



Effectiveness of Radon Filter in Multiple Attenuation: An Analysis on Real and Synthetic Data

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Summary

The attenuation of multiple reflections in marine seismic data has been a high priority in seismic industry for many years. Much partial solution exists that are able to tackle the problem in particular circumstances. There is however no method or group of methods that work in all area. Multiple removal, algorithms have been based on two differentiating properties i.e. moveout and predictability. Radon transform seismic data into a domain where multiples and primaries are readily distinguishable and can be separated. This separation allows multiples energy to be easily removed prior to transforming the data back into T-X domain. Algorithms of radon filter relay on residual moveout to discriminate multiples from primaries. Velocities must be picked with sufficient accuracy to distinguish primary energy from slightly slower multiple energy. Radon filter requires no knowledge of the multiple generating mechanism and attenuates multiples at all offsets equally. It also works fairly well with non-uniform geometries. Radon filter is still effective when primaries and multiples are co-incident at near offsets in T-X domain. A minimum moveout of 30 from near trace to far trace is required for this technique to be effective. A greater moveout differential increases its effectiveness.

The study shows the importance of velocity in the effectiveness of the radon filter on multiples attenuation by taking the synthetic CDP gathers. The filter attenuates the multiple even when these are overlapping at near offsets with the primary events. The radon filter has been applied on a marine dataset of West Coast, India to attenuate the multiples to get the meaningful image of the subsurface. An attempt was successfully made to attenuate the multiple by adopting radon filter techniques and it is shown with the synthetic data that velocities must be picked with sufficient accuracy to be used in applying NMO for input data radon filter.

Introduction

Multiples attenuation remains an integral part of a marine processing flow as seismic imaging techniques assume that the input data are free of multiples. The presence of multiples leaves us with spurious images and amplitudes. Primary events may create outstanding multiples to perplex and perturb seismic interpreters. The removal of multiples becomes necessary to obtain true image of the subsurface. The diversity of multiple attenuation methods available and continual rapid advance of multiple attenuation process in general can make it difficult to decide which technique is best suited to our particular data set. There is however no method or group of methods that works in all area. Methods that attenuate multiples can be classified (M. Das, 2006) as belonging to three categories:

1. Methods based on prediction and then subtraction of multiples from seismic data.

2. Methods that separate primary from multiples in some domain or other based on their properties
3. Methods based on modeling of the multiples and their adaptive subtraction.

The first group assumes that the key difference between multiple and primary is that the multiples are periodic while primaries are not. Predictive deconvolution in T-X or tau-P domain is based on this periodicity of multiples. These methods are effective on the periodicity of the multiples. The second group assumes that by applying some transform to the data, the separation between primaries and multiples can be distinctly achieved and by muting a portion of the data in transform domain, multiples can be attenuated. The transform is based on a feature that differentiates the difference in moveout between primary and multiple events. Many methods based on separability exist to attenuate multiples like Stacking, FK Filter, Radon filter etc. (Foster and Mosher 1992, M M Nurul et al. 1999). These methods are effective when their assumptions and prerequisites are satisfied. The third



group is based on modeling of the multiples generation and then their subtraction from the recorded data. The modeling may be carried out by creating subsurface model. But now techniques (Surface Related Multiple Elimination, SRME) are available which requires no prior knowledge of the subsurface geology (Verschuur, DJ, 1992). The recorded data itself is used as a first estimate of the primary wavefield. The process then becomes a series of cross-convolution of common midpoint gathers. The SRME algorithm generates a pre-stack multiple model and then subtract it from the data. SRME methods require a regularized geometry and consideration of aliasing issues. The geometry regularization required by SRME combined with its iterative nature makes it expensive and/or computer intensive process. Sometimes, these requirements of SRME with the data or even after interpolation of data are not met which decreases its effectiveness in attenuation of multiples. SRME is also used as a part of cascaded de-multiple sequence along with radon filter. (Terje Weisser, 2006) Table -1 shows the different algorithm of multiples suppression used in the industry.

Table 1: Different algorithm of multiples suppression.

Domain	Algorithm	Features
T	Predictive Decon	Periodicity
Tau-p	Predictive Decon in Radon Transform	Periodicity
t-x	Stacking	Separability
Tau-p	Filtering in Radon Transform	Separability
f-k	Filtering in Fourier Transform	Separability
t-x	SRME	Modeling from data itself

Radon Transform Methodology

Filtering in Radon Transform is one of the effective tools for attenuation of multiple and is extensively used in the industry. Radon transform models the original data along a range of lines, parabolas, or hyperbolas. The modeled multiples are subtracted from the input seismic data to get filtered output. The radon transform distinguishes between primaries and multiples based on the residual moveout from the near to far offsets of CDP gathers. Therefore it requires NMO corrected gathers and hence stacking velocity analysis is to be carried before the application. A parabolic form of the radon transform is used since multiples have an approximately parabolic form in radon domain after NMO correction. A hyperbolic approximation is more accurate at times around deeper depth but is not accurate for shallower events as the

parabolic method. Linear form of the radon transform is used for modeling linear events and therefore used for suppression of ground rolls and other linear coherent noises. Radon transform also finds application in suppression of random noise by modeling primary events. In this case primary events are modeled and used to estimate the noise so that it can be subtracted from the input to get the noise free data. The radon transform directly estimates the modeled primary and using this as the direct output may produce an overly synthetic result. Therefore, first noise is calculated by subtracting modeled primary from the input data. This noise is scaled down by multiplying with a constant or by a time and CDP dependent scalar.

Since, separation of multiples from primaries is based on event curvature, Radon filtering should be applied on gathers that carry no structural information i.e. CDP gathers. Radon transform are commonly used for suppression of ground roll, incoherent noise and multiples in seismic data processing. The suppression of multiples also greatly facilitates velocity analysis. However, it is most important that removal of noise/multiples should not degrade the signal component of the reflections.

Study On Synthetic Data

Synthetic CDP gather is utilized to analyze the effectiveness of radon filter in attenuation of multiples. The CDP gather with 60 fold and maximum offset of 2950 m is generated. The reflection events and their velocity are shown in Table: 2

Table 2: Model for generating events

Events	TWT (ms)	Velocity (m/s)
Water Bottom (WB)	2000	1500
Primary-1	3300	1700
First Multiple of WB	4000	1500
Primary-2	4150	1820
Primary-3	4500	2020
Second Multiple of WB	6000	1500

Figure 1 shows the input CDP gather, radon transform and data transformed back to t-x domain without any muting. The NMO is applied with actual velocity of primaries at 2000, 3300, 4150 and 4500 ms. The primary events show the almost zero residual moveout in radon transformed data while multiple events shows the positive residual moveout. Now it is quite easy to separate out the primaries with multiples by picking



the mute as shown in the figure. The figure 2 shows the first and second order of multiples of water bottom which have been modeled with the muted data (shown in the figure 2b). These modeled multiples have been subtracted from the input CDP gather and filtered output is shown in figure 3. Note that the first and second order multiple of water bottom have been eliminated from the gather.

Radon filter is able to attenuate multiple even if it is overlapping with the primary event at near offsets. The same synthetic gather taken for analysis except the primary event is shifted to 4000 ms instead of 4150ms. However, the CDP gather is corrected with the correct velocity of primary at that level (i.e. 1820

m/s). This causes the flattening of the primary events including primary at 4000 ms while the multiple at 4000 ms and 6000 ms shows positive residual moveout. Hence, the two events at 4000 ms have different residual moveout in radon transform. The primary event has zero residual moveout while multiple still has around 200 ms residual moveout (Figure 7). Therefore primary and multiple can easily be separated out in radon domain by picking the mute as shown in figure 8. The filtered out put is shown in figure 9 in which both the multiples have been eliminated effectively.

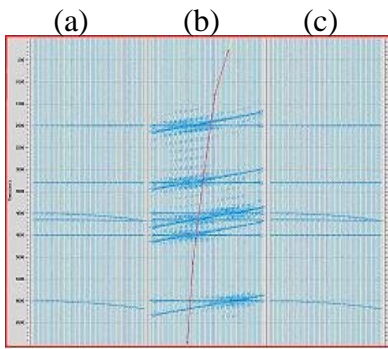


Figure 1: NMO corrected CDP gather (a), radon transform (b) and transformed back to t-x domain without any muting (c).

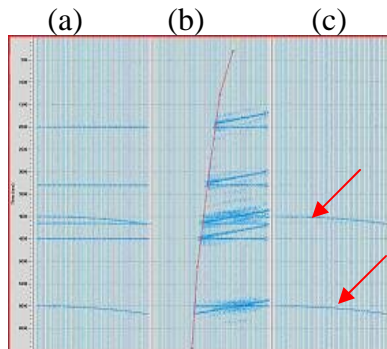


Figure 2: NMO corrected CDP gather (a), muted radon transform (b) and modeled multiple in t-x domain (c) shown with red arrow.

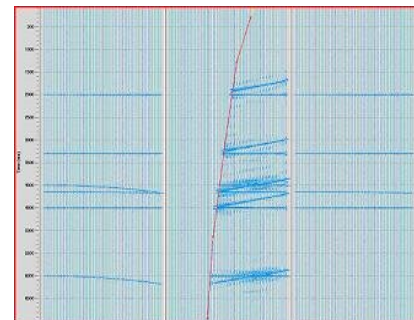


Figure 3: NMO corrected CDP gather (a), muted radon transform (b) and filtered output in t-x domain (c).

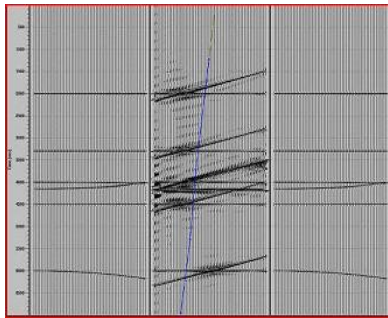


Figure 4: Radon analysis of CDP gathers (NMO applied with 1500 m/s velocity at 4150 ms)

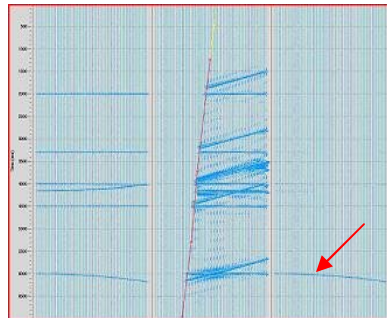


Figure 5: Modeled Multiple (c) shown with red arrow.

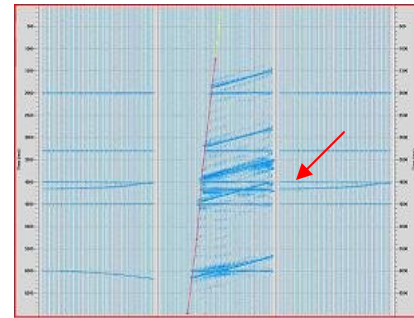


Figure 6: Filtered output still contain multiple at 4000 ms (c) shown with red arrow.

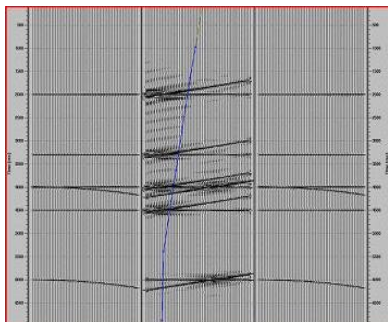


Figure 7: Radon analysis of CDP gather with overlapping primary and multiple events at 4000 ms at near offsets

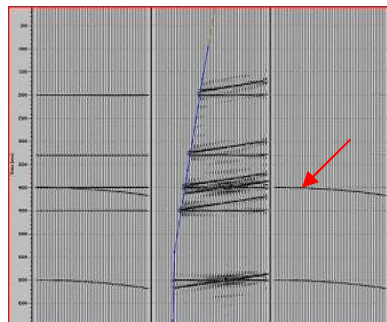


Figure 8: Modeled multiple (c) shown with red arrow.

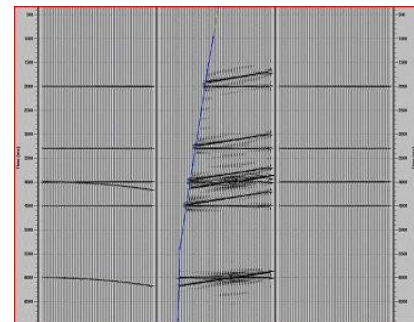


Figure 9: Radon filter output (c) is free of both order of water bottom multiple.



Real Data Example

The radon filter is effectively applied for attenuating the multiple on the real dataset of Kerala-Konkan area of West Coast of India. The area has problem of a strong water bottom multiple. The potential exploration targets of Mesozoic sediments are overlain by Early Paleocene Deccan basalts. The 92 fold 2D seismic data is acquired with group interval and shot interval 25 m each. The maximum far offset is 4625 m. The PSTM is to be carried out with the objective to improve imaging at level Tertiary and Pre-Tertiary. This has necessitated the conditioning of data so that it does not have any multiples energy. The radon filter is applied to attenuate the multiple and its parameters were optimized with the interactive module of radon filter. The multiples of water bottom have been eliminated attenuated in the CDP gather (Figure 10. Radon analysis of a CDP gather along with its radon transform and data transformed back to t-x domain without any muting is shown in the figure 11. The primary energy is concentrated near zero or positive residual moveout while multiples energy shows the positive residual moveout. To separate out the primary and multiples energy, a mute has been picked in radon domain as shown in figure 12b. The multiples which have been modeled with the muted data in radon domain are shown in the figure 12c. These modeled multiples have been subtracted from the input CDP gather and filtered output is shown in Figure 13.

The radon filter also facilitates the velocity analysis and avoids picking of the velocity of multiples. The semblance obtained before and after radon filter application is shown in figure 14 and 15. A comparison of PSTM image obtained with and without radon filter has also been shown in figure 16 and 17. The clear image obtained with the application of radon filter will be helpful in carrying out meaningful interpretation.

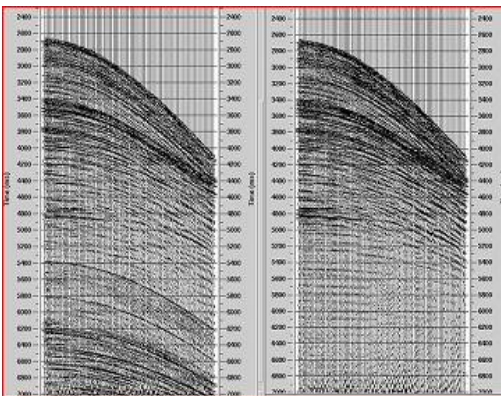


Fig 10: CDP gather before and after Radon filter

Conclusion

Radon filter techniques of multiples attenuation are based on residual moveout to discriminate multiples from primaries. Velocities must be picked with sufficient accuracy to distinguish primary energy from slightly slower multiples energy. Radon filter is still effective when primaries and multiples are co-incident at near offsets in T-X domain. It provides a high degree of attenuation, especially on long period multiples found in deep water. It works similarly well in all areas, but experiences difficulties when the moveout differential decreases, such as with peg-leg multiples or multiple energy found on the near traces. The Radon filter is currently the mainstay of marine demultiple processing flows.

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Reference

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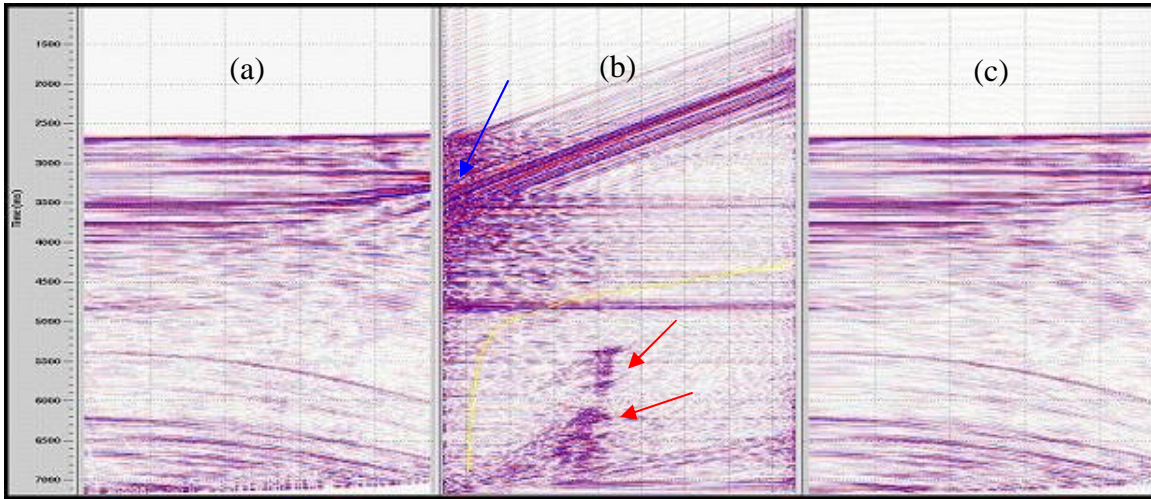


Figure 11: NMO corrected CDP gather, radon transform and data transformed back to t-x domain without any muting. Primary energy is shown with blue arrow and multiple energy with red arrows.

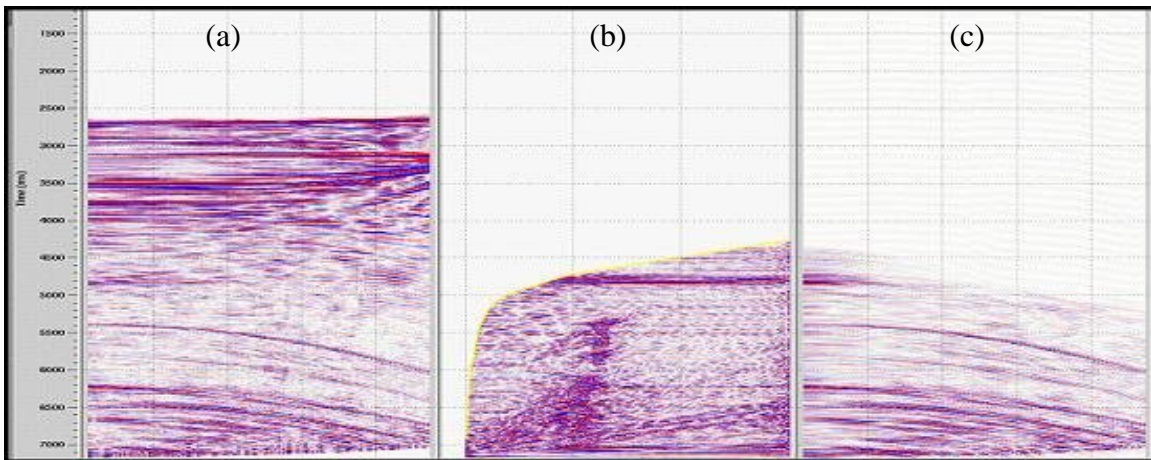


Figure 12: The Modeled multiples (c)

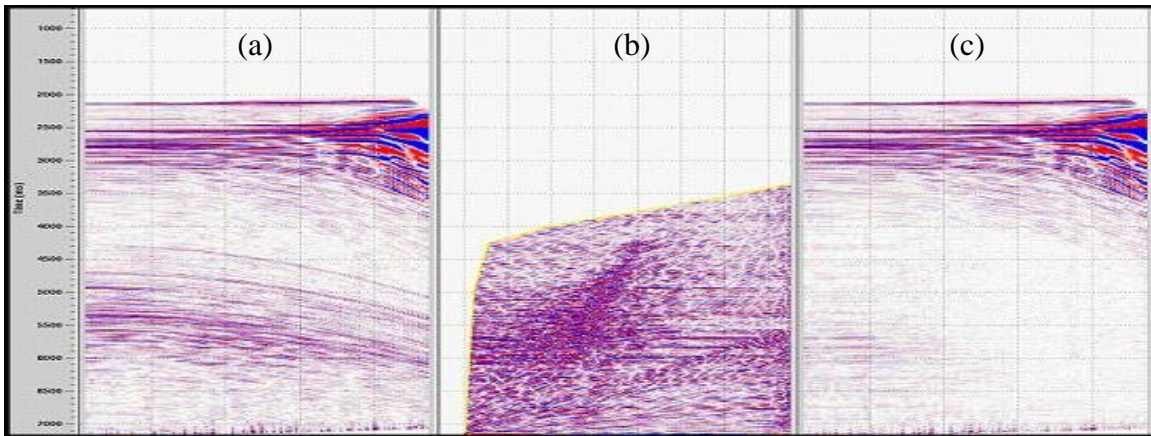


Figure 13: Filtered CDP gather

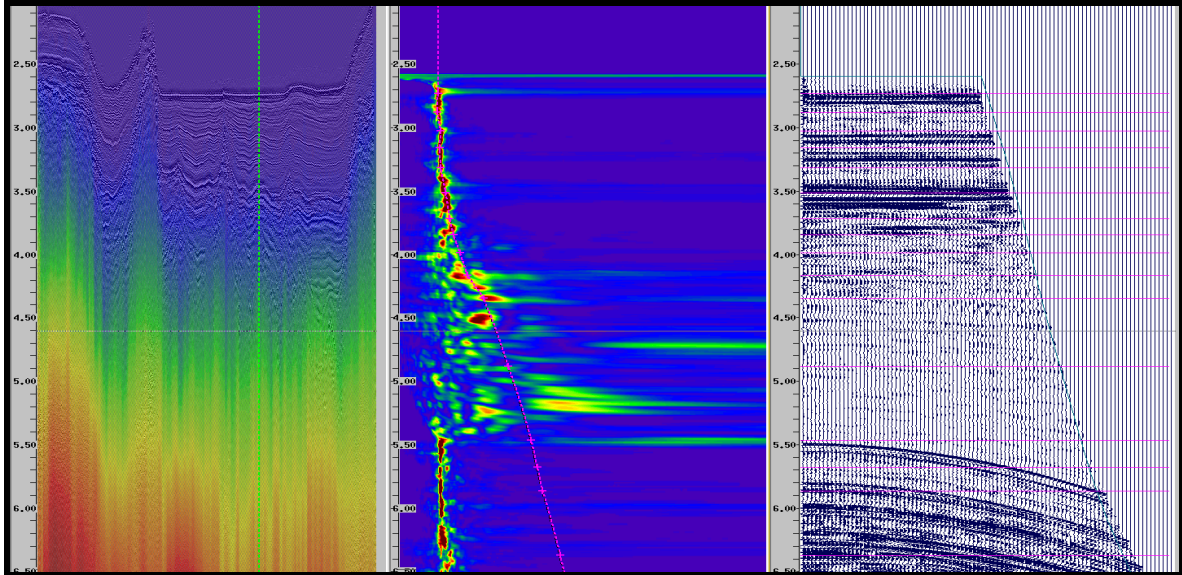


Figure14: Velocity Panel of a CMP gather without Radon filter

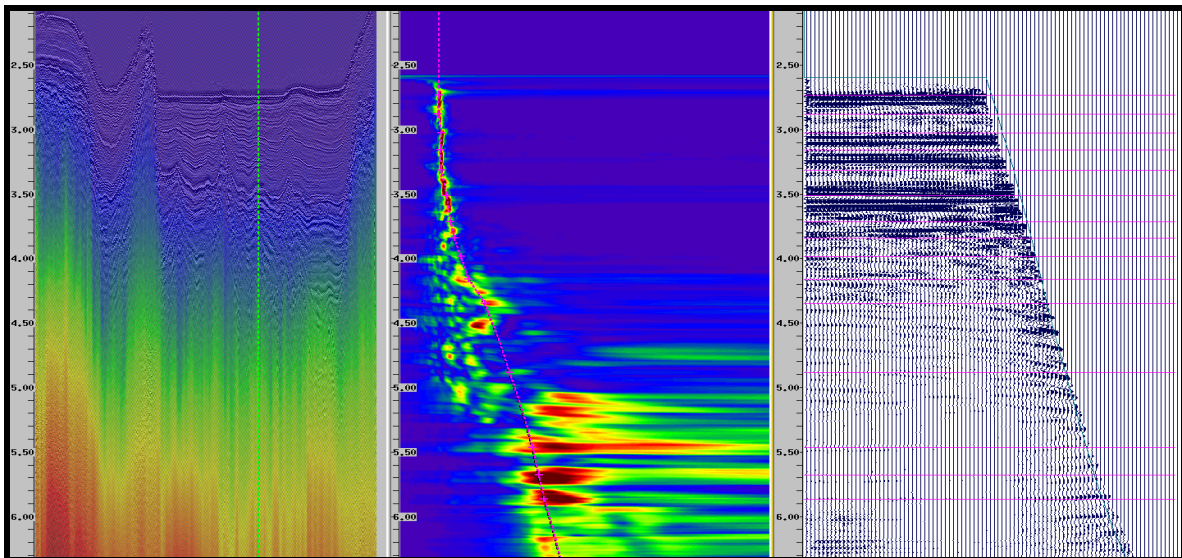


Figure15: Velocity Panel of same CMP gather after Radon filter

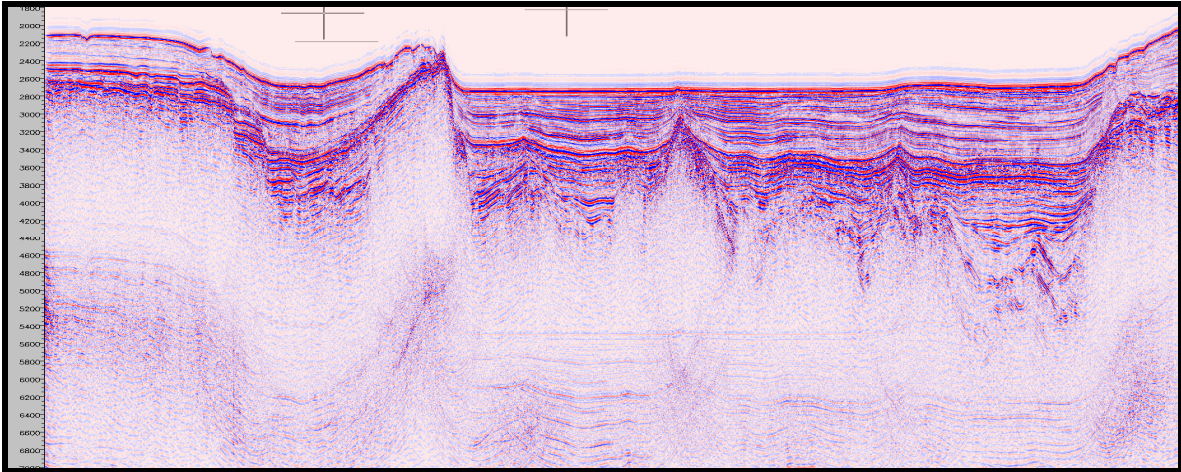


Figure16: PSTM Section without Radon Filter

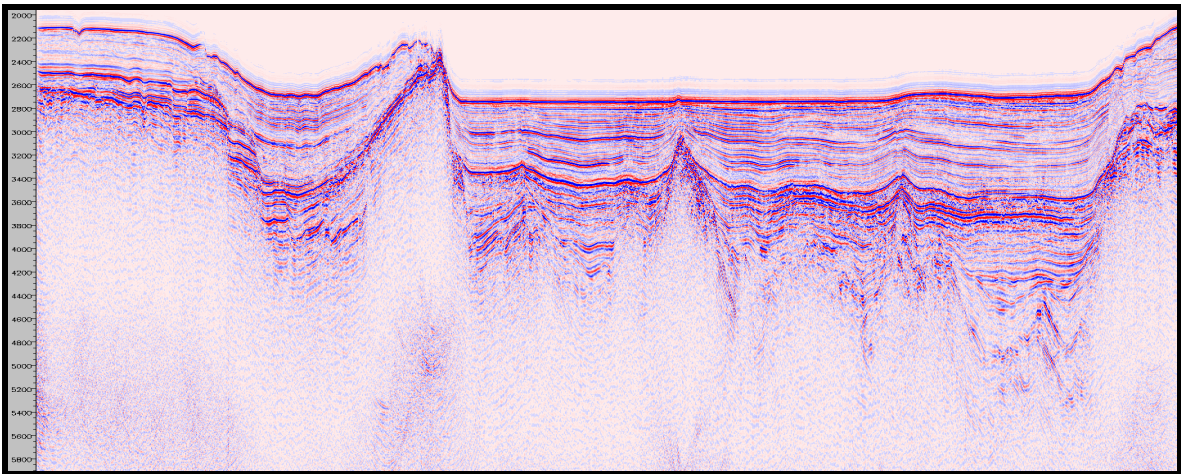


Figure17: PSTM Section after Radon Filter