7th International Conference & Exposition
on Petroleum Geophysics

"HYDERABAD 2008"

P - 360

Seismic Imaging Over Rugged Terrain (Some Indian Case Studies)

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Summary

Depth imaging, over rugged terrain always demands a good time section with clearly seen events right from shallow to deeper portion of it. Any ambiguity in time interpretation of the shallower events will lead to an improper accounting of the ray bending causing progressive distortion of the depth section. One of the possible reasons significantly deteriorating the shallower events was found to be statics.

Estimation of heterogeneity of the near surface both with respect to depth and velocity and removing it from the reflection two way travel time is classically known as static correction (statics). Application of field statics, computed with the assumption of vertical ray path from surface to datum and straight between the datum and reflecting point, becomes ineffective when near surface has a rugged topography with respect to both velocity and depth.

A number of 2-D lines from thrust fold area of Himalayn foot hills were chosen for the present study. Comparative study of the processed out puts reveals that application of refraction statics calculated from first break has brought out significant improvement not only in the shallower part but also in deeper part of the stack sections.

Introduction

First break travel time information in a shot record inherently contains both near-surface velocity and elevation effects. Conventional field static computation methodology can not properly account the rapid elevation changes from picket to picket. Present study came in to being after a number of failures in imaging foot hills data with conventional field statics.

To make the study a bit general, seismic profiles were chosen from areas where elevation changes were found rapid from picket to picket. For example, within a lateral station interval of 30 meters, elevation changes were found from 20 meters to 100 meters even.

As the computation of refraction statics involves modeling of the near-surface, its definition is mandatory here. Identification of first break wavelet from a noisy shot gather is a difficult task. It depends on the individual's skill. For faithful first-break picking shorter offset ranges were taken. Issues like first-break wavelet shape change and its remedy is avoided here.

Surface consistent static solution was obtained from picked first-break travel time by using generalized linear inversion algorithm of **Taner et al (1988)**. They used classical delay time equation for statics computation. Delay time is not an observable quantity; it is defined as the time between the shot or receiver and the refractor minus the time necessary to travel the normal projection of the ray path on the refractor (**Marsden**). Total delay time will have two components, shot end delay time and receiver end delay time. **As the delay time is associated with refraction path and the first arrival time, the statics so computed is popularly known as First Break Refraction Statics.**

The effectiveness of the computed static is judged at the shot level itself by checking the linearity in the first break arrival times and better alignment of the reflection events. Confidence level in velocity picking is increased due to increased coherency of the events. Stack section shows significant improvement both at shallow and deeper levels showing thrusts coming up to the surface.

Near Surface Definition

Modeling of the **near-surface, a layer of unconsolidated materials with variable thickness and velocity, running almost parallel to the topography**, is of great concern while computing static corrections in rugged terrain. The success of refraction statics depends on how close we can model the near-surface to reality by estimating its thickness and velocity.

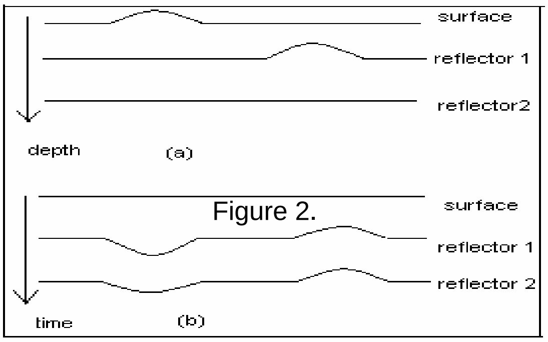

Figure 1

The essence of the near surface depth velocity problem can be illustrated by Figure 1.

Assuming interval velocity constant, the variable overburden thickness due to undulating topography in Figure 1(a) does not match with seismic in figure 1(b). The similar seismic can be produced by keeping thickness constant and by giving lower interval velocity in thicker portion and higher interval velocity in thinner portion of the depth model, in Figure 1(a), (**Marsden**).

The presence of low or high velocity layers by themselves, does not pose problems. The problems occur due to their variations. Usually the near surface velocity information is obtained by LVL and up-hole survey for statics computations. In thrust fold belt area due to irregular topography and rugged terrain, mapping LVL is practically impossible. Close grid Up-hole survey for regular data acquisition is also not practical.

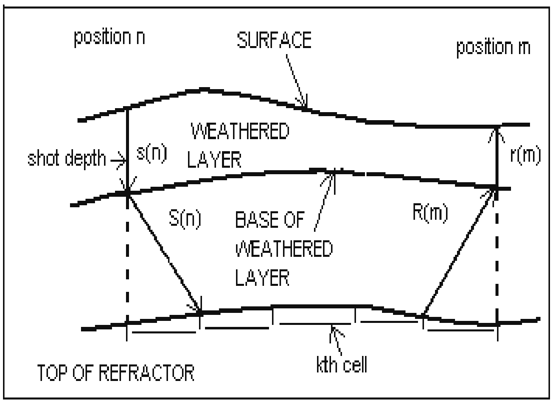

Figure 2: Near surface model

Methodology and Technique

The near-surface model by taner et al. is shown in the Figure 2. Refractor surface is subdivided in to regular cells. If t (n, m) is the picked first-break time for shot location n and receiver location m, then the we can write t (n, m) = S (n) + R (m) + ∑ [σ (k) .Δ (k)] + s (n) +r (m), where S (n) and R (m) are the delay times at nth shot location and mth receiver location corresponding to long wavelength source and receiver statics. σ (k) is the slowness at kth cell located along the horizontal path between nth and mth surface stations. Δ (k) is the sub-path length in the kth cell of the path between nth and mth surface locations. The sum of the product of sub-path length and slowness will give the travel-time along the refractor between the shot and the receiver. s (n) is the short wavelength surface static at the nth shot position **n** and r (m) is the short wavelength receiver static at the mth position **m**. If the source is dynamite t (n, m) is modified by up-hole time.

The surface weathering layer consists of very low velocity material. The layer below it is more consolidated and continues more or less uniformly down to the refracting layer. The weathering layer and the top of the refracting layer vary smoothly in the spatial direction, both in geometry and velocity. Due to the length of the Fresnel zone of waves arriving at the surface from the refractor, only the longer wavelength undulations of the first break times can be attributed to the refracted first arrivals. Therefore, the short wavelength perturbations must be generated from the surface weathering layer.

The near-surface weathering layer is modeled by computing a smooth near-surface elevation. A smoothing operator of length on the order of Fresnel zone, the effective distance covered by a wave front originating from a disturbance on the refractor, is used to compute the smoothed elevation.

Elevation statics are computed now between the actual and smoothed surface using weathering velocity. Elevation statics thus calculated are now subtracted from the original first break travel times prior to delay time and refractor velocity computations.

Long wavelength statics are computed now from the modified first arrival times using an iterative delay time solution. One or two refractor solutions may be specified. First arrivals originating from a given refractor are identified by offsets. When specifying two refractor solutions, care should be taken that first arrivals are not overlapped. Multiple trial runs may be necessary to obtain reasonable layer velocity estimates based on the computed refractor velocity.

Computed delays and slowness are used for subsequent long wavelength statics computations. Their effects are also removed from the original uphole-corrected first arrival times, leaving residual travel times that are reduced to surface consistency yielding the short wavelength component of the refraction statics solution.

Processing Steps

Figure 3 shows the processing steps followed for the present study.

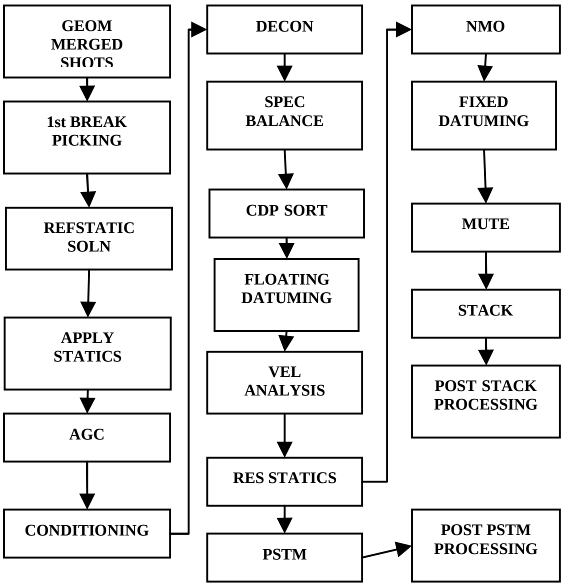

Figure 3: Processing flow chart

On **geometry merged shot data, first-break travel times** are picked and stored in data base as a file. This travel time file is next **inverted** and static solutions are obtained for shot and receiver components. In the introduction, offset limitations, for first-break picking was mentioned, but not at the cost of second refractor which may be mandatory for near surface modeling. Statics thus obtained is applied on the shot gathers followed by application of **gain** (we applied moderate window **agc** here as gain). Foot hills data demands proper **signal conditioning** as it is associated with shot generated linear noises and high amplitude bursts. After signal conditioning, **deconvolution** and **spectral balancing** is done and data is written on disk. Till now the data is in **fixed datum**. Disk written data is now **cdp sorted** and taken to **floating datum** followed by **velocity analysis** and **residual statics** computations. Residual statics corrected gather is written in the disk as final gather which is taken to **Geo-Depth** with floating datum header for running **PSTM**. In Geo-Depth while creating the floating datum model, the horizontal datum and replacement velocity has to be supplied by the user. The model based output gather is already in the fixed datum. Hence one need not apply statics to get fixed datum stack. For conventional stack section as may be desired sometimes, the NMO corrected gather is brought to horizontal or fixed datum with a replacement velocity and then muted to get stack output. Post stack processing is then followed.

Results and Discussions

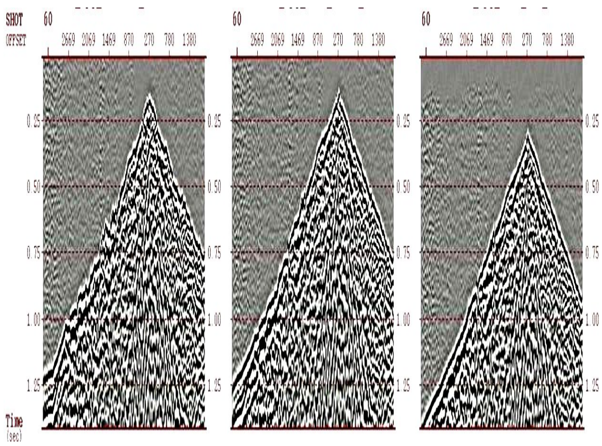

Figure 4

Figure 4 shows zoomed portion of the first arrivals of a shot record without field statics (left), with conventional field statics (middle) and the right most with refraction statics. Linearity in the first-break arrival time is the first QC for good static solution. Figures, depicting other important quality checks like good alignments of the reflectors, sharp semblances in velocity picking, are not incorporated here.

In Figure 5 & 6 stack section with conventional field statics and with refraction statics is compared. It may be noted that the decollement surface at 2 sec. in Figure 5, is running almost parallel to the surface elevation shown at the top. This parallelism, which is absent in Figure 6, may be attributed to erroneous field statics. It may be interesting to mention here that the spurious structure created at the decollement surface is caused by long-wavelength changes in the near surface layers (long wavelength statics).

An overall improvement in stack sections after application of refraction statics is shown in figures 8 & 10 with their counterparts in figures 7 & 9 processed with conventional field statics.

In figure 11, time stack section of a seismic line processed with refraction statics is shown to compare with its PSTM processed stack section shown below in figure 12.

Conclusions

The generalized linear inversion scheme by taner et al, for static computation has its own theoretical limitations. But application of statics obtained by this scheme did a better job to improve seismic sections.

When the input raw shot gathers are noisy, it is better to remove the noises at pre stack stage. Any process which distorts the first break wavelet shape should be avoided prior to first break picking. Picking error due to inconsistency of the source wavelet, common to land data, was not taken care in the present study.

Identification of first break and its picking may consume lot of time but better picking will always result to a better static solution. Sometimes where there is no weather layer information, near offset travel time may be used to compute weathered layer velocity. Selection of multi layers, in near surface modeling, depends on the distribution of picks along the profile. Highly dispersive picks are to be avoided for modeling. Re-picking of first breaks on the refraction statics applied shot gather and re-modeling the near surface with newly picked times, was not tried. From the present work it is concluded that for imaging data over rugged terrain, refraction statics solution is a better option for statics, in comparison to conventional field statics.

Acknowledgement

The author expresses his sincere thanks to Director (E) ONGC, for giving permission to carry out this work and is extremely grateful to Mr. Subroto Kumar Das, GGM-Head GEOPIC for his valuable technical support throughout the work. Thanks are also extended to Mr. Kunal Niyogi, GM-Head processing, for his constant encouragement. Help from colleagues, Mr. Polash R. Bora, Dr. Jagmeet Singh, Mr.Y.E.R Sastry and Dr. Achinto Pal, is sincerely acknowledged.

References

Dave Marsden, 1993, Static corrections – a review, Part-I, II and III, Leading Edge, Vol: 43, January, February and March, 1993.

Turhan Taner, M., Donald E. Wagner, Edip Baysal, and Lee Lu, 1988, A unified method for 2-D and 3-D refraction statics, Geophysics, Vol: 63, No: 1, Page 260-274.

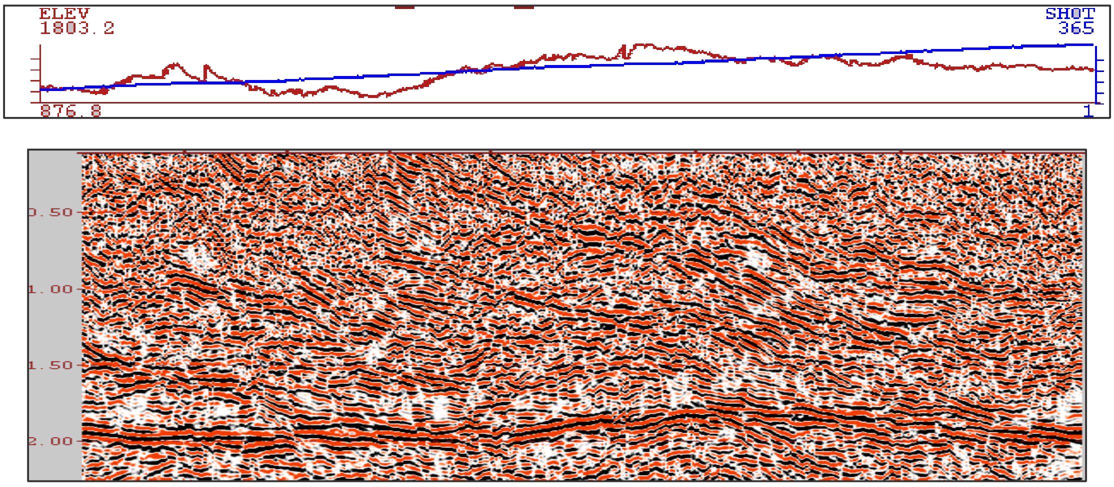

Figure 5: Stack section of a line x with field statics

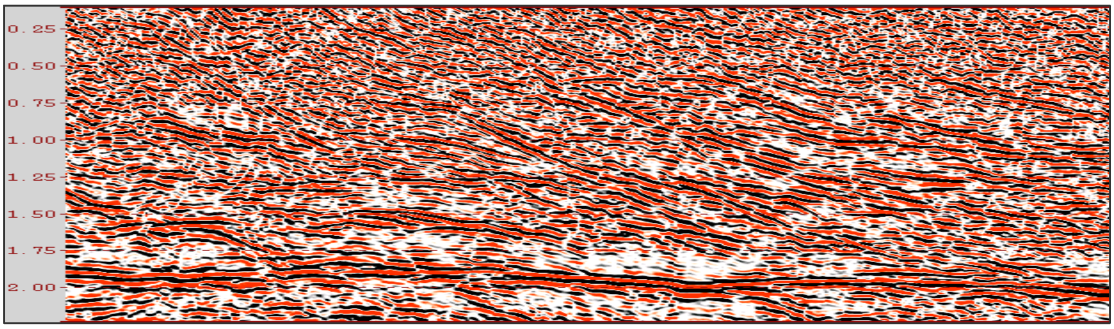

Figure 6: Stack section of the same line x, as shown in figure 5, with refraction statics

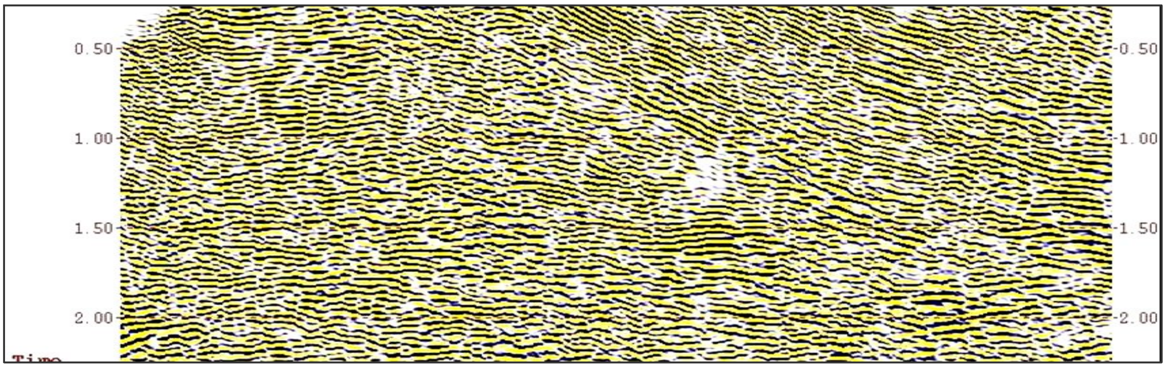

Figure 7: Stack section of a line y with field statics

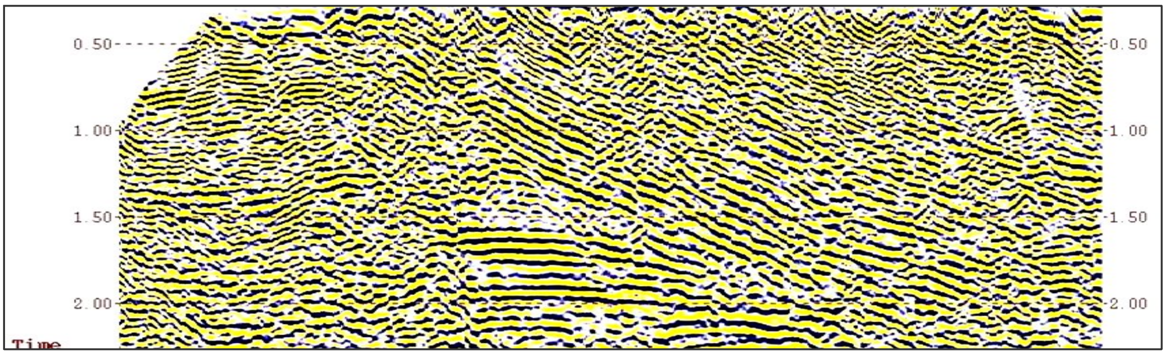

Figure 8: Stack section of the same line y, as shown in figure 7, with refraction statics

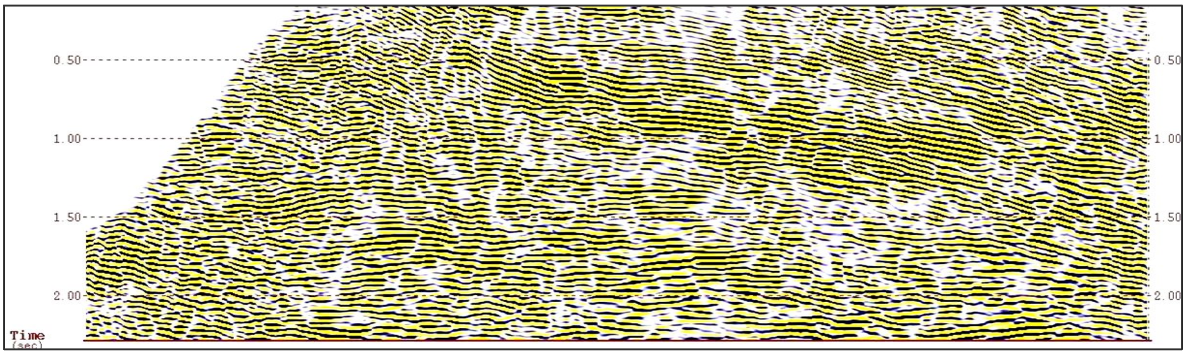

Figure 9: Stack section of a line m with field statics

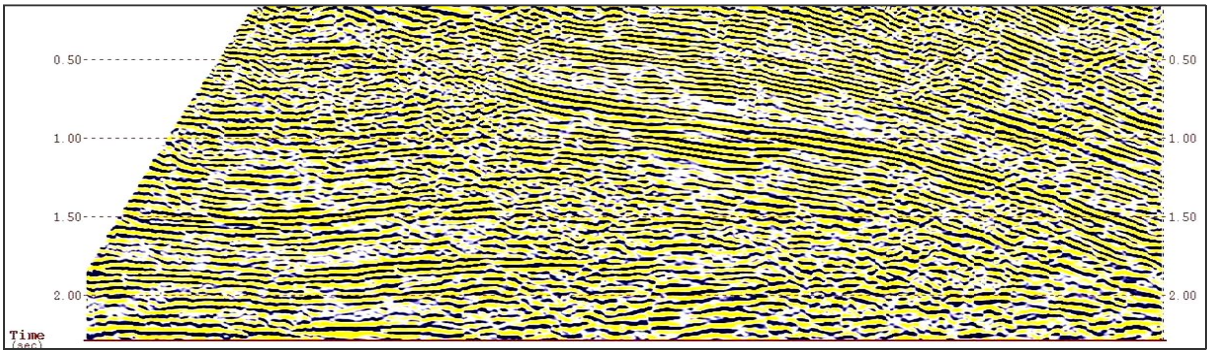

Figure 10: Stack section of the same line m, as shown in figure 9, with refraction statics

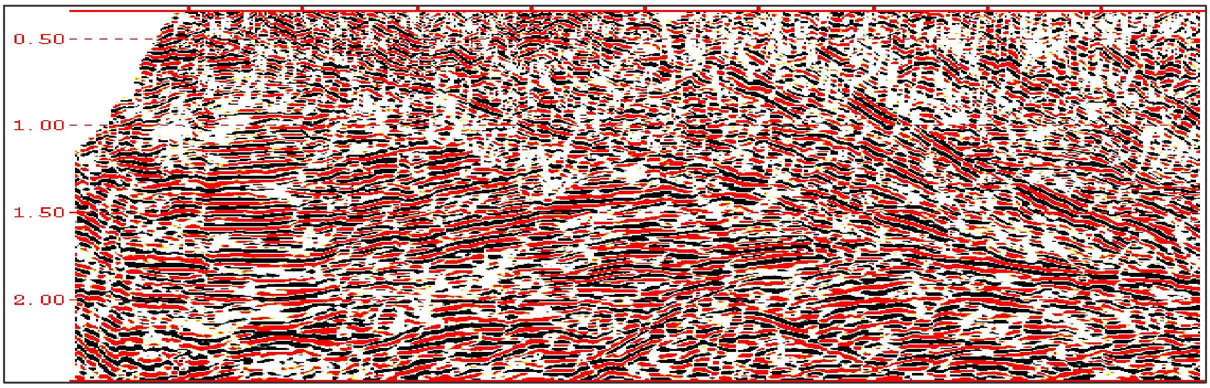

Figure 11: Stack section of a line n with refraction statics

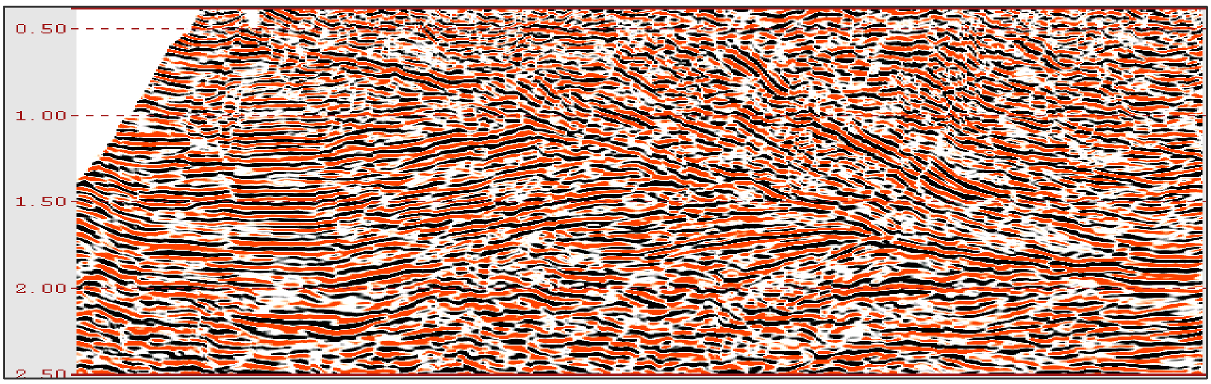

Figure 12: PSTM stack section of the same line n, as shown in figure 11 above