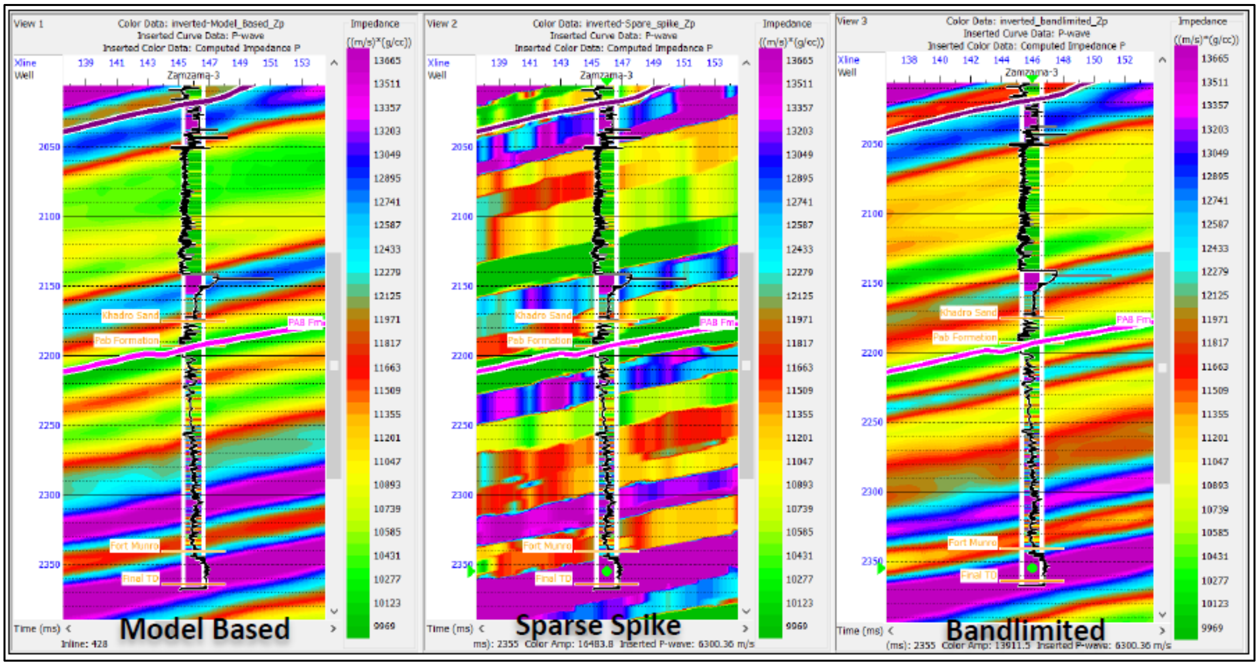

Figure 6.22: Comparative study of inverted impedance sections of MBI, SSI, BLI.

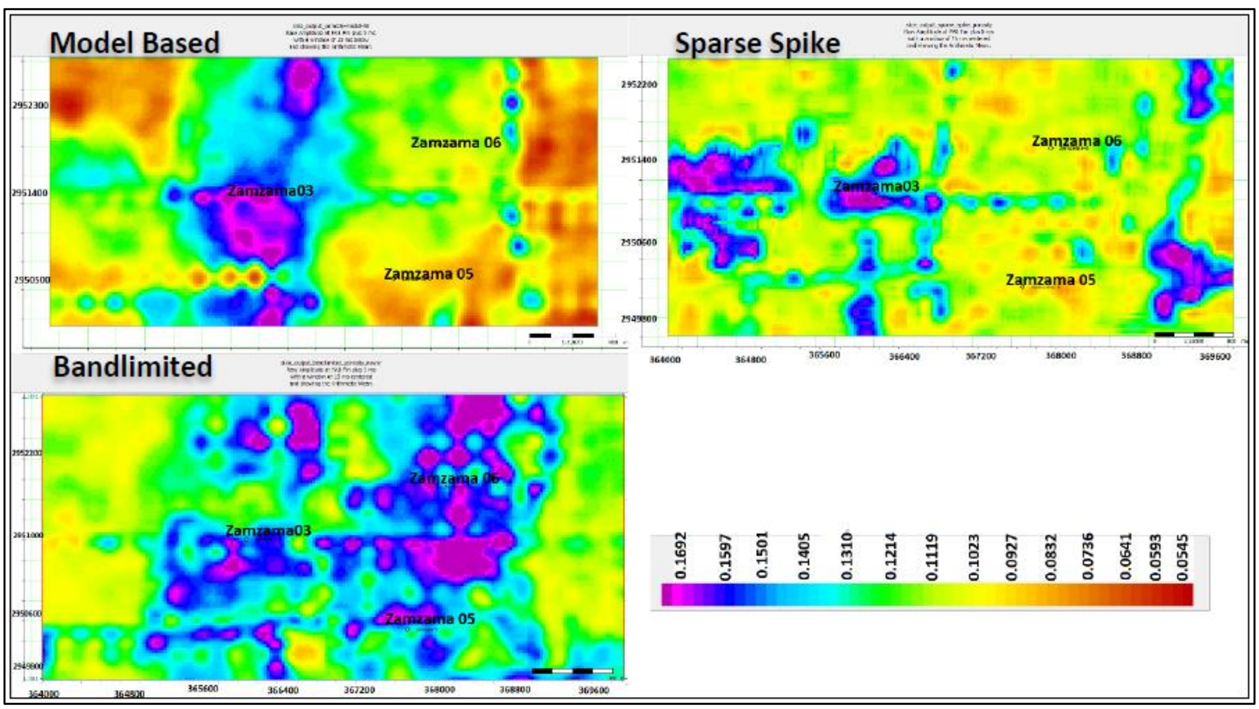

Figure 6.23: Comparative study of porosity maps of MBI, SSI, BLI.

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