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The Power of 3D Projection Filtering: Examples from Foldbelt Areas of India

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Summary

In the framework of seismic image processing, one is often interested in the restoration and enhancement of the quality of the seismic image. This process is carried out to attenuate degradation due to sensors during data acquisition or introduced by some preprocessing procedures. Random noise that can not be predicted from trace to trace can mask other seismic energy, hindering other noise attenuation processes or disguising subtle structural or stratigraphic features. Random noise attenuation by projection filtering reduces incoherent noise by eliminating data that are not linearly predictable. It can be applied on 2D or 3D seismic data, on data ordered into any domain, for example, shot gathers, cross-spreads or common offset planes either pre or poststack. Signal to noise ratio enhancement in the F-X domain has been proposed by Canales (1994) as a method for random noise attenuation. The technique is widely accepted and used in the industry. The method is very effective, easy to implement and very efficient in the computational sense.

In the present paper, a novel approach proposed by Soubaras (1994, 1995, 2000) which is based on the concept of projection filtering has been used to attenuate random noise and thereby enhancing the quality of seismic image, on 3D poststack seismic data sets pertaining to foldbelt areas of A&AA basin, India and the seismic images are found to be momentously a cut above that of pre-projection filtering.

Introduction

F-X projection filtering (Soubaras, 1994, 1995) is a statistical noise attenuation technique that differs from F-X prediction filtering in that the noise is obtained by filtering the data with the auto-deconvolved prediction error filter instead of the prediction filter itself. This auto-deconvolution step is necessary to ensure coherency with the predictable signal plus noise model and the result is superior performance of the projection filtering. The most straight forward and efficient 3D implementation of projection filtering can be done in the F-X-Ky domain. Projection filtering makes use of causal prediction error filters, spectral factorization and recursive filtering. The generalization of these concepts to 2 dimensions can be done by using the helix transform (Clearbout, 1998). A 2D signal a(nx, ny) is causal if it is zero for nx < 0 and nx = 0; ny < 0 ; A 2D minimum phase signal is causal 2D signal with a 2D causal inverse. The 1D spectral factorization problem, that is finding a minimum phase signal of a given autocorrelation has been widely studied, and a variety of algorithms exist. 2D spectral factorization can be done by the helix transform by transforming a 2D problem into a 1D one. A (f-x-y) 3D extension of projection filtering based on the helix transform was presented by Ozdemir et al., (1999). As a theoretical tool the helix transform is a powerful tool allowing the transposition of 1D properties into 2D properties. However, it does not always give an efficient algorithm. Soubaras (2000) showed that the Fourier transform allows the reduction of a 2D spectral factorization into 1D factorization and the resulting 2D algorithms are very efficient. 2D spectral factorization by Fourier transform and 2D spectral factorization in the (X-

Ky) domain are mathematically explained by Soubaras (2000).

Method of Projection Filtering

F-X-K_y Projection filtering

Projection filtering uses a 2D causal prediction error filter $a(i_x;\ i_y)$, with $a(0,0)=1$. The filter coefficients are zero for $i_x=0$ and $0 \le i_y \le p_y$ or for $1 \le i_x \le p_x$ and $-p_y \le i_y \le p_y$.
As (f-x) projection filtering is a 1D algorithm applied in X for every frequency, the easiest way to extend it to 3D is to apply the 1D algorithm in X for every (f, k_y). The prediction error filter is computed in the (x-k_y) domain, and the pre-whitened autocorrelation obtained.

$Rk_y(Z_x) = Ak_y(Z_x)\ Ak_y(Z_x) + €^2$ ………………………..(1)

The damped prediction filter ($K_y(Z_x)$ is obtained by 1D spectral factorization in x of $RK_y(Z_x)$. The phase correction Φ (K_y) ensuring the 2 D minimum phase property is not needed as we divide the data Dk_y (Z_x) by this damped prediction filter by 1D recursive filtering in X for each K_y. We then compute the system that would give the prediction error filter. $AK_y(Z_x)$ minimizing the energy of A(D/C):

Min $V(K_y)$ = a* K_y R K_y . a K_y ……………………………..(2)

Solving this system independently for every K_y gives the solution corresponding to a very large P_y. If we want to impose a finite P_y, we have to compute all the RK_y matrices independently and solve in a (i_y):

Min $V(K_y)$, with ak_y = $a(i_y)$ € …………………………….(3)

which is a linear system. The iterations can continue by re-computing the prediction error filters in the ky domain. The linear system (3) is the only step which couples between them the computations for different k_y. The spectral factorization step does not. This (f-x-k_y) projection filtering can be used for missing line restoration as for every k_y the 2 D missing trace restoration as for k_y the 2D missing trace restoration algorithm (Soubaras.1995) can be used. Projection filtering can also be used for interpolation (Soubaras, 1997).

Examples:

Banskandi, Gojalia and Manikyanagar structural highs are situated in Cachar and Tripura fold belt areas of Assam-Arakan geosyncline which mostly cover the northeastern frontier agency (Fig.1).

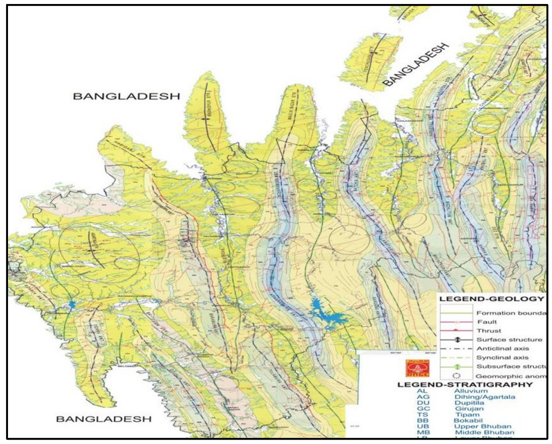

Fig.1.Northeastern frontier agency showing Banskandi, Gojalia and Rokhia anticlines.

These structures are of hydrocarbon interest and 3D seismic surveys have been carried out to image them. *Albeit* they are good candidates for seismic prospection in the theoretical sense, they are not very seismic friendly as far as seismic data acquisition is concerned. However, good care and proper planning of seismic exploration programs have helped in deciphering these structures with standards of international quality. Seismic data processing has been carried out by processing geophysicists of Regional Computer Centre, Oil and Natural Gas Corporation Limited, Jorhat, Assam, with stringent quality assurance and all possible efforts have been made to output the best possible images of these structures. The adopted processing flow follows all basic processing steps, rigorous velocity analysis, residual static corrections, Dipmoveout (DMO), stack and migration.

In the present study, the stack outputs after DMO are considered as input for 3D projection filtering and attempted to reduce the random noise level thereby to enhance the signal strength. Several tests have been carried out for parameterization of projection filtering and the outputs are shown along with the inputs for comparison. Initially the tests were carried out in the deeper part of the seismic section where the random noise dominates and the lengths of the spatial and temporal operators for projection filtering are estimated.

Banskandi Anticline:

Rengte-Banskandi-Pathimara group is an eastern group of structures and lies between Silchar syncline in the east and Labak syncline in the west. Banskandi structure lies concealed north of Rengte and was discovered through geomorphic analysis. Seismic survey later confirmed the presence of the structure which is a narrow elongated anticline bounded by two reverse faults. Several wells have been drilled over this structure and found that the gas accumulations are confined to the central part of the structure. The Banskandi structure was covered initially by two dimensional seismic surveys and an isochron map has been prepared to mark the extension of the structure (Fig.2).

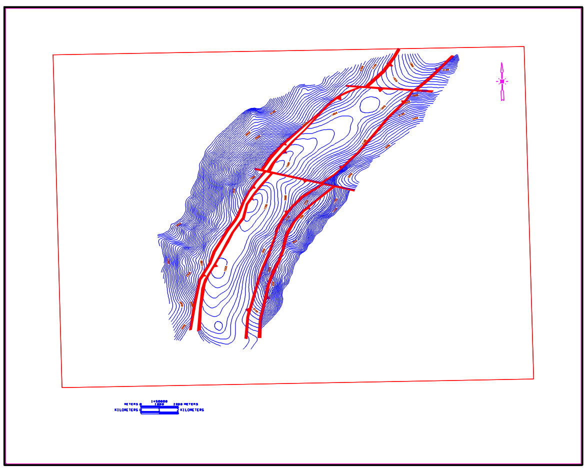

Fig.2.Isochron map of Banskandi anticline at formation upper Bhuban level.

Later, 3D seismic survey has been carried out over a part of Banskandi structure and the data has been processed by applying DMO correction. The stacked data contain signal as well as random noise. F-X-Y prediction filtering was applied to attenuate random noise but the technique did not yield convincing result. So, Projection filtering as discussed in aforementioned lines has been applied on a test data taken from the 3D volume and found that best results are obtained. The parameters for projection filtering are optimized and applied on the full volume. Some inlines (Figures 3 to 12) from the volume are shown here to highlight the efficacy of Projection filtering.

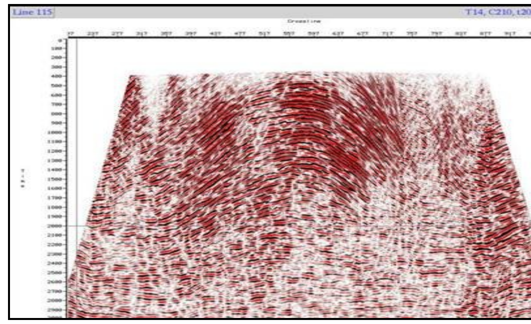

Fig. 3.The DMO stack of inline 115 from the 3D volume of Banaskandi area

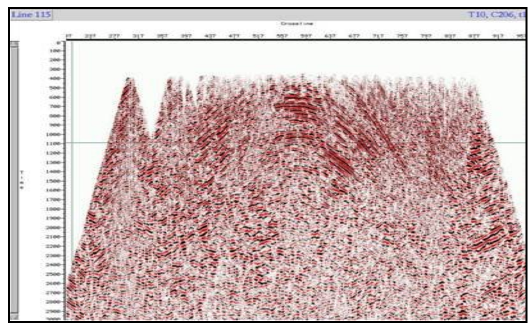

Fig.4.The DMO stack of inline 115 after Projection filtering

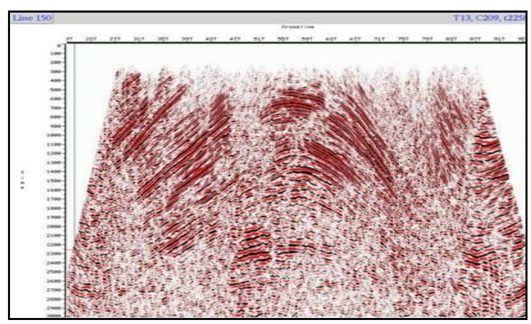

Fig.5.The DMO stack on inline 150 from the 3D volume of Banaskandi area before Projection filtering

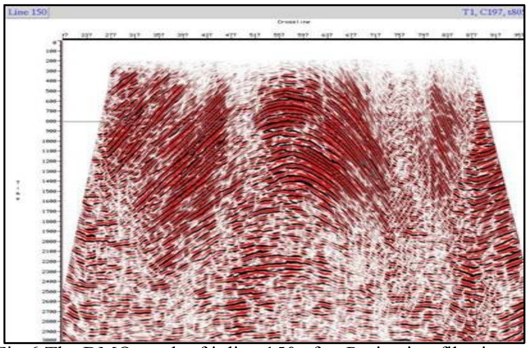

Fig.6.The DMO stack of inline 150 after Projection filtering

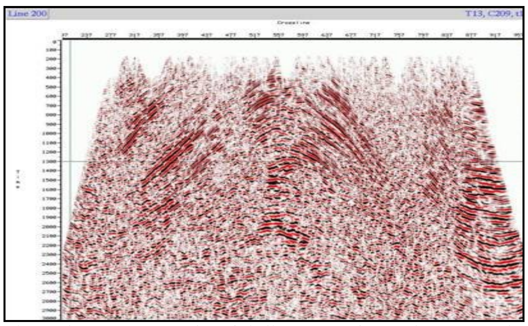

Fig.7.The DMO stack of inline 200 from the 3D volume of Banaskandi area

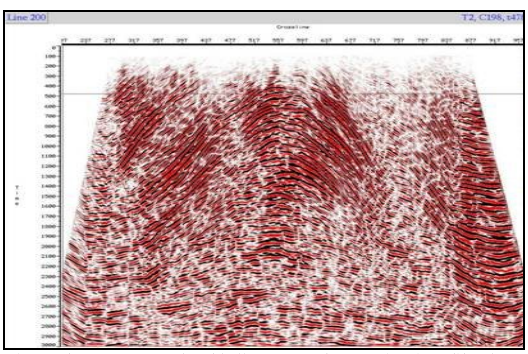

Fig.8.The DMO stack of inline 200 after Projection filtering

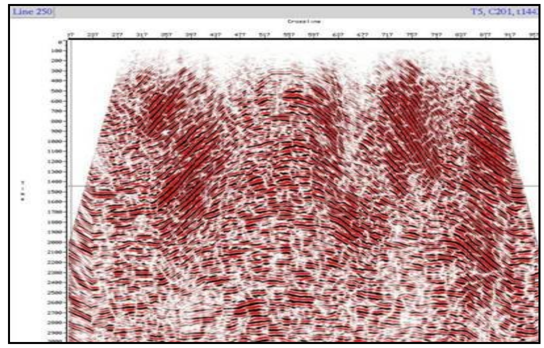

Fig.9.The DMO stack of inline 250 from the 3D volume of Banaskandi area

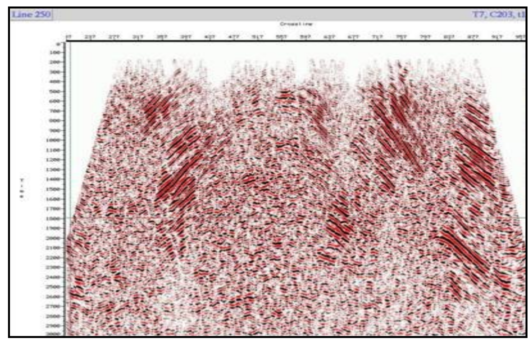

Fig.10.The DMO stack of inline 250 after Projection filtering

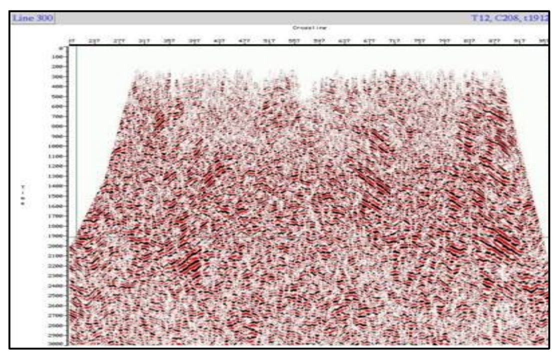

Fig.11.The DMO stack of inline 300 from the 3D volume of Banaskandi area

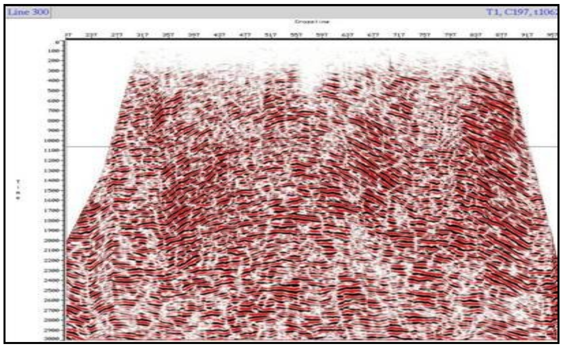

Fig.12.The DMO stack of inline 300 after Projection filtering

Gojalia Anticline:

Gojalia anticline is one of the important structures in South Western Tripura (Fig. 13) in north eastern part of India. The area of study lies in the northern part of the Gojalia anticline.

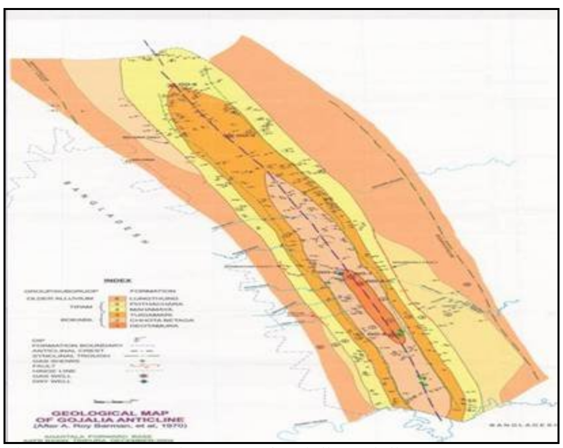

Fig.13.The structural aspects of Gojalia anticline

The presence of commercial gas was proven by wells in the surveyed area. Precise mapping of faults, extension of sands of the proven wells and identifying any additional prospects are the objectives of the project. The Gojalia anticline is located in the southern part of Tripura and is en-echelon to Baramura structure in the northeast and Tichna structure in the North West. It is a NNW-SSE trending, elongated, and doubly plunging asymmetric anticline, about 40 km long, with flat crest and steeply dipping flanks.

Some inlines from the 3D seismic volume (Figures 14 to 22) are shown here to demonstrate the merit of projection filtering.

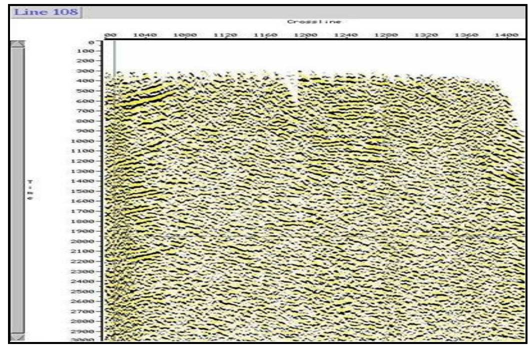

Fig.14.The DMO stack of inline 108 from the 3D volume of Gojalia area

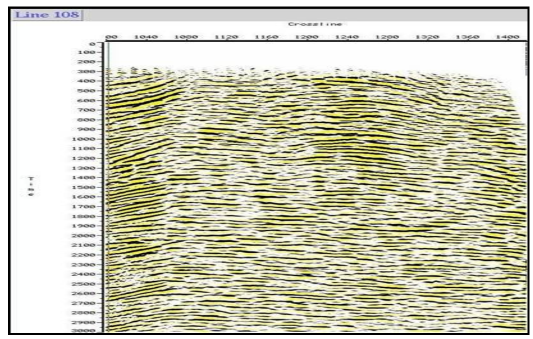

Fig.15.The DMO stack of inline 108 after Projection filtering

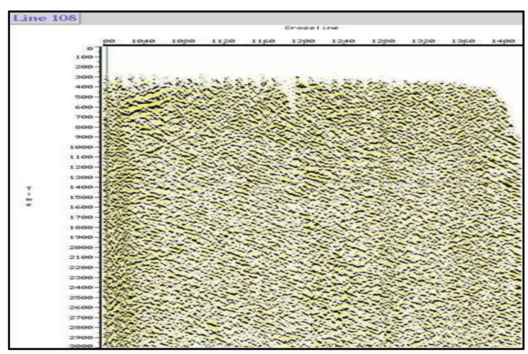

Fig.16.The difference section of inline 108 from the 3D volume of Gojalia area

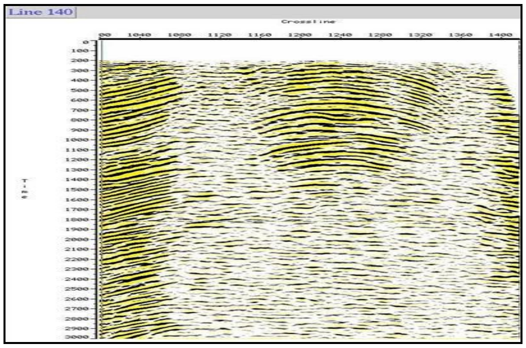

Fig.17.The DMO stack of inline 140 from the 3D volume of Gojalia area

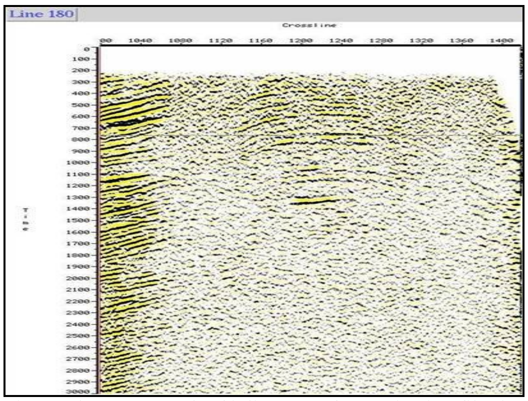

Fig.18.The DMO stack of inline 140 after Projection filtering

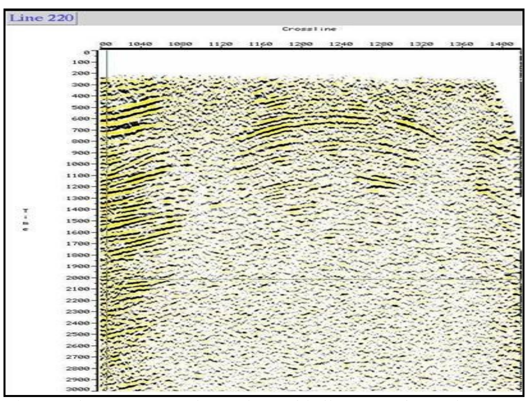

Fig.19.The DMO stack section of inline 180 from the 3D volume of Gojalia area

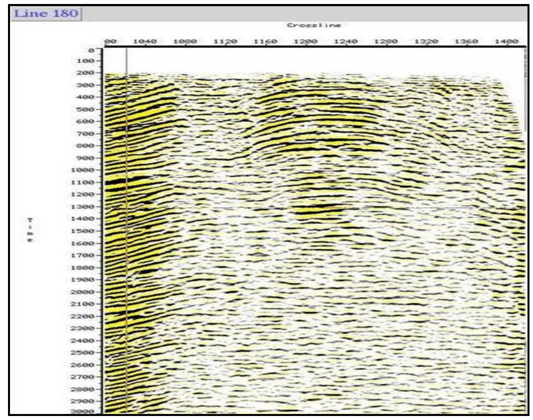

Fig.20.The DMO stack of inline 180 after Projection filtering

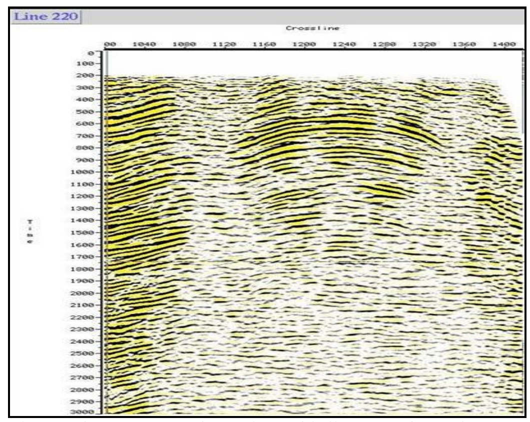

Fig.21.The DMO stack section of inline 220 from the 3D volume of Gojalia area

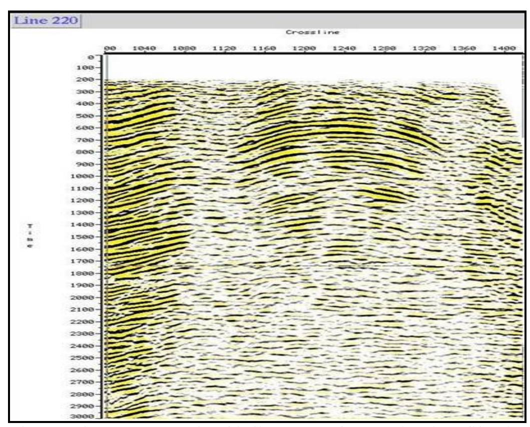

Fig.22.The DMO stack of inline 220 after Projection filtering

Rokhia Anticline:

Rokhia anticline is the outermost structure of the frontal fold belt of Tripura. It is tectonically the least disturbed and is an elongated gently folded doubly plunging, flat topped, symmetrical anticline, trending NNW-SSE. The structure contains two culminations, one occurring around Putia village and other, south of Jaangalia village separated by a broad saddle. The northern culmination is structurally higher by about 175 mts than the southern one. Dip of the beds, in the western flank of northern culmination varies from 7^{o} to 9^{o} and that in eastern limb varies from 8^{o} to $12^{o}$with generally lesser values in the axial zone. Dip of the beds in north –north westerly plunge is about 1^{o} to 2^{o} and in the south-south easterly plunge varies from 2^{o} to 3^{o}.

The oldest sediments exposed in the core of the anticline is Tipam Group of sediments, comprising alternating argillaceous and arenaceous beds. Four litho-units have been identified. The bottom three units are the parts of Tipam group, whereas the uppermost unit is the part of Dupitilla Formation (Fig.23).

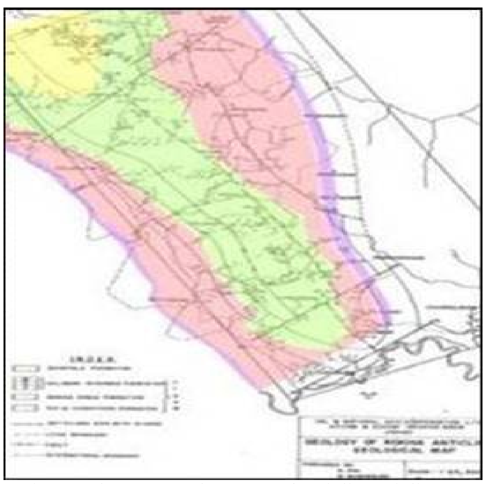

Fig. 23.The structural aspects of Gojalia anticline

The bottom unit is arenaceous followed by argillaceous sequence and then arenaceous sequence repeating itself. The uppermost sequence is argillaceous in nature. The core of the northern culmination is occupied by older arenaceous sequence whereas the core of southern culmination is comparatively younger argillaceous sequence of Tipam Group.

Figures 24 to 31 illustrate the power of projection filtering in enhancing the signal strength while attenuating the random noise.

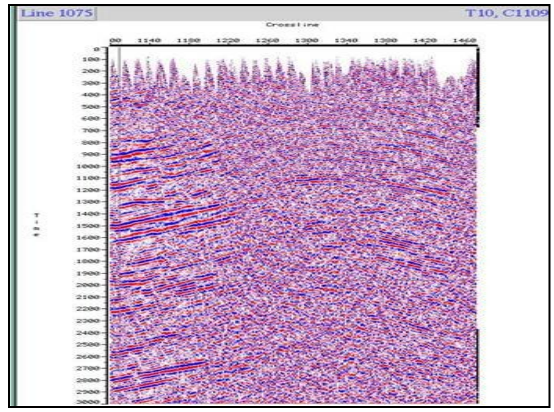

Fig.24. DMO stack of inline 1075 from 3D volume of Rokhia anticline

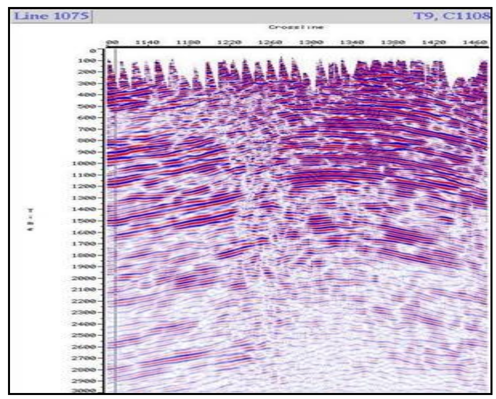

Fig.25. DMO stack of inline 1075 from Rokhia anticline after Projection filtering

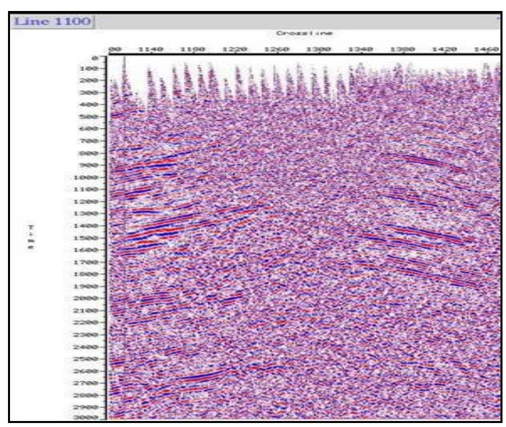

Fig.26.DMO stack of inline 1100 from 3D volume of Rokhia anticline

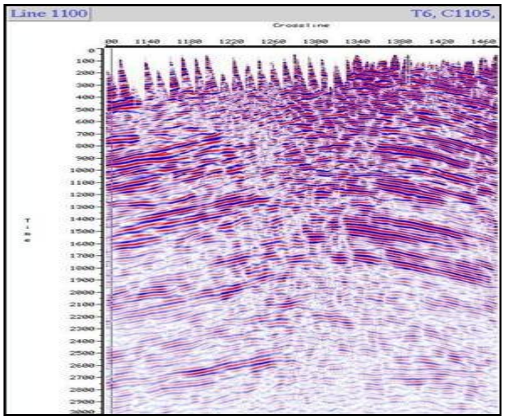

Fig.27. DMO stack of inline 1100 from Rokhia anticline after Projection filtering

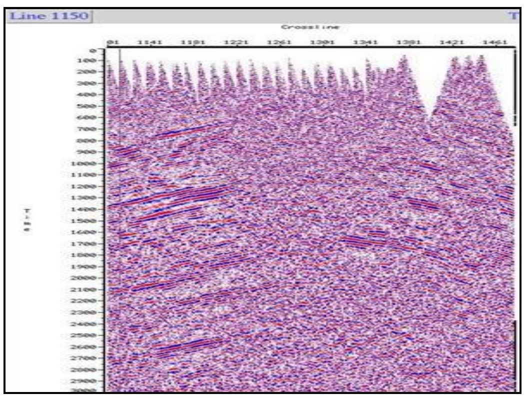

Fig.28. DMO stack of inline 1150 from 3D volume of Rokhia anticline

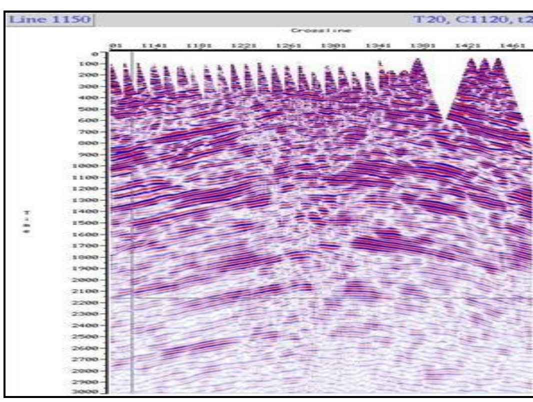

Fig. 29.DMO stack of inline 1150 from Rokhia anticline after Projection filtering

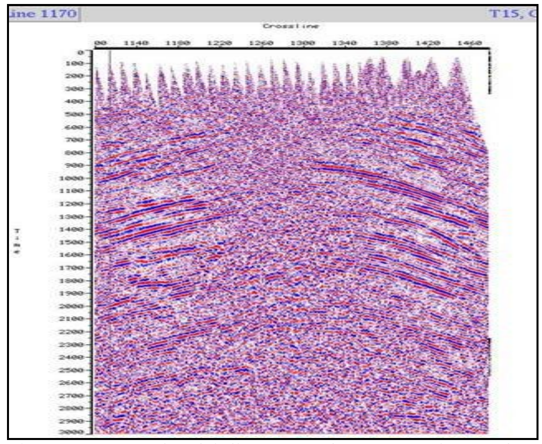

Fig.30.DMO stack of inline 1170 from 3D volume of Rokhia anticline

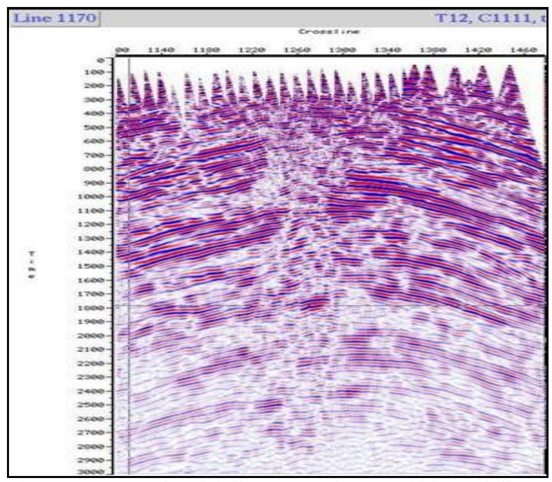

Fig.31.DMO stack of inline 1170 from Rokhia anticline after Projection filtering

Conclusion

The Projection filtering in f-x-k_y domain proffered by Soubarass (1994, 1995, and 2000) has been applied on post-stack 3D seismic datasets from foldbelt areas of A&AA Basin, India namely Banskandi anticline, Gojalia anticline and Rokhia anticline to remove random noise. Some inlines from each dataset before and after Projection filtering are shown in this paper. The outputs after Projection filtering explicitly show the removal of random noise, improved continuity and stability of the reflections. While optimizing the parameters for Projection filtering, the auxiliary outputs which contained the difference between the input and output are carefully studied for the presence of random noise and absence of signal. It is found that the method is very powerful in attenuating the random noise by saving the signal, easy to optimize the parameters and require not much computer resources.

Random noise generally dominates in the fold belt data irrespective of 2D or 3D. The most popular methods that are in vogue to suppress random noise are prediction filtering and projection filtering. The limitations of prediction filtering are: high amplitude noise produces flaws in t-x or f-x prediction filtering, reduction of reflection amplitudes, generating spurious events and the most important flaw that stems from prediction filtering is even if the signal is perfectly predicted, the output of the filtering does not perfectly separate the signal and noise. These limitations can be kept away in the projection filtering. When used on three sets of foldbelt post-stack 3D seismic data, projection filtering effectively removed the random noise and enhanced the imaging. Although not discussed in this paper, Projection filtering can also be used for swell noise attenuation at sea, missing trace restoration on a 3D grid, interpolation from a fine grid to a finer grid in pre or post stack domains.

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