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Post stack inversion for reservoir characterization of KG basin associated with gas hydrate prospects

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ABSTRACT
Post–stack inversion transforms a single seismic data volume into acoustic impedance through integration of seismic data and well data. Benefits of acoustic impedance obtained after inversion are well established for stratigraphic interpretation in comparison to conventional seismic data analysis. Model based and band limited post stack seismic inversion are carried out with a 2D seismic data to derive the stratigraphic information. The methodology of inversion includes statistical analysis of log derived acoustic impedance with P-wave velocity, density and spectral analysis of seismic data, wavelet estimation, seismic to well tie, generation of initial 2-D geological model. Use of model based inversion scheme and band limited inversion has validated inverted impedance results. Present study is based on data from Krishna Godavari basin of India. Model based and band limited inversion results have helped in delineating the stratigraphic prospect in the study area. This study demonstrates the effectiveness of using acoustic impedance volume for performing stratigraphic interpretation and reservoir characterization. From this study, it is noticed that near vertical reflection two way time 250 ms to 350 ms with CDP 630-700 have high acoustic impedance contrast, which can be interpreted as potential gas hydrate saturated zone.

INTRODUCTION

Seismic attributes derived from time, amplitude and frequency do not provide adequate information of reservoir properties on a layer by layer basis. Layer by layer information can be derived by means of stratigraphic inversion of post stack seismic data in terms of acoustic impedance. There are many inversion techniques, which are utilized in the industry for extraction of acoustic impedance from post stack seismic data. These techniques are band-limited, model based, and neural network nonlinear inversions (Russell, 1988, Duboz et al., 1998, Keys and Foster, 1998, Van Reil, 2000). In this study, model based inversion and band limited inversion technique have been utilized for inverting a 2D seismic data set into acoustic impedance volumes from Krishna Godavari(KG) basin of India. Inverted results of study area show that the generated acoustic impedance enhances vertical resolution, which simplifies lithologic and stratigraphic definitions. Both band limited inversion and model based inversion provide strong impedance contrast, probably identifying the presence of gas bearing formation associated with gas hydrates. However, model based inversion provides better resolution compared to band limited inversion in identifying gas zone.

GEOLOGICAL SETTING OF KG BASIN

The KG basin located near the mid portion of the eastern continental margin of India "Eastern Continental Margin of India (ECMI)" is a petroliferous basin, producing oil and gas. It contains a large number of structures and traps, which have been identfied for drilling on the land and offshore parts of the basin (Rao, 2001).The regional seismic section shows an 8 km thick pile of Mesozoic and Tertiary sedimentary sequences (Rao, 2001).This sediment deposition covers a vast range of geologic settings such as costal basin, delta, shelf-slope apron, deep-sea channel, and deep water fan complex. The basin has emerged as one of the frontier areas for future hydrocarbon exploration—after the multi-trillion cubic feet supergiant gas discovery in the recent years (Bastia et al.,2010). The basin has significant hydrocarbon potential both in the Tertiary delta as well as in the channel– levee–overbank play types in deep water. Wide-spread occurrences of BSRs coinciding with the base of the gas hydrate stability zone indicate gas hydrates in the KG basin (Sain and Gupta, 2012). The Indian NGHP Expedition 01 discovered the richest marine gas hydrate accumulation at the KG basin (Collett et al., 2008; Lee and Collett, 2009). The samples of gas hydrates have been recovered from 25m to 160m below seafloor. Gas hydrate occurs as solid nodules and fill the fractures in clay/silt and sub-horizontal veins. The bathymetry, rate of sedimentation, sediment thickness, geothermal gradient, seafloor temperature, and total organic carbon content indicate that the KG basin has a high potential for gas hydrates (Sain and Gupta, 2008). Recently acquired multichannel seismic (MCS) data also show wide-spread signatures of gas-hydrates in the KG basin.

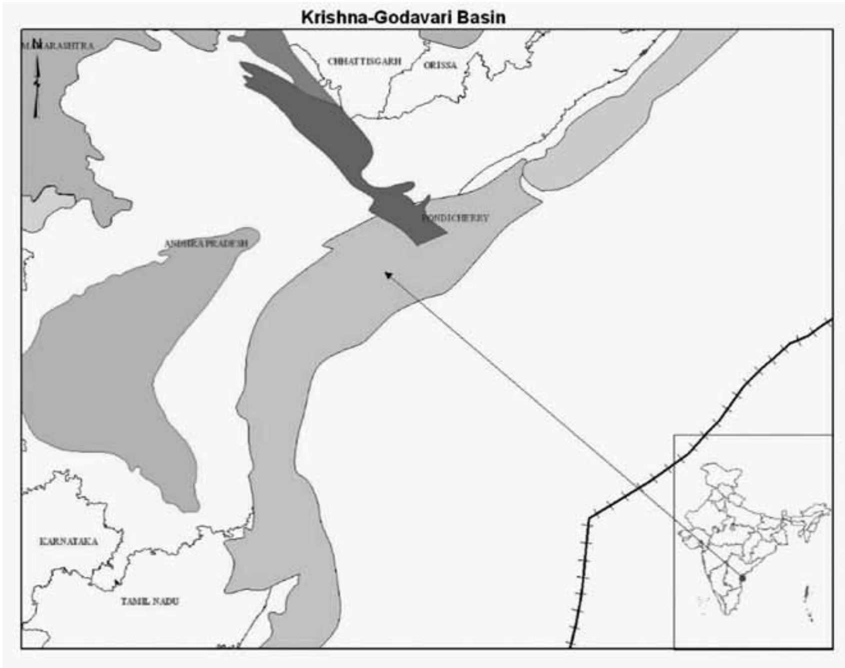

Figure 1. Study area, Krishna Godavari basin of India

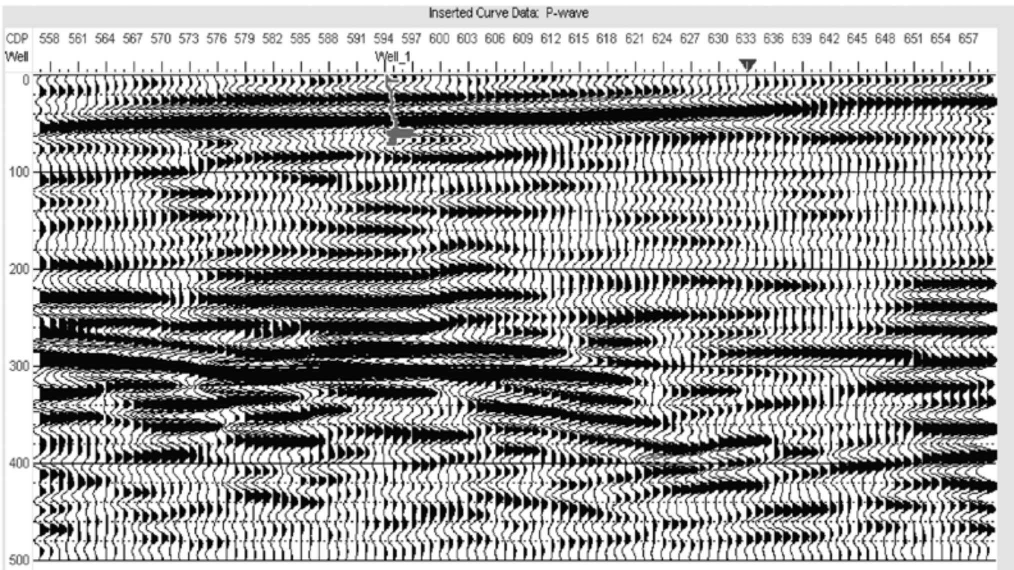

Figure 2. A stacked seismic section from KG basin India, in which the inserted log data is P-wave data, and the corresponding well location is 595 CDP.

METHODOLOGY

The seismic traces in the stacked seismic section (shown in Figure 2) can be modelled as the convolution of the earth's reflectivity and a band limited seismic wavelet, which can be written as

$$s_t = [r_t * w_t] \qquad (1)$$

Where s_t is the seismic trace, w_t is the seismic wavelet and r_t is the reflectivity. The reflectivity, in turn, is related to the acoustic impedance of the earth by

$$r_t = \frac{z_{t+1} - z_t}{z_{t+1} + z_t} \qquad (2)$$

Where r_t is the zero-offset P -wave reflection coefficient and $z_t = \rho v_t$ is the ρ -impedance of layer, where ρ is density, v_t is P-wave velocity. Lindseth (1979) showed that if we assume

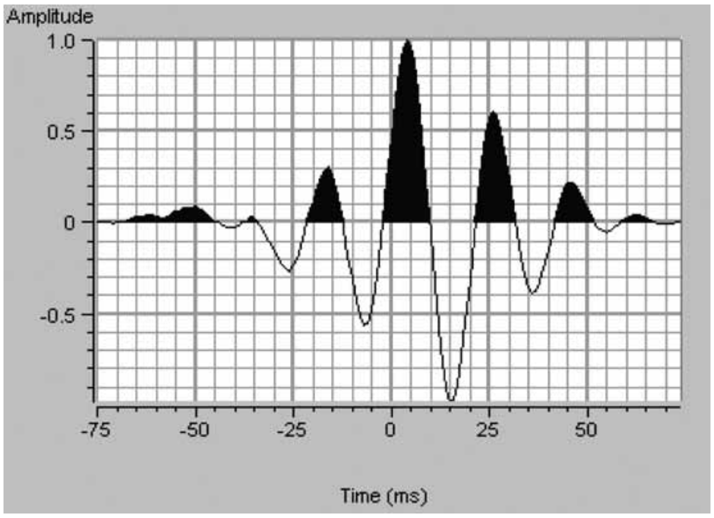

Figure 3. time domain response of wavelet, which has been extracted from seismic as well as log data for both band limited and model based inversion.

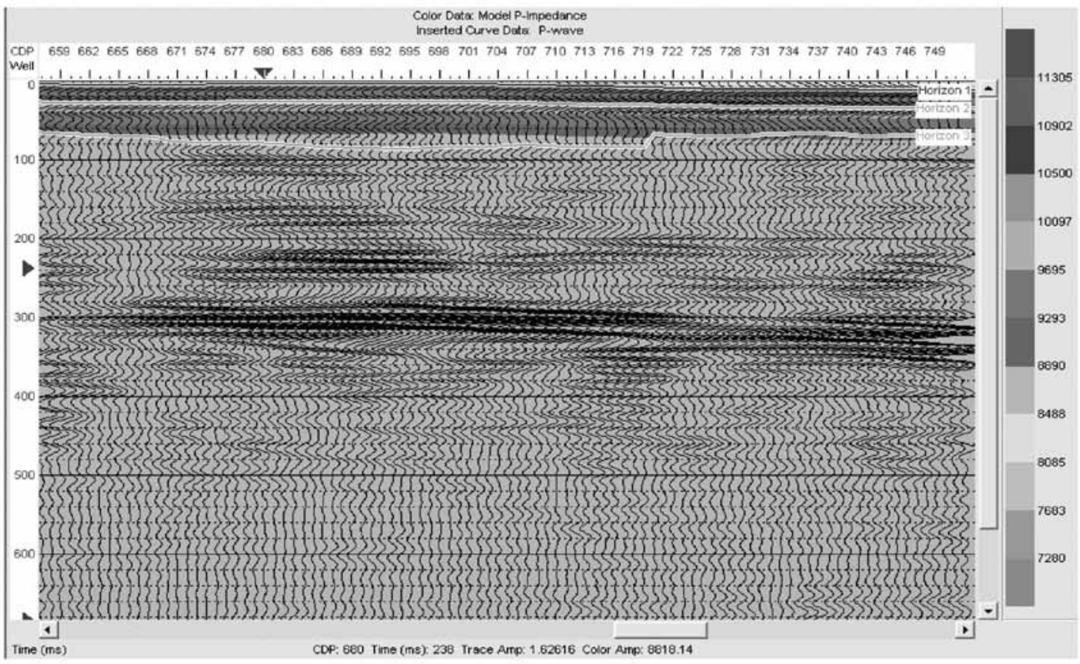

Figure 4. Initial model generated from seismic section, well log data and extracted wavelet which has been inverted farther for final inverted model.

that the recorded seismic signal is as given in equation (2), we can invert this equation to recover the P-impedance using the recursive equation given by

$$z_{t+1}=z_t\left[\frac{1+r_t}{1-r_t}\right] \tag{3}$$

By applying equation (3) to a seismic trace we can effectively transform, or invert, the seismic reflection data to P-impedance. However, as also recognized by Lindseth, there are a number of problems with this procedure. The most severe problem is that the recorded seismic trace is not the reflectivity given in equation (2) but rather the convolutional model given in equation (1). The effect of the band limited wavelet is to remove the low frequency component of the reflectivity. This means that it cannot be recovered by the recursive inversion procedure of equation (3). After proper processing and scaling of the seismic data, an intuitive approach to recovering the low frequency component is to simply extract this component from well log data and add it back to the seismic. In this

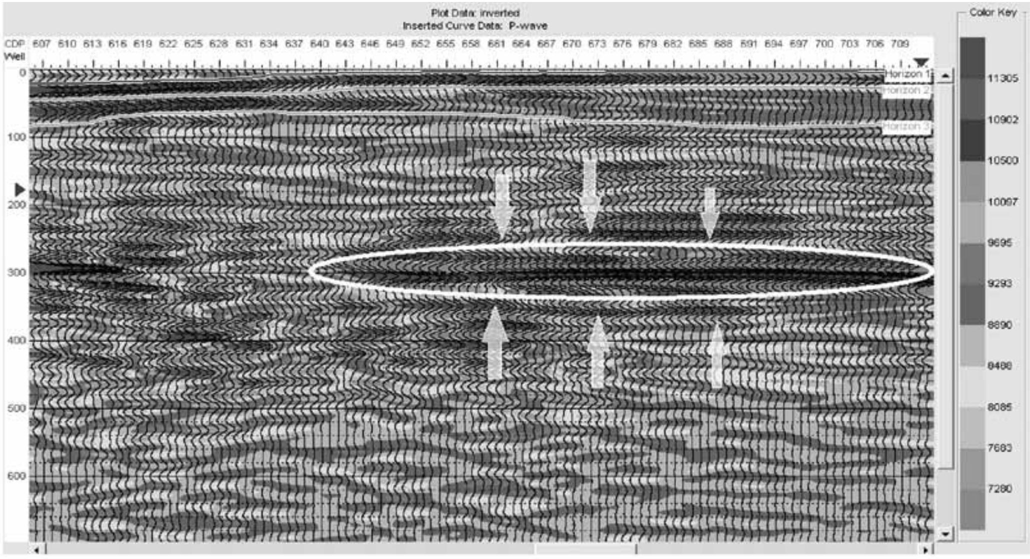

Figure 5. Band limited inversion of seismic data shown in fig 2,where white colord elliptical region shows high impedance contrast zone,that is between 250 ms to 350 ms time and CDP 630 to 700.

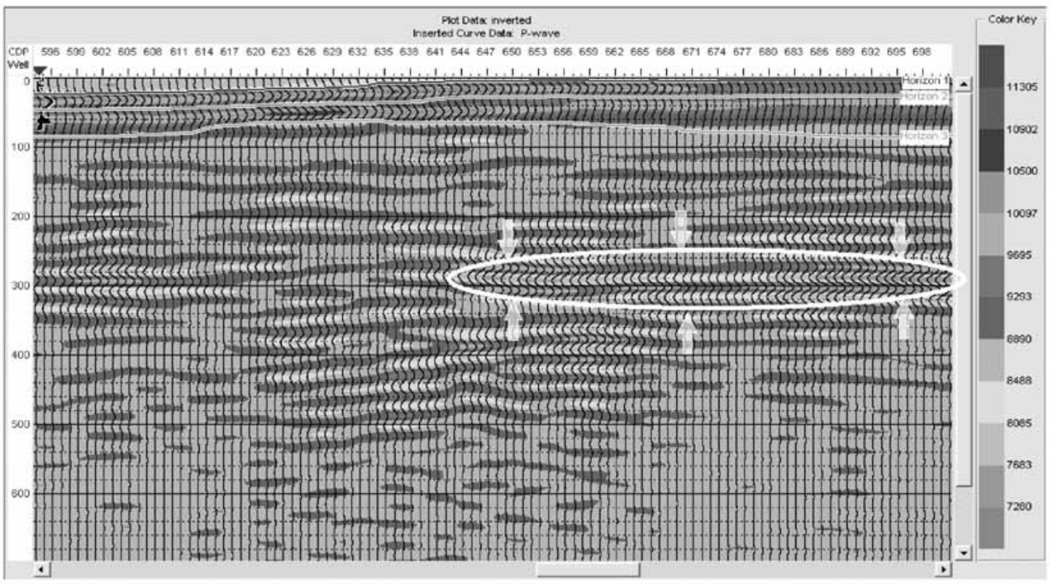

Figure 6. Model based inversion of seismic data shown in fig 2,where white colord elliptical region shows high impedance contrast zone,that is between 250 ms to 350 ms time and CDP 630 to 700.

study, model based inversion and band limited inversion algorithms are used for inverting the seismic data volumes. In model-based inversion we start with a low frequency model of the P-impedance and then perturb this model until we obtain a good fit between the seismic data and synthetic trace computed by applying equations (1) and (2). Both band limited and model-based inversion use the assumption that we have extracted a good estimate of the seismic wavelet.

RESULTS/DISCUSSIONS

2D seismic data volume shown in figure 2 acts as an input for buliding the model for final inversion.The seismic data consist of CDP 300 to 1000,and the well location is marked at CDP 595.Wavelet extracted from seismic is used for well to seismic correlation. A good seismic well tie results in correlation .65.After correlation a wavelet (fig.3) is extracted from corrected well log data,and this wavelet is used to build a convolutional model.

Finally the initial model (fig.4) is generated using the seismic and well log data.This single model is used for both inversion methods to create impedance volume.Bandlimited inversion involves integreting the seismic data directly to produce a band limited inverted trace and then deriving the missing low frequency trend from geological model,which is shown in the fig.5. From this figure,we have seen that near time 250 to 350 ms with CDP 630-700, there are some high impedance contrasts, which can be interpretad as gas zone.

In model based inversion (Fig 6),we started with an initial model of earth's geology and perturb this model until the derived synthetic seismic section best fits the observed seismic data.The model based method has the appearance of a'blocky'looking impedance.

From the figure.6 it is confirmed that near 250 to 350 ms time with CDP 630-700 there are high acqoustic impedance contrasts.This zone can be interpreted as free gas zone.Among the two inversion methods model based inversion gives best result and best resolution.This high impedance contrast zone may be a potential gas hydrate saturated zone.

CONCLUSIONS

From the above study it can be demostrated that post stack invertion may give us a better vertical as well as lateral resolution for reservoir chractarization. Both band limited and model based inversion gives fairly good result at TWT 250 ms to 350 ms corresponding to CDP 630-700 position. But, model based inversion shows better resolution than band limited inversion. This is because of band limited inversion produces a frequency limited estimate of the impedance. Although the model-based results look relatively more reasonable geologically (blockier, less smoothed appearance, and less dramatic swings), both inversions show a high impedance contrast zone at the gas hydrate zone.This trend is expected. However, there are high impedance contrast zones elsewhere on both inversions, probably due to shales. Thus,high impedance contrast associated with "bright" amplitudes is an indicator of gas hydrate saturated zone.

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