8th Biennial International Conference
& Exposition on Petroleum Geophysics

"HYDERABAD 2010"

P-299

Improving Resolution with Spectral Balancing- A Case study

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Summary:

The resolution limit of seismic data is a complex issue that involves on wavelet frequency, phase characteristics and data quality. Spatial as well as temporal resolution is the key to extraction of stratigraphic detail from the seismic data. Interpreters also feel difficulty while integrating seismic, VSP and log data due to higher spectral contents of VSP and Log data and therefore expect comparable bandwidth of the seismic data. For getting greater reflection detail from seismic data utmost care is required at the acquisition stage. Attempts are also to be made during processing stage to enhance the spectral bandwidth. Present attempt deals with the enhancing the resolution through Pre-stack time migration and spectral balancing of the data acquired in an area of Mumbai offshore and processed onboard up to post stack migration. The main objective of interpretation of the data was to locate porosity development within the carbonates by using methods like acoustic inversion. This was a challenging task for the interpreter, as the bandwidth variation between log data and seismic was huge. It is felt necessary to enhance the seismic data bandwidth at the time of processing by using optimized spectral balancing and use that data for inversion study.

Pre- stack time migration and spectral balancing techniques of improving the resolution were attempted on the data. Rigorous testing was carried out for the application of spectral balancing on PSTM gathers and volume. Comparison of results suggested spectral balancing to be applied on PSTM volume than on gathers. Significant improvement has been obtained in stratigraphic details while interpreting the data of this prospect of South Mumbai High. Inversion studies were carried out using the spectrally balanced data and the lowering of impedance has been identified in a zone around the basement. A well drilled in this area has produced hydrocarbons from the identified zone. This has clearly demonstrated the usage of spectral balancing to obtain better attributes studies and porosity estimations in carbonates.

Introduction:

Enhancing the frequency contents of surface seismic data has always been a quest for geophysicists ever since the seismic method was introduced. In fact, seismic resolution is the key to extraction of stratigraphic detail from the seismic data. Seismic resolution comprises two aspects - the vertical resolution and horizontal resolution. The vertical or temporal resolution is concerned with the ability to distinguish two close seismic events corresponding to different depth levels. The horizontal or spatial resolution is concerned with the ability to distinguish and recognize two laterally displaced features as two distinct adjacent events. Both aspects are important for interpreting small features on seismic data. Migration procedures are usually put in place for collapsing the Fresnel zones that enhance spatial resolution in addition to migration of the events to its correct position. Various Prestack imaging techniques in time and depth domain have improved the spatial resolution. Focusing our attention to the temporal or vertical resolution requires increasing bandwidth of the seismic data. Widess (1973) proposed $\lambda/8$ as the resolution limit, λ being the predominant wavelength. In the presence of noise resolution is usually taken to be only λ /4.

However, wavelength is the yardstick for resolution which in turn depends on velocity and frequency. Since, there is nothing we can do for velocity, which shows a general increasing trend with depth, the key factor that determines resolution is frequency. For getting greater reflection detail from seismic data utmost care is required at the acquisition stage to acquire higher frequency data. Attempts are also to be made during processing stage to enhance the spectral bandwidth.

It is common observation that seismic waves propagating through the earth are attenuated. In contrast to spherical spreading, this loss is frequency dependent i.e. higher frequencies are absorbed more rapidly than lower frequencies resulting in narrow frequency spectrum of recorded energy towards lower end of spectrum of input energy. Moreover, absorption appears to vary with the lithology of the medium. There is need to enhance the frequency content during processing of seismic data to make subtle geologic features identifiable. But enhancement of frequency may also leads to an increase in noise levels along with higher resolution and hence careful approach is required. There are many approaches for the frequency enhancement of seismic data that range from spiking deconvolution, Q-compensation, spectral balancing to loop reconvolution (Young, 2005). Curvature attributes (Satinder Chopra, 2007) is also a powerful tool for improving the resolution and helps in mapping channels, faults and other stratigraphic features. Conventional way of improving the resolution of seismic data is spiking deconvolution (Yilmaz, 1987) which designs an inverse filter to compress the seismic wavelet into an impulse. The process is more commonly applied on gathers. Spectral balancing sometimes called whitening or broadening is a process applied to improve resolution of the seismic data. In this paper, Spectral balancing is tested on PSTM gathers and stacked volume on a dataset from Mumbai offshore resulting in improved resolution. The dataset used for the study is 3D seismic vintage from Mumbai offshore block of western offshore basin. The objective of this study is to enhance the bandwidth of seismic data enabling identification of impedance variation on inverted data for interpreting the porosity development within the carbonates.

Theory:

The objective of spectral balancing is to boost the frequencies to obtain perfect resolution. While this spectrum could in theory be obtained, in practice it would likely result in the boosting of noise at low and high frequencies. More sensible would be to balance the data within its own bandwidth (Figure 1). Spectral balancing splits the dataset into several narrow frequency bands by bandpass filtering. Each frequency bands is equalized by its scaling function which depends upon the amplitude levels in this band. All these scaled frequency bands together are added to obtain the balanced sections. Some applications allow a percentage of the input data to be added back to improve the results. Rigorous testing needs to be performed on the data to enhance the frequency spectra within sensible bandwidth.

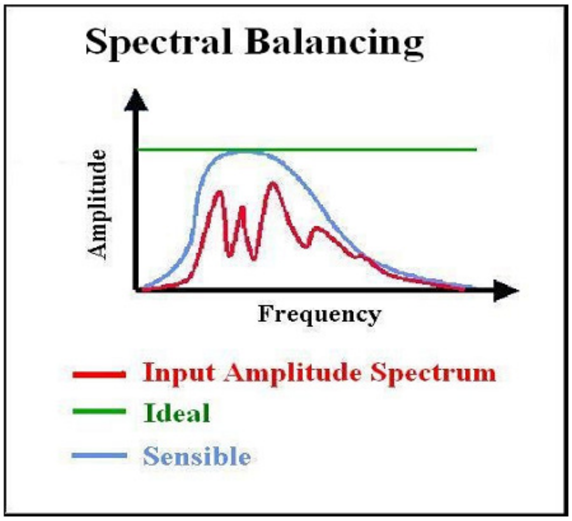

Figure 1: Spectral Balancing

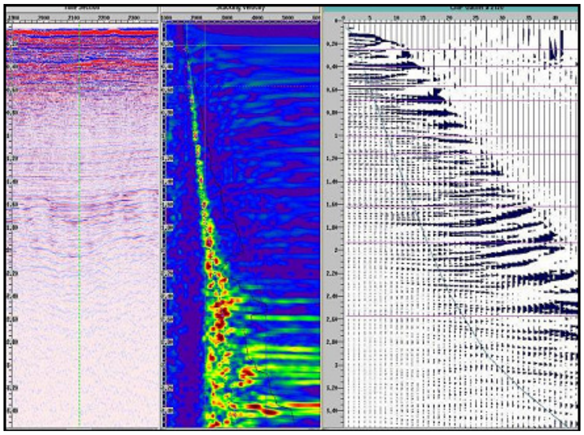

Figure 2: Velocity analysis

Improving the Resolution:

A. PSTM:

Onboard processed decon gathers which has been subjected to pre-processing, multiple removal and deconvolution were taken for further processing for improving the resolution. The data has been regularized for foldage resulting in uniform foldage as well as recovery of missing offsets before pre-stack time migration. PSTM on target lines at an interval of 20 inlines (500 mts.) were carried with the available DMO velocity. RMS velocity (Figure 2) has been updated with the analysis on PSTM gathers of target lines in close grid to obtain final RMS velocity volume. Various aperture sizes were also tested to obtain better image and improved resolution with the PSTM.

B. Spectral Balancing:

Spectral balancing analyses were carried out on PSTM gathers as well as stacked volume. A number of frequency ranges were tested for spectral balancing. Spectral Balancing of frequencies from 5 to 90 Hz provided good result in improving the resolution without increasing noise. The spectral balancing of frequencies beyond 90 Hz produces more noises. The spectral balancing on PSTM gathers has been applied and resulting stacked section is compared with the balancing applied on PSTM stacked volume (Figure 3). It is observed from the comparison that spectral balancing on stacked volume provided better resolution than balancing on gathers and then stacking the balanced gathers. The comparison of PSTM section and frequency spectrum before and after spectral balancing is shown in Figure 4 & 5**.** It is evident from the section as well as spectrum that appreciable improvement is obtained from the application of spectral balancing. Balanced PSTM volume is subjected to FXY decon for attenuating random noise and it is provided to interpreters in bin size of 12.5 X 12.5 by interpolating an inline between two inlines.

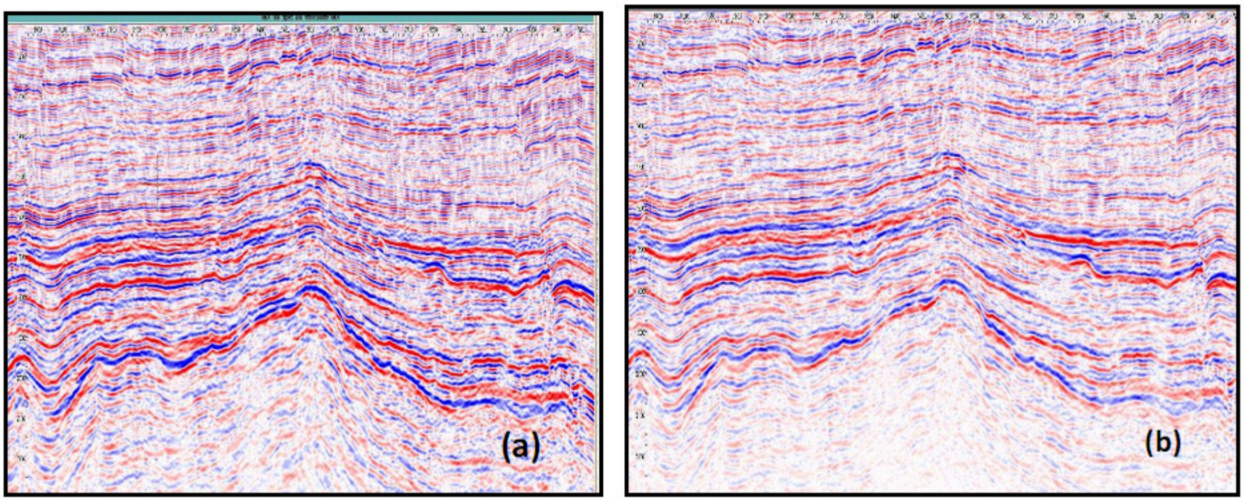

Figure 3: Comparison Spec balancing on PSTM stacked volume (a) and Spec balancing on PSTM gathers (b).

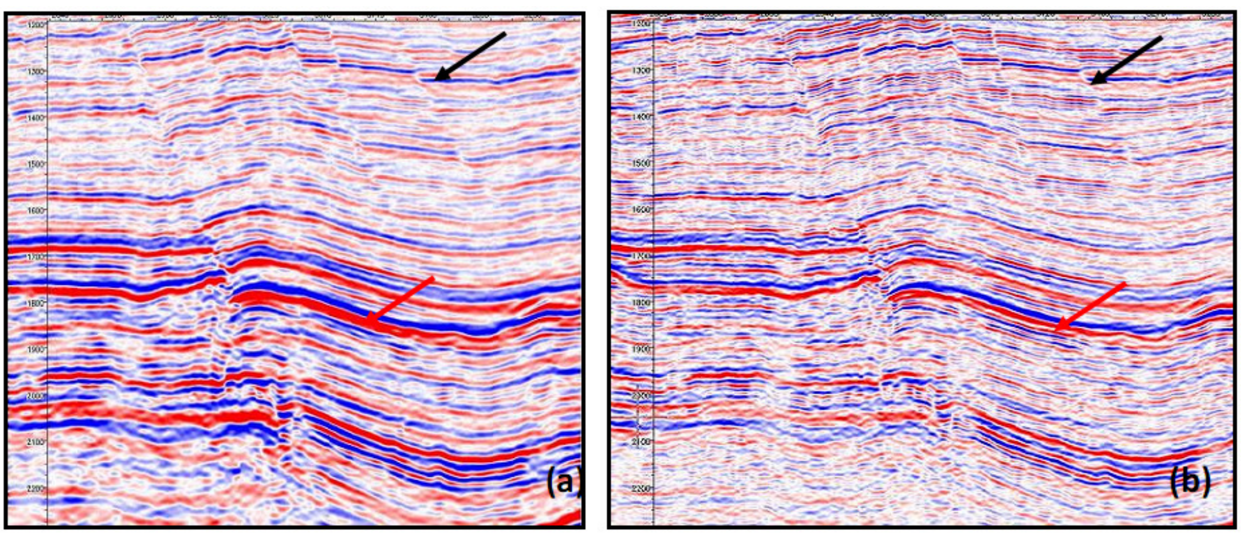

Figure 4: Comparison of PSTM section without (a) and with (b) spectral balancing. The SpecBal data clearly brought out the fault (black arrow) and also the improvement in resolution (red arrow) is clearly visible.

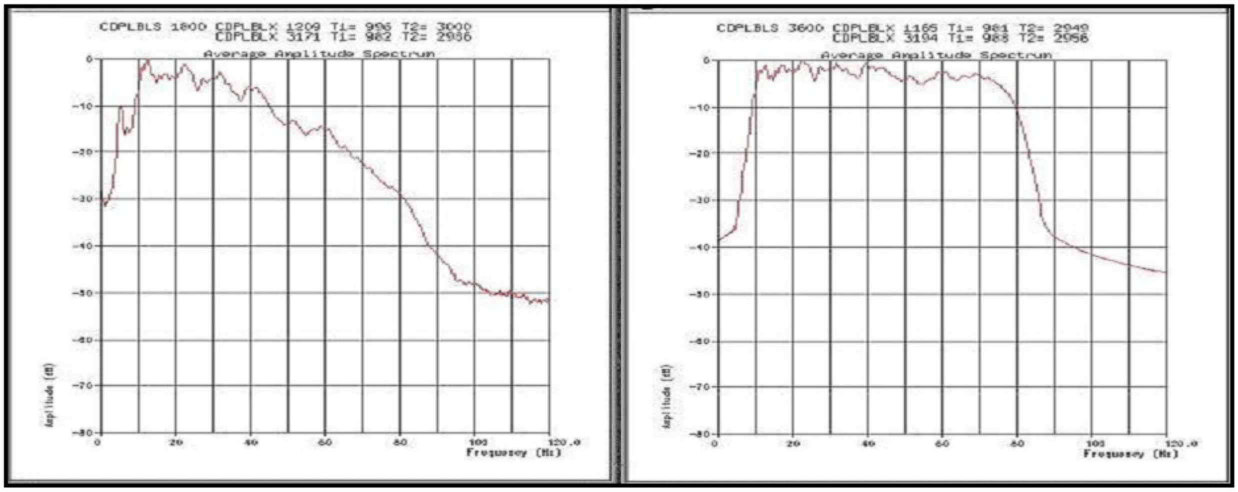

Figure 5: Comparison of amplitude spectrum of target zones in PSTM section without (a) and with (b) spectral balancing

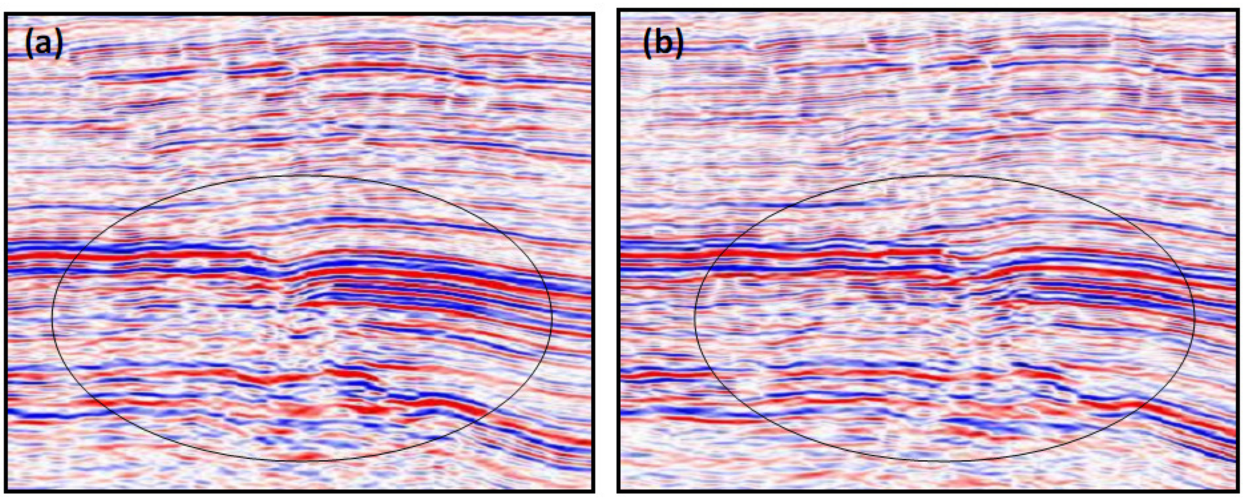

Figure 6: Comparison of inline section processed earlier (a) and re-processed PSTM inline section with spectral balancing (b).

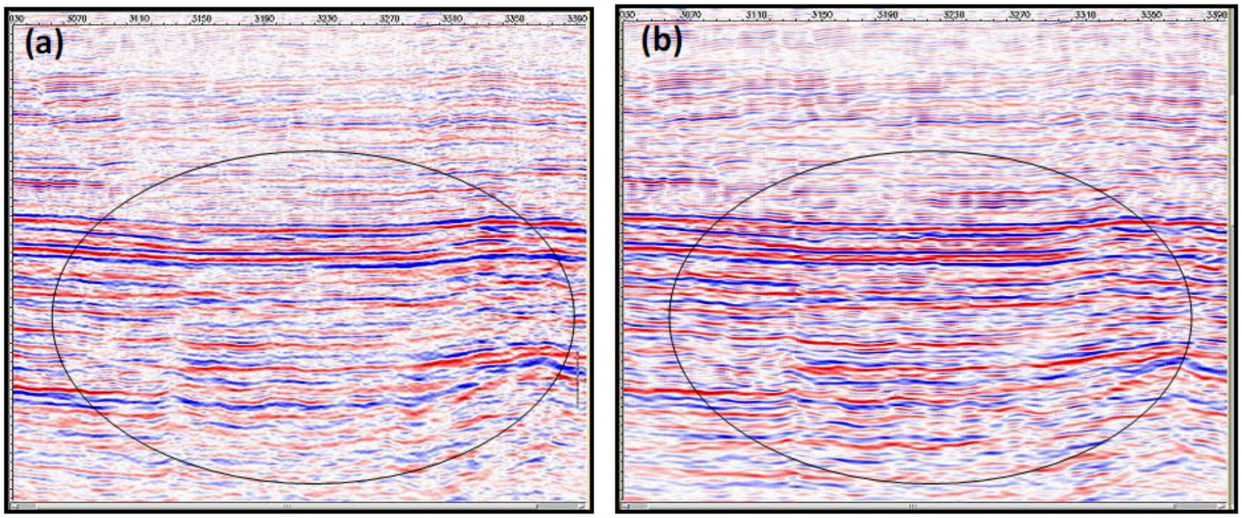

Figure 7: Comparison of crossline section processed earlier (a) and re-processed PSTM crossline section with spec balance (b).

Value addition:

Reprocessing with targeted flow of PSTM and spectral balancing rewarded with a much higher fidelity image of the subsurface than earlier processed data. The results are compared in inline as well as crossline direction. Figure 6 shows an inline PSTM section with earlier processed section. The delineation of faults are much clearer and clarified detailed geologic setting and improved structural features. Appreciable improvement is also visible in a crossline shown in Figure 7. The figure 8 a,b show the comparison in zoomed section with the well-A postion.

The spectral balanced PSTM data has been used to carry out the inversion studies using the Hampson Russels' STRATA software. The P wave and density logs were filtered to lower in frequencies of logs in order to obtain the best match. Based on this the impedance of a zone of around 20 msec above the basement was computed. This has clearly brought out the zone of low impedance (Blue green yellow and red zone; Figure-9). This zone is interpreted to be zone of better porosity. Based on this a well-A was drilled and the well produced hydrocarbons from the above zone.

Conclusion:

Pre-stack time migration and subsequent spectral balancing on PSTM stacked volume has resulted in improved resolution. Spectral Balancing on stacked volume provided better result than spectral balancing on gathers. Inversion studies carried out using the spectrally balanced data provided better attributes and identification of low impedance zone. This has clearly demonstrated the usage of spectral balancing to obtain better attributes studies and porosity estimations in carbonates.

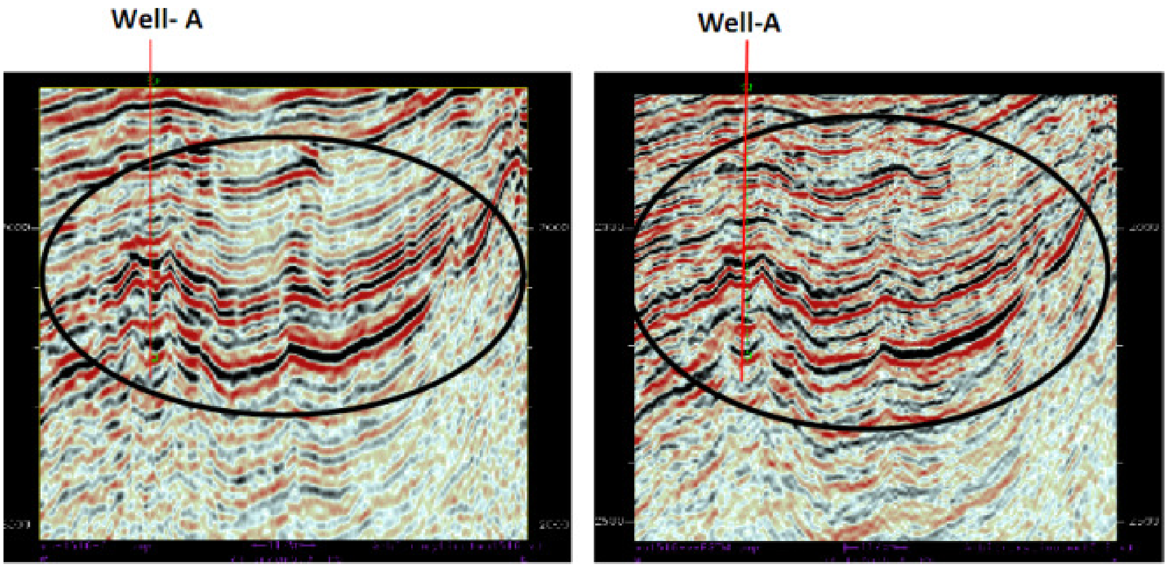

Figure 8: Part of seismic section of earlier processed data indicating low frequency (a) and part of seismic section of Spectral balanced PSTM processed data indicating high frequency at the zone of interest (b)

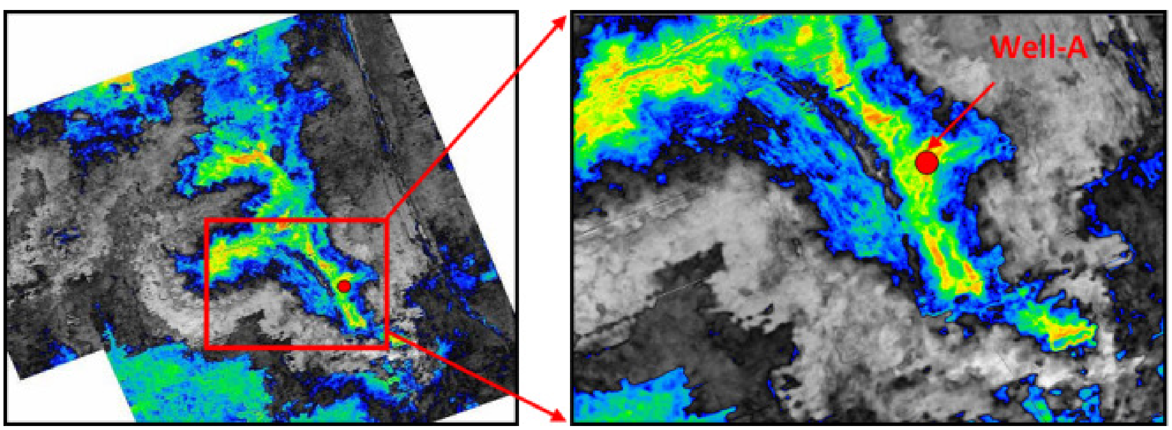

Figure 9: The impedance map of the carbonate section of the area using the spectral balanced data. Yellow to red colour indicates low impedance areas interpreted to be the porosity zones in the Carbonates.

Acknowledgement:

Authors are grateful to Shri DK Pande, Director (E), ONGC for permission to publish this work. Authors are thankful to Shri SV Rao, ED-Basin Manager and Shri V. Vairavan, GM(Geol) - Block Manager for providing the necessary facilities and assigning the work to be carried out. Authors are also thankful to Mr. D K Vishnoi, CG(S), Mr. Srinivasa, CG(S) and Smt. Sucheta Dhotiwala, CG for help and support during the processing and inversion of the data.

Views expressed in this paper are that of the author only and may not necessarily be of ONGC.

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