



**P-252**

## **Analysis on Effectiveness of Spectral Balancing in Signal Enhancement - A Case Study**

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### **Summary:**

*Precise mapping of channel sands within Daman and Mahuva formations along with deeper prospects within trap and below in the Northern part of Mumbai offshore Basin was very difficult with the existing processed dataset. Therefore, to improve the existing data an attempt has been made by re-processing the data from pre-stack stage and subsequent improvement through spectral whitening / balancing on migrated data. Spectral Whitening sometimes called balancing or broadening is a process usually applied to improve the resolution and appearance of seismic data. This case study deals with reprocessing aspects and significant role of spectral whitening in broadening the band width which helped in mapping of channel sands as envisaged.*

### **Introduction:**

Mumbai offshore is most prospective petroliferous Basin in the West coast sedimentary province of India. Virtually most of the commercially exploitable hydrocarbons discovered so far are located in this basin. It came into existence during upper cretaceous time because of faulting of Deccan Trap Basement. Proven sedimentary reservoirs in the Mumbai Basin range from Paleocene to Middle Miocene in age. Less conventional reservoirs are also located in the crystalline basement and the Maastrichtian age volcanics of the Deccan Trap. Of these, the most productive reservoirs to date are the Mumbai and Bassein formations. The Lower Oligocene Mahuva and Mukta formations also appear to be increasingly important reservoirs, particularly around the Surat Depression. Shallow marine limestones of the Mukta Formation and the more transitional limestones, sandstones and siltstones of the Mahuva Formation contain both primary and secondary porosities. Similar lithologies and facies in the overlying Upper Oligocene to Lower Miocene Alibag and Daman formations also provide reservoirs. These Oligo-Miocene units are considered to have significant further potential in the area of study (**Fig-1**). With the objective of mapping the channels sands within Daman and Mahuva formations and imaging below trap, the existing 3D seismic data was re-looked for enhancing the continuity and the band width. A variety of methods was attempted to equalize / balanced the

spectrum without boosting noise with the help of spectral whitening.

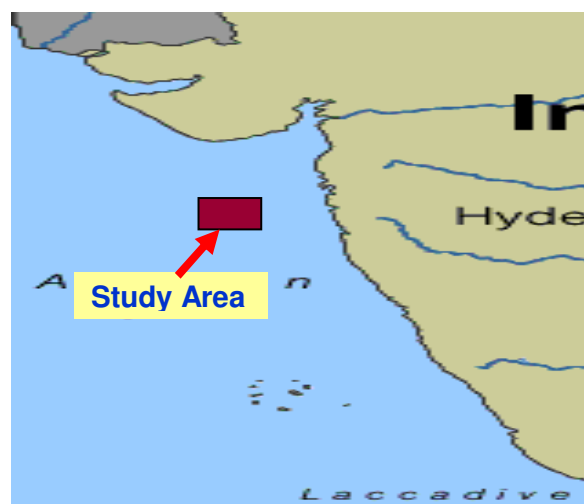


Fig. 1: Study Area

### **Methodology:**

The existing 3D data was pre conditioned after removal of random noise as well as high amplitude bursts (**Fig- 2**),



regularized for fold and offset and precise velocity analysis. For improving the spectra in pre processing spiking deconv with suitable operator Length and design window was attempted. Spectral whitening was rigorously tested to meet the objectives on pre stack migrated gathers as well as on the migrated stack.

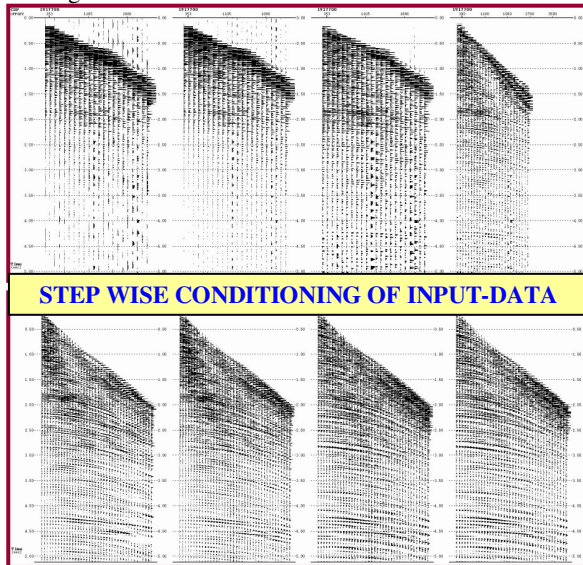


Fig-2 Data conditioning

## Spectral Balancing:

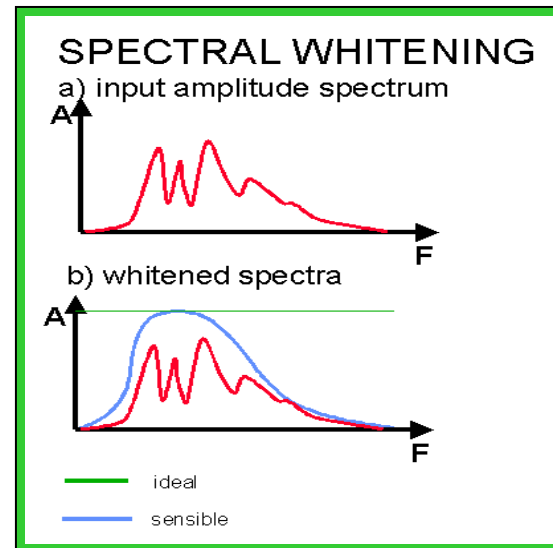


Fig 3: Theoretical Spectral whitening

The theory of spectral whitening is described by the figure showing an input amplitude spectrum Fig-3(a) of typically a migrated section. The objective of spectral whitening is to boost the balance of frequencies ultimately to obtain perfect resolution as shown by the green line in Fig-3(b). 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 whiten the data within its own bandwidth as shown schematically by the blue curve. The commonest form of spectral whitening is to split the dataset into several narrow frequency bands by bandpass filtering, equalizing the sections by AGC or some other scaling function and add the resulting sections together. One can choose the number of filter bands (i.e. select the output spectrum) and the degree of scaling applied. Some applications allow a percentage of the input data to be added back to improve the results.

Spectral balancing actually does time invariant zero phase deconvolution on seismic data. The objective of deconvolution is to derive a filter,  $F(f)$ , and apply it to the recorded trace,  $X(f)$ , to yield the earth reflectivity,  $R(f)$ . Mathematically, deconvolution is:  $R(f) \text{ estimated} = X(f) \times F(f)$ . To derive the filter  $F(f)$ , we begin at the convolution



model of the seismic trace. The convolution model of the trace may be expressed in the frequency domain as follows:  $X(f) = R(f) \times W(f) + N(f)$ , where:  $X(f)$  = the recorded seismic trace - the initial information,  $R(f)$  = the unknown earth reflectivity sequence, i.e., the desired output,  $W(f)$  = the unknown seismic wavelet,  $N(f)$  = the unknown added background noise. Since we have three unknowns,  $R(f)$ ,  $W(f)$ , and  $N(f)$ , and only one known quantity,  $X(f)$ , some assumptions are necessary. They are incorporated into the zero-phase deconvolution process as follows:

- The first assumption is that the noise term,  $N(f)$ , may be neglected.
- The phase of  $W(f)$  is assumed to be zero,  $W(f) = |W(f)|$ .
- If the subsurface reflectivity sequence is random, then the reflectivity is uncorrelated, and the amplitude spectrum is close to white  $|R(f)| = \text{constant}$ .
- Deconvolution, is the process of filtering the data with the inverse filter of the estimated wavelet.

There are some practical problems with the preceding formulation. It can be shown that a short time domain wavelet has a smooth broad frequency-domain spectrum (Berkhout 1984, chapter 1.2). The shorter the wavelet, the smoother and broader the spectrum. In fact, the spectrum of any given trace is not at all smooth. From this observation, it follows that some type of smoothing should be performed on the spectrum before it is used as a wavelet estimate. To overcome these problems, spectral balancing uses running-average smoothing in the AGC option and user-specified averaging in the BALANCE option.

**Scale Option:** With this option, a specified scalar is applied at 0 hertz and another is applied at the aliasing frequency. Specified scalars are also applied at an optional number of designated frequencies between. The scalars are interpolated between the user-supplied values.

**AGC Option:** The AGC option applied an AGC operator to the frequency domain samples. The average magnitude of the frequency is computed for a given gate length. A scalar is calculated as the inverse of the average magnitude and it is applied to the frequency at the centre of the gate. The gate is incremented from a first frequency through a last frequency. A new scalar is calculated for each frequency sample.

**Balance Option:** The method used by the BALANCE option is comparable to the trace balancing performed by the BALANCE program, except that the samples are frequency rather than time. The user specifies a series of start and end frequencies that serve as balance window. A desired output level for each balance window may also be specified. It calculates a scalar for each window that makes the average magnitude value equal to the desired output amplitude. The scalar is applied at the central frequency of the balance window. Scalars are interpolated between frequency window centers.

### Discussion Of Test Results:

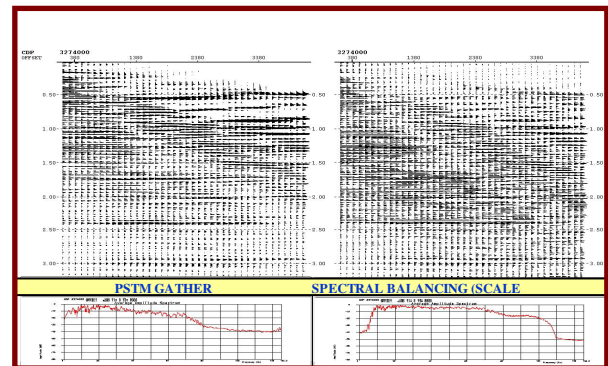


Fig-4 Analysis with scale option

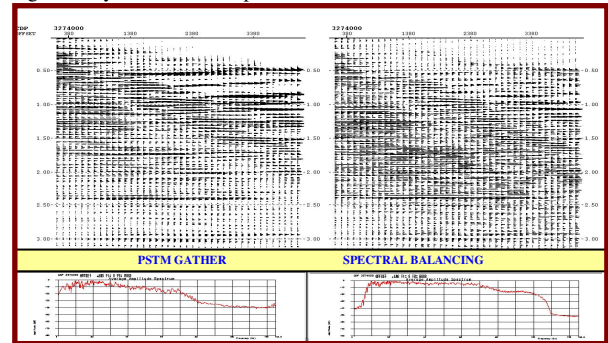


Fig-5 Analysis with Balance option





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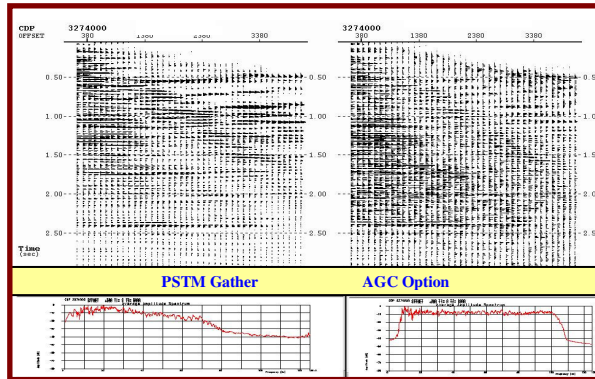


Fig-6 Analysis with AGC option

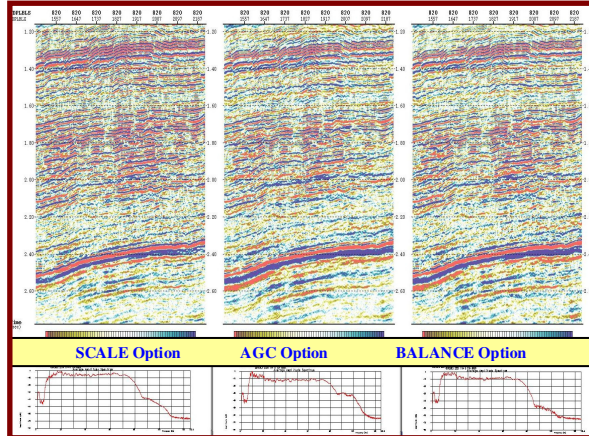


Fig-7 Comparison in Pre-stack application mode

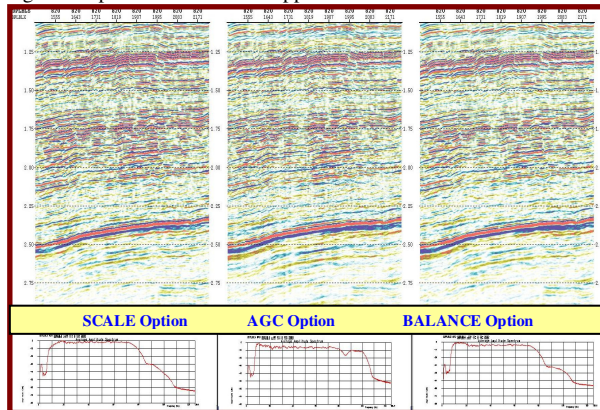


Fig-8 Comparison in Post-stack mode

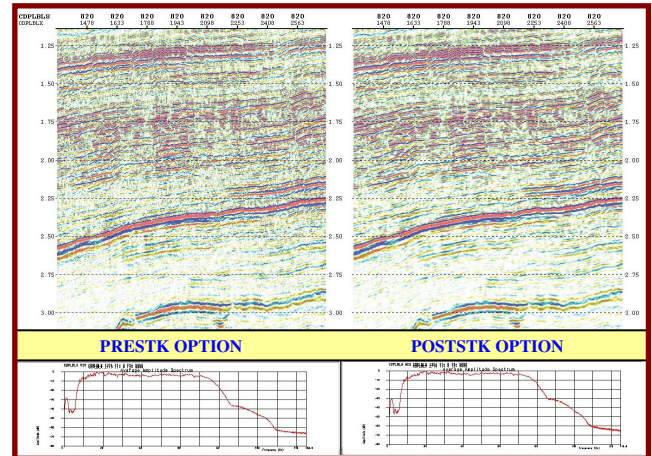


Fig-9 Comparison in Pre-stack and Post-stack (scale option)

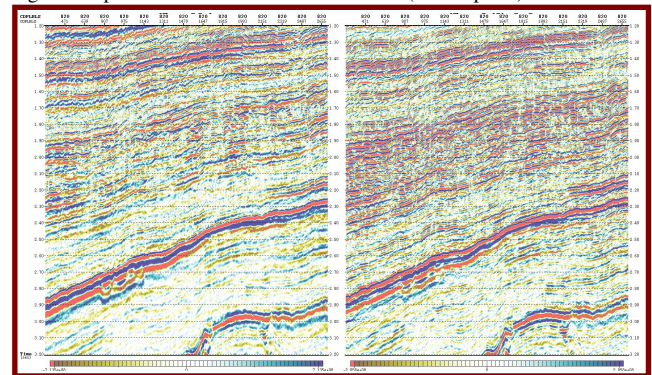


Fig- 10 PSTM STACK After Spectral Balancing

Currently, test results are produced for, Scale, Balance & AGC option to boost the frequency spectra on migrated gathers as well as on migrated stack section. The results of scale, Balance & AGC options of spectral whitening on PSTM gathers are shown in **Fig- 4** , **Fig-5** and **Fig-6** respectively. As per the analysis of Amplitude Spectrum it is observed that AGC option has wide spectrum compared to others two whereas its gathers are contaminated with noise. Results of Spectral whitening application on gathers and stack for Scale, Balance & AGC shown in **Fig-7** were analyzed. These three options were separately applied on stack data as shown in **Fig-8**. Analysis of section and their amplitude spectrum suggests that Scale option worked well to improve the resolution without increasing the noise. Scale option of Balancing provided better results than





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other two options of spectral whitening. Finally pre and post application of spectral balancing with scale option are compared as per **Fig-9**. It is observed that balancing on post-stack provided better resolution than balancing on pre-stack mode. The application of spectral balancing on PSTM stack data has appreciably improved the frequency content of the data. Image has become sharper and reflection events looks more focused and continuous after balancing. Significant improvement in the resolution of stratigraphic horizons and faults at shallower level is seen (**Fig- 10**). The re-processing of the data has added value as can be seen from comparing with the earlier processed volume as shown in **Fig- 11**. The continuity of the events in target zones and delineation of faults are more prominent in the present volume. The improvement is more pronounced in the zoom section (**Fig- 12**). Imaging at deeper level has improved and events are mappable. **Fig-13,14 &15** shows the added advantage of current volume while carrying out interpretation.

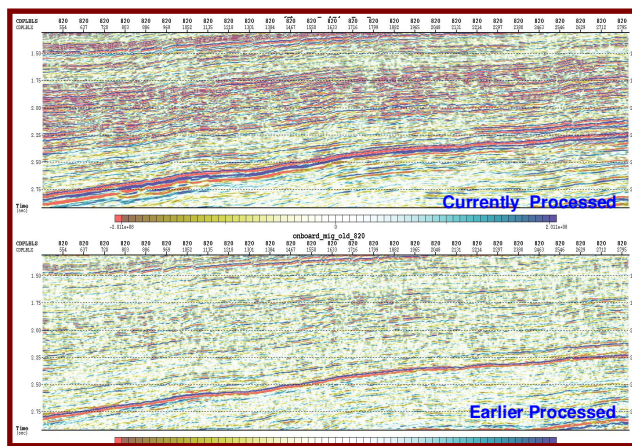


Fig-11 Currently Processed v/s Earlier Processed

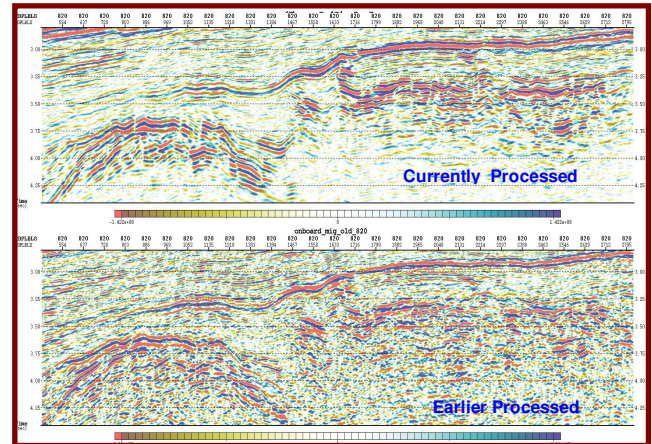


Fig-12 Currently Processed v/s Earlier Processed (Zoom)

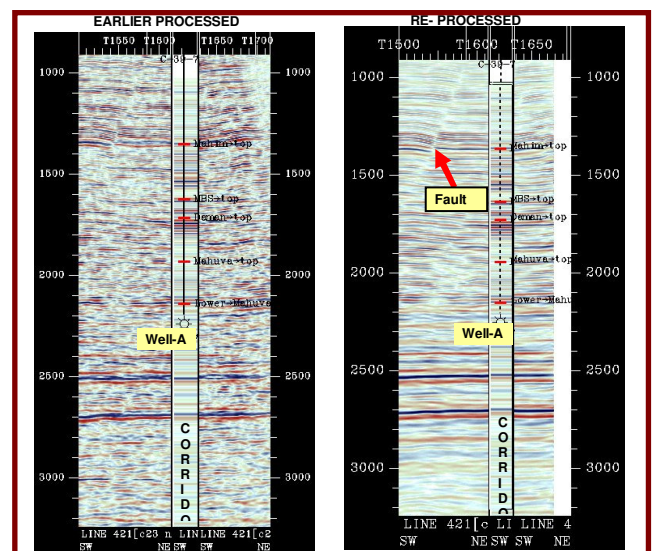


Fig-13 Comp. Earlier Processed and Re-processed Data



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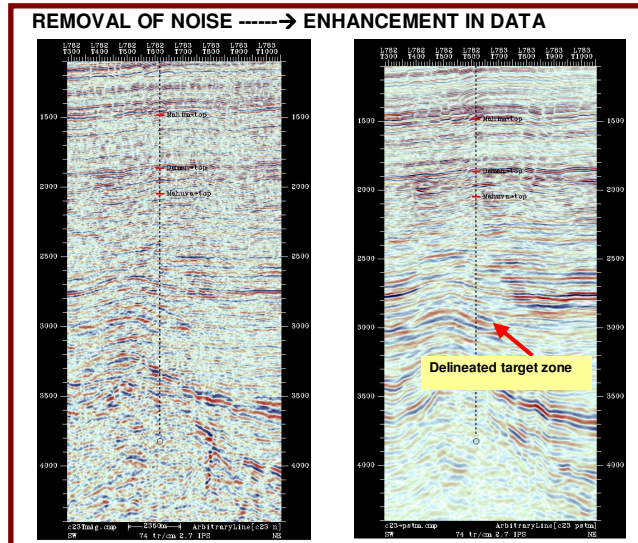


Fig-14 Comparison Earlier Processed and Re-processed Data

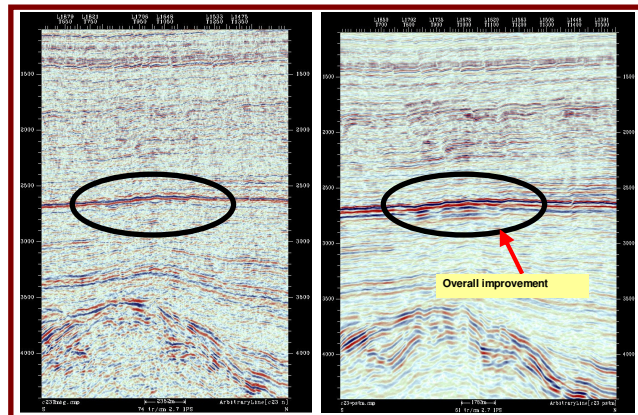


Fig-15 Comparison Earlier Processed and Re-processed Data

### Conclusion:

- Spectral balancing proved to be an effective tool for enhancing the overall image quality.
- Spectral balancing helped in improving the signal bandwidth to map the horizons more accurately & confidently
- The continuity of the events, delineation of faults and identification of anomalous body in target zone are more prominent in the present volume which have significantly added the value to the data.
- All the stratigraphic horizons are very well matched with the corridor stack. Identification of a prospective zone at 3.0 sec as shown in (Fig -15).

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### References:

Technical article , WIGGLE-ONGC magazine April-September2005: Role of spectral balancing in signal enhancement by P R Balak etal.

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