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High Resolution through Deabsorption: A case study from foldbelt area of India

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Summary

Seismic data processing plays a major role in providing reliable subsurface image affecting the interpretation and thereby influences the exploration strategy. In general the quality of seismic data recorded over fold belt areas is poor due to the subsurface complexities and poses a major challenge even to obtain reliable structural image. The design of processing sequence and optimization of parameters is aimed to enhance the structural and stratigraphic information. In the present work, an attempt was made to improve the subsurface image considering the utility of inverse Q-filtering as an alternative to deconvolution or spectral balancing during the post-stack processing.

Methods and algorithms exist for an accurate time and space varying inverse Q - filtering also called Deabsorption to seismic data. Both amplitude and phase correction can be applied separately or simultaneously to pre or post stack seismic data from land or marine environment. Deabsorption is very efficient than deconvolution or spectral balancing to compensate for earth filtering effects and when S/N is low. The Q values depend on velocity, density and bulk modulus of the rock medium and vary from place to place through the earth and in different geological formations. The degree of frequency loss and phase distortion is inversely related to the Q value of the earth Large Q values imply low absorption and small Q values indicate high absorption. The phase correction is an important aspect of controlled phase processing whereas amplitude correction can be used as an alternative to spectral balancing to overcome the limitations of statistical methods like spiking deconvolution.

The strateg of adopting inverse Q-filtering as an alternative to the application of deconvolution and spectral balancing was tested over 2-D seismic data recorded over foldbelt area of Assam and Assam-Arakan basin, India, The application of Deabsorption through data driven Q values resulted in better illumination of subsurface geological features.

Introduction

Tripura- Cachar- Mizoram fold belt of Assam and Assam Arakan basin was formed as a result of six diastrophic movements during closing of Indian and Burmese Plates. The first two tectonic disturbances that occurred during the post Cretaceous and post Eocene times were confined to the eastern parts of the region. The third disturbance of post Oligocene age had a wide spread effect on the region. The post Miocene movements gave rise to the deposition of the conglomeratic sediments of Pliocene age. The late Pliocene movements are responsible for the rise of the Arakan mounts that supplied the coarse sediments filling Molasse troughs. The last folding movements occurred towards the close of the Pleistocene age, although small scale uplifts and wrapping still continue.

Two dimensional CDP surveys are conducted in Mizoram foldbelt area of Assam and Assam Arakan

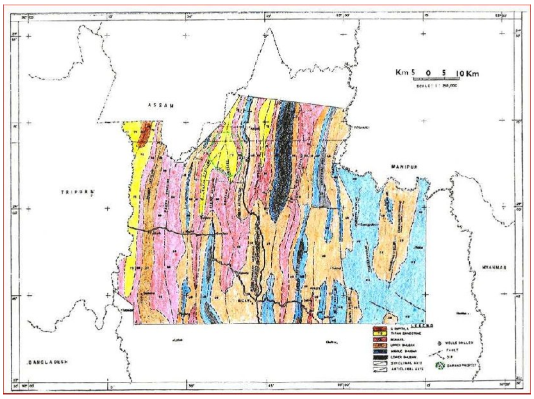

Fig:1- Geological map of Mizoram fold belt area

basin which is geographically situated in the northeastern part of India. Mizoram fold belt area is traversed by tight and narrow anticlines and broad and gentle synclines and the geological map is shown in fig.1 while fig.2 depicts geological cross section.. In such areas the signal to noise ratio is very low and necessitates utmost care at each and every stage of processing in order to deduce reliable subsurface image.

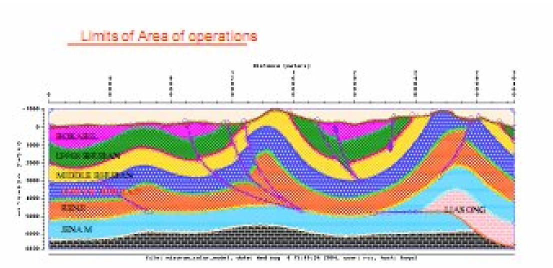

Fig:2- Geological cross-section of Mizoram fold belt area

Apart from the loss of amplitude, due to spherical spreading of the wave-front, which can be considered as frequency independent, there is also a certain loss from absorption due to frictional dissipation of the elastic energy into heat, as the wave propagates through the earth. In the seismic data we observe an increasing loss of amplitude and phase distortion of the wavelet, with time. The amplitude distortion is due to a frequency dependent attenuation while the phase distortion is due to dissipation. The frequency dependence of both attenuation and dispersion is exponential. The high frequency components of the spectrum of the seismic wavelet travel with a higher velocity and are more quickly attenuated and phase shifted than the low frequency components. This phenomenon entails a non-stationary nature of the seismic wavelet on recorded data and loss of seismic resolution. As seismic waves propagate through the earth, some energy is lost by attenuation, quantified by the number Q. The mechanisms by which attenuation occurs are the subject of debate. There are two schools of thought, one is intrinsic attenuation and another is scattering attenuation. The debate spins around intrinsic and scattering attenuation (Dvorkin and New, 1993, Hargreaves, 1992).

Q can be estimated by calculating the spectral ratio of a reference signal's amplitude spectrum with that of a data window in overlapping time windows moving down the trace. The slope of the logarithm of the spectral ratio against frequency is inversely proportional to Q. The reference signal may be a wavelet, constant for all traces, or
a fixed time window from the data.

Once the Q values are estimated from the data, they can be used for Deabsorption studies. The deabsorption or inverse- Q filtering can be performed trace by trace. A method proposed by Varela et.al (1993) which reproduces the currently accepted attenuation-dispersion relations in a continuous manner, thus allowing accurate amplitude and deabsorption.

The amplitude and phase corrections can be applied separately or simultaneously in pre-stack or post-stack domains from 2D or 3D seismic data that come from land or marine environment.

There is a growing interest concerning deabsorption targeted towards its application in seismic data processing. The degree of frequency loss and phase distortion is inversely related to the Q value of the earth. Large Q values imply low absorption and small Q values imply high absorption. The Q factor depends on velocity, density and bulk modulus of the medium. Usual Q values range from 100 to 200.

The seismic quality factor, Q, which is a measure of attenuation, can be estimated and there is a growing interest to generate a cube of Q values from a stack or migrated volume. Q can be used as an attribute for interpretational purposes. It is also possible to perform spatial averaging of all the attenuation estimates at each time and obtain a mean Q value for each time.

Example

The seismic reflection data acquired over Mizoram area along two profiles AA and BB (fig.3) and a sample field record shown in fig 4.

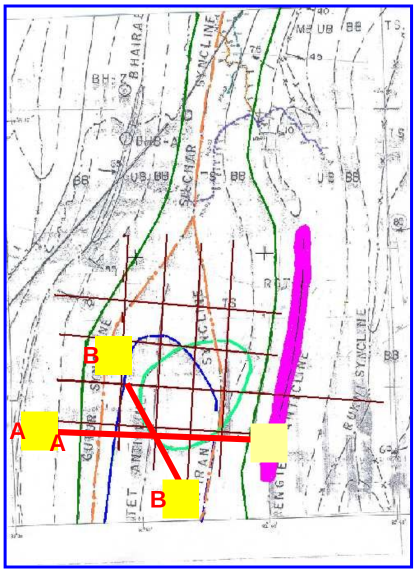

Fig:3 Location map of area of investigation

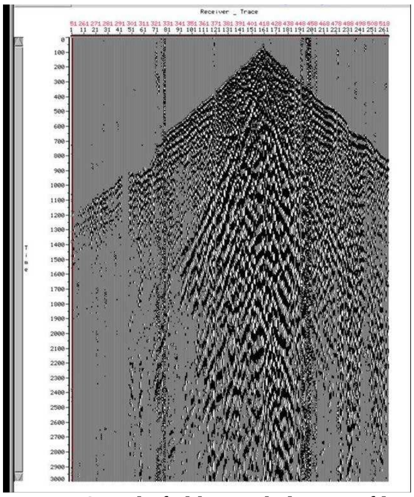

Fig:4- Sample field record along profile-AA

This 2-D seismic data has been processed through conventional processing sequence comprising mainly (i) attenuation of ground roll using 1D wavelet transform along with a band pass filter (application of field statics and amplitude recovery (iiI) multi pass velocity analysis and application of residual statics (iv) application of dip move out correction and stack (v) attenuation of random noise in F-X domain and (vi) migration. The stack data thus obtained along profile AA is shown in fig.5 while its corresponding migration is depicted in fig.6 Also the stack and migrated sections pertaining to profile BB are depicted in figures 7 and 8 respectively.

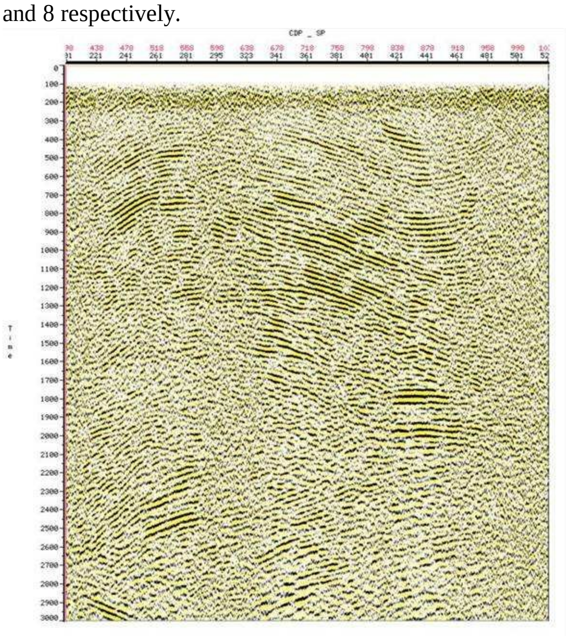

Fig.5:- DMO stack section along profile -AA

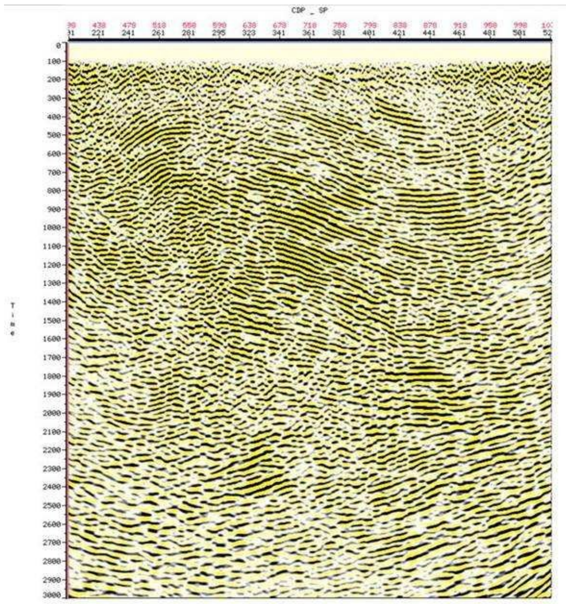

Fig.6:- Migrated stack along profile-AA

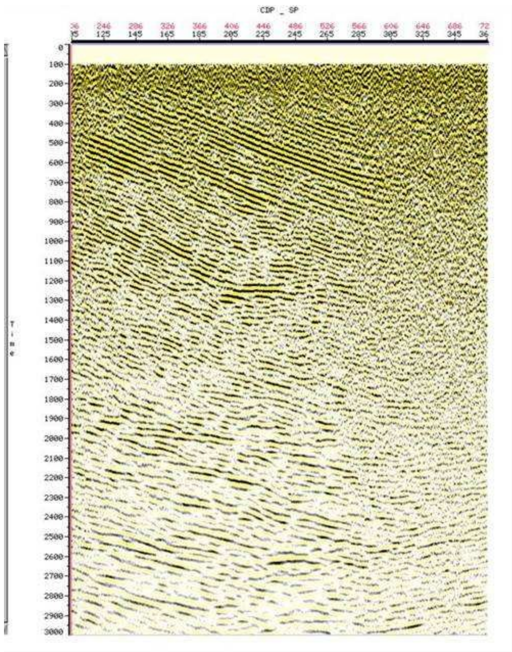

Fig.7:- DMO stack section along profile - BB

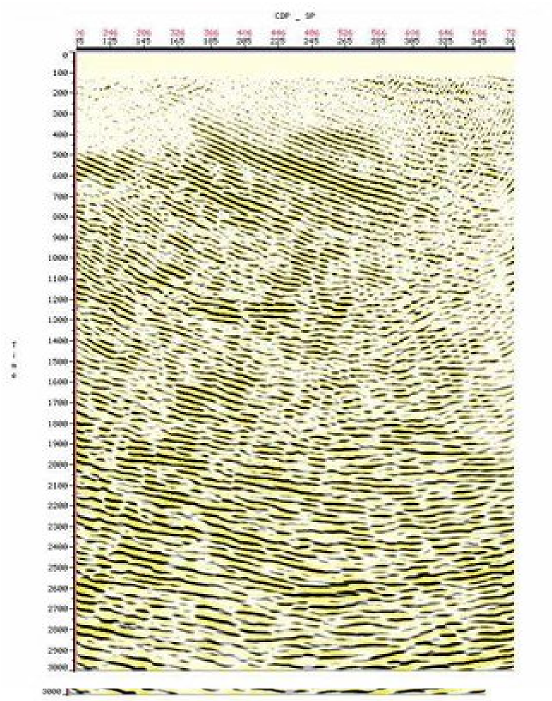

Fig.8:- Migrated stack along profile - BB

The seismic data deduced using conventional approach indicates that the subsurface image is not in corroboration with the anticipated geological model in respect of both amplitude and frequency content. Therefore an attempt is made to improve the quality by applying deconvolution and spectral whitening to the stack data of profile AA and the same is depicted in fig.9. Analysis of the results indicate loss of resolution in addition to boosting random noise in the higher end of the spectrum.

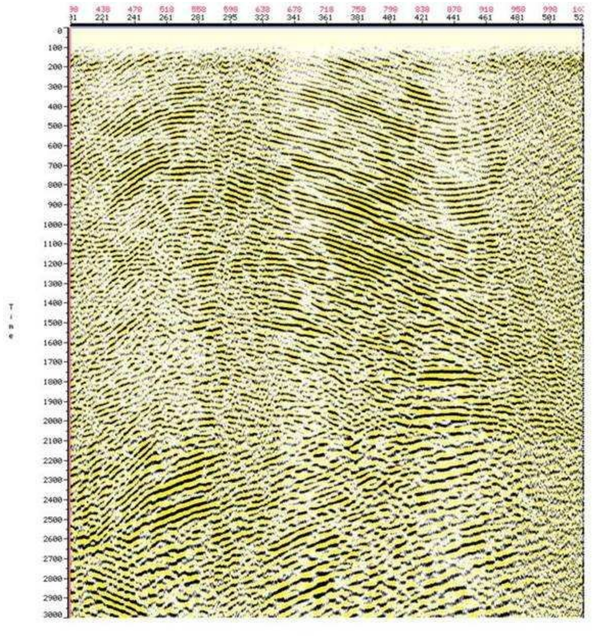

Fig.9:- Stack section alng profile – AA after deconvolution and spectral whitening

In view of the above observations, an endeavor is made to enhance the output data quality by adopting a high resolution processing strategy that includes (i) denoising in F-X domain (ii) estimation of Q-values from data (iii) removal of high frequency noise and (iv) application of inverse Q-filter. This post-stack methodology is tested on the data recorded over the profiles AA and BB and the resulting stack and migrated seismic data are shown in figures 10 to 13. It is observed that the data obtained through deabsorption is superior to that obtained using deconvolution and spectral balancing with regard to amplitude stability, reflection standout, continuity and resolution.

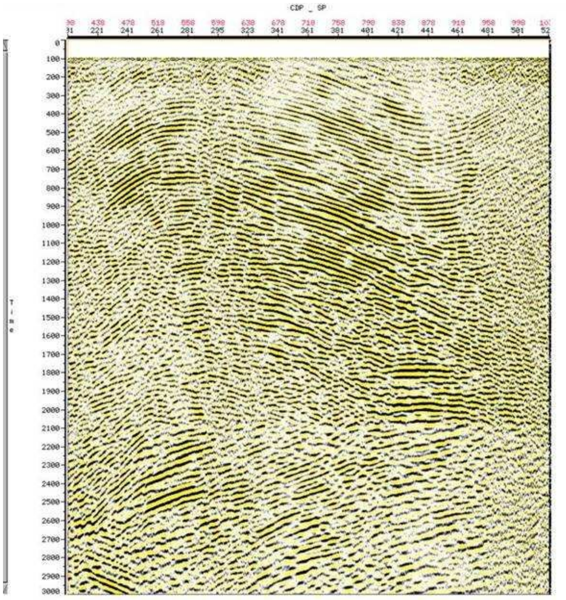

Fig.10:- Stack section along profile – AA after post-stack deabsorption

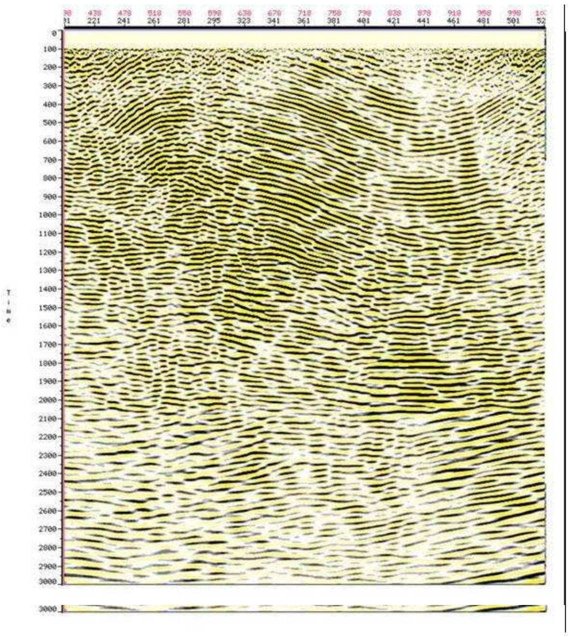

Fig.11:- Migrated stack section along profile – AA after post-stack deabsorption

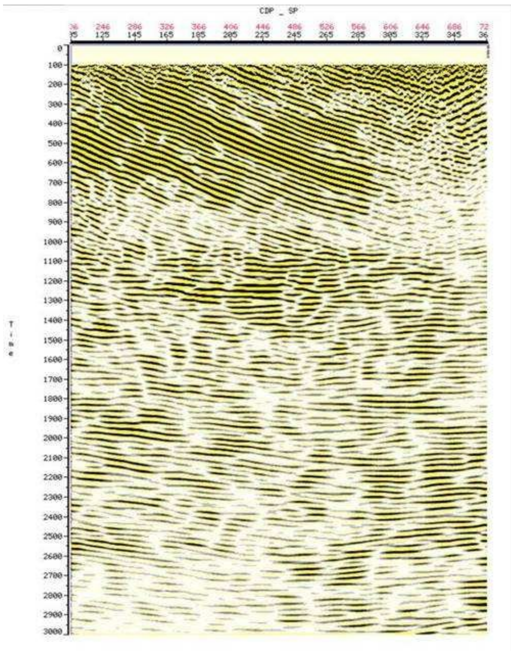

Fig12:- Stack section along profile – BB after post-stack deabsorption

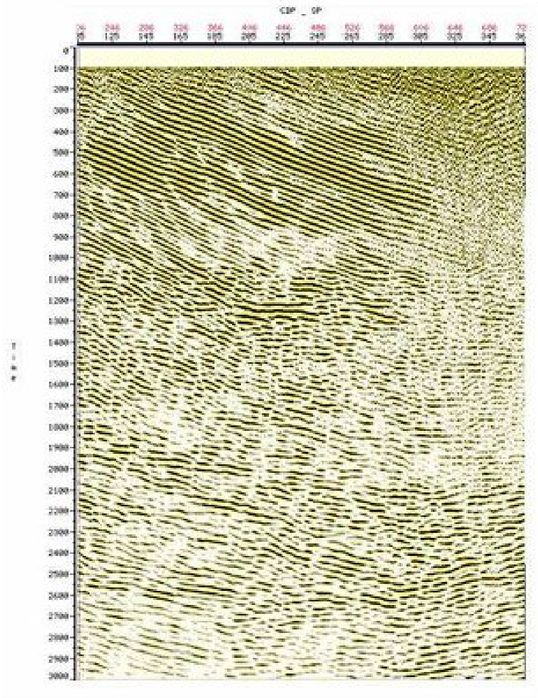

Fig.13:- Migrated stack section along profile – BB after post-stack deabsorption

Discussion and Conclusion

The quality of seismic data recorded over fold belt zones is poor due to sever distortion of both amplitude and frequency caused by subsurface geometry. In addition, the low or top-heavy fold and irregular spatial sampling and cause deleterious effects during the processing especially for DMO correction. The problem will further be exaggerated for Pre-stack time migration. The quality of stack and migration can be improved either by whitening after post-stack deconvolution or by applying inverse Q- filter to stack data. In the present case, the data pertaining to Mizoram fold belt area was processed implementing both the approaches. How ever, the results indicate that the data obtained by subjecting data to deabsorption through data driven Q values was found to be successful in enhancing reflection standout, continuity and resolution. Hence, the case study suggests that enhancement of data during post-stack processing can be done through deabsorption so as to yield better subsurface image especially in fold belt areas. This case study also suggests that *status quo* processing is not always advantageous and advanced techniques can improve subsurface imaging.

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