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A STATIC CORRECTION TECHNIQUE FOR SEISMIC SURVEY IN RUGGED EXPLORATION AREAS

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ABSTRACT

Static correction are very important for seismic survey in rugged exploration areas. A new refraction static correction technique is proposed in the paper. The technique is precise, convenient and effective for short and longer spatial wavelength statics in rugged exploration areas. The technique is composed of 5 steps: first arrival picking, selection of sections in first arrivals for static calculation, thickness and velocity inversion, error decomposition and elimination and calculation of static correction value. Two field examples are included in the paper.

1. INTRODUCTION

Reflection seismic method is commonly used in geothermal exploration. In most of land exploration areas, the surface is covered with weathered layer of low velocity. When seismic wave travel through the layer, different thickness and velocity of the layer can cause different time delay of the wave. Field data show that variation of the upper layer can cause a dramatic deterioration in the quality of land seismic data (Figure 1).

Especially the time delays caused by the weathered layer in more rugged areas are very complex and difficult to calculate the delay corrections, as called statics (or static corrections). Good static results can not be obtained by using conventional field statics, refraction statics and residual statics. Static corrections with high accuracy are most important in the processing of seismic data in the areas for they lead to improved quality subsequent processing steps which, in turn, impact the integrity, quality and resolution of the imaged section. Also, if static corrections are not properly derived, then a whole catalog of problems can be set to the interpreter(such as lines with varible datum, seismic events which mistie at intersections, false structural anomalies remaining in the data, false events being created out of noise).

A new refraction static correction technique is proposed in the paper. The technique is convinent to calculate statics with high precision, especially in rugged exploration areas. It is effective for short spatial wavelength statics and also effective for longer spatial wavelength statics. It can be used for 2-D seismic data and also for 3-D data.

2. METHOD AND TECHNIQUE

As usually, if the values of travel time delay are quite small and the signal/noise ratio is high, residual static corrections based on reflection energy maximum can be only used. But in mountainous areas, the static values are large and the signal/noise ratio is rather low frequently. In these cases refraction static procedure base on velocities and thickness inversion of the low velocity layer by the first arrivals is conventional technique for static corrections. In practice the LVL inversion static techniques can not obtain satisfied results in most of rugged exploration areas because of the random errors caused by the non-uniform of LVL. A method of error decomposition and elimination proposed greatly improved the static results.The static correction technique is composed of 5 steps as follow.

2.1 First arrival picking of shot gathers

Maximum amplitude ratio and energy ratio of seismic wave of every trace are used for the first step of first arrival picking. Maximum amplitude ratio F of a trace is calculated by the formula (1),

$$F(i)=\frac{A_m(W_i)}{\frac{1}{i-1}\sum_{j=0}^{i-1}A_m(W_j)} \quad (1)$$

Where W_i (i=1,2,…) are apparent periods of seismic wave in the trace; $A_m(W_i)$ is the maximum amplitude in the apparent period. Energy G is calculated using

$$G(i)=\frac{E_i}{\frac{1}{i}\sum_{j=1}^{i}E_j} \quad (2)$$

Where E_i is the energy of seismic wave in the apparent period, that is

$$E_i = \sum_{j=t}^{t+W_i} A_j^2 \quad (3)$$

Choosing two threshold C1 and C2, when F C1 and G C2, A_m is the first arrival. Usually C1, C2 is located within 1.3~3.0.

The second step of first arrival picking is using the parallel characteristic of the first arrival curves.(Figure 4). The first arrival curve of a shot point must be parallel with those of other shot points. So, the errors of individual points in first arrival picking can be eliminated by comparing with others.

2.2 Selection of sections in first arrivals for static calculation

The first arrival sections used to calculate statics should be the refraction waves which refracted by same velocity boundary. For many exploration areas the boundary is water table. But for some mountain areas the refraction boundary may be very complex. Sometimes there are many refraction boundaries and variation with place to place. So it is quite necessary to pay attention to choose the section in first arrivals those are refracted by a same boundary.

2.3 Thickness and velocity inversion

Thickness and velocity inversion of low velocity layer is applied as a main step for conventional refraction static correction techniques[1,2]. The thickness and velocity inversion are used for static (travel-time delay) calculation. But for the technique proposed in the paper, the step is just a supplementary one. Sometimes it is necessary for long spatial wavelength static computation and for improving the fit error of seismic events at intersections.

Usually two simplified models are used for our inversion. One is only thickness inversion in the condition of constant velocity and another is velocity inversion with same thickness of the low-velocity zone. Of course these two models are not able to represent the actual low-velocity layer. But the statics or travel-time delays through the models and the actual layer are equivalent.

2.4 Error decomposition and elimination

The step is a key step in the technique. As we know, more or less errors must exist in the static results of all kinds of techniques. We hope to reduce the errors. The idea to eliminate errors we used depends on the principle of maximum smoothness. It means that the first arrival curves must be those with maximum smoothness if the statics is the best.

Depending on the principle the statics computation formulas are obtained

$$\Delta t_i = \sum_{k=1}^{K} \left(g_i + u_i^{(k)} \right) \quad (4)$$

$$\Delta t_j = \sum_{k=1}^{K} \left(h_j + v_j^{(k)} \right) \quad (5)$$

Where Δt_i is static correction value for the $i-th$ shot point; Δt_j is static correction value for the $j-th$ receiver point; K is iteration number, and

$$g_i = \frac{1}{M} \sum_{j=1}^{M} g_{i,j}$$

$$h_j = \frac{1}{N} \sum_{i=1}^{N} h_{i,j}$$

$$h_{i,j} = g_{i,j} - g_i$$

$$u_i = \frac{1}{M} \sum_{j=1}^{M} u_{i,j}$$

$$u_{i,j} = h_{i,j} - h_i$$

$$v_j = \frac{1}{N} \sum_{i=1}^{N} v_{i,j}$$

$$v_{i,j} = u_{i,j} - u_i$$

Where N is total shot point number of the profile; M is total receiver point number; $g_{i,j}$ is field static correction value at j-th receiver of i-th shot point.

2.5 Calculating static correction values

Calculation of static correction values at all receivers and shot points are carried out by formula (4) and (5).

3. CHECK-UP AND APPRAISAL OF STATIC RESULTS

The computed static results can be checked and appraised by following three aspects

3.1 General speaking, the static correction values (or curves) of receiver and shot points should tend to be parallel with each other. And the curves should be correlated with topograph curve of the surface.

3.2 Usually without static corrections the first arrival curves of shot gathers are not smooth and negatively correlated with elevation of the surface (Figure 2). The same data processed with static corrections become smooth (Figure 3). Otherwise, sign and positions of the static values should be checked.

3.3 From the overall view of the figure composed by first arrival curves of all shot points before static corrections (Figure 4), we can see the values vary with elevation of the surface. The same Figure after static corrections become regular as a parallel quadrilateral in overall.

4. EXAMPLES

The statics technique proposed in the paper has been widely used for the processing of seismic data in China. Two examples are included. One is in a rugged loess plateau area, Northwest of China as shown in Figure 1. The other is Line MZ in a mountain area of Tarim basin, Northwest of China as shown in Figure 2 to Figure 9.

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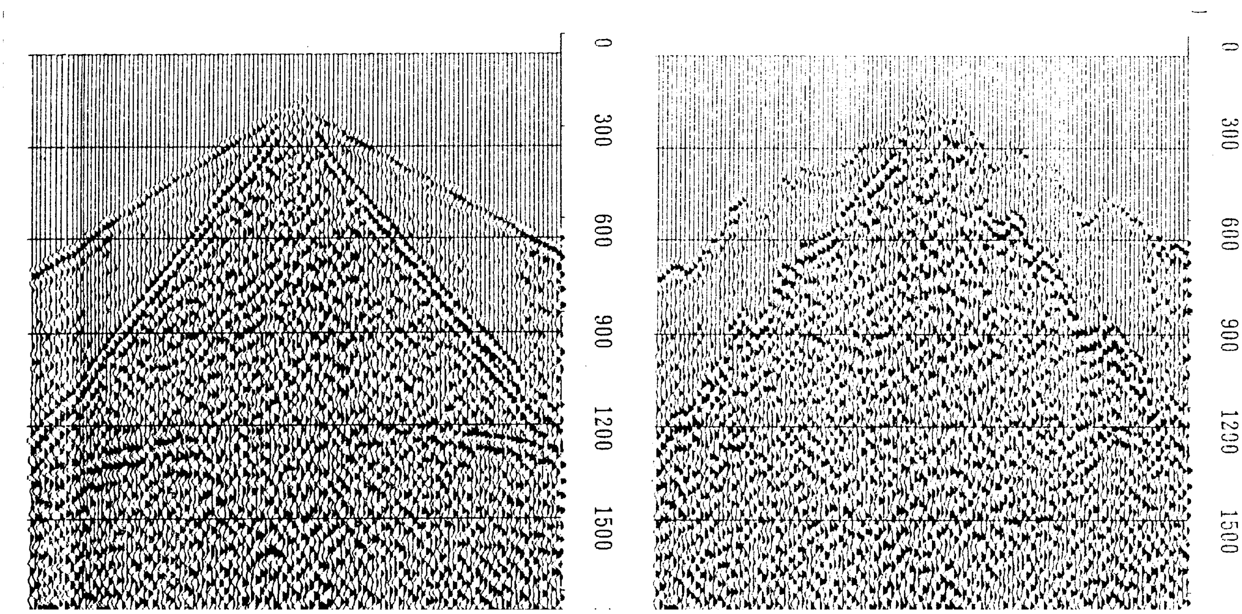
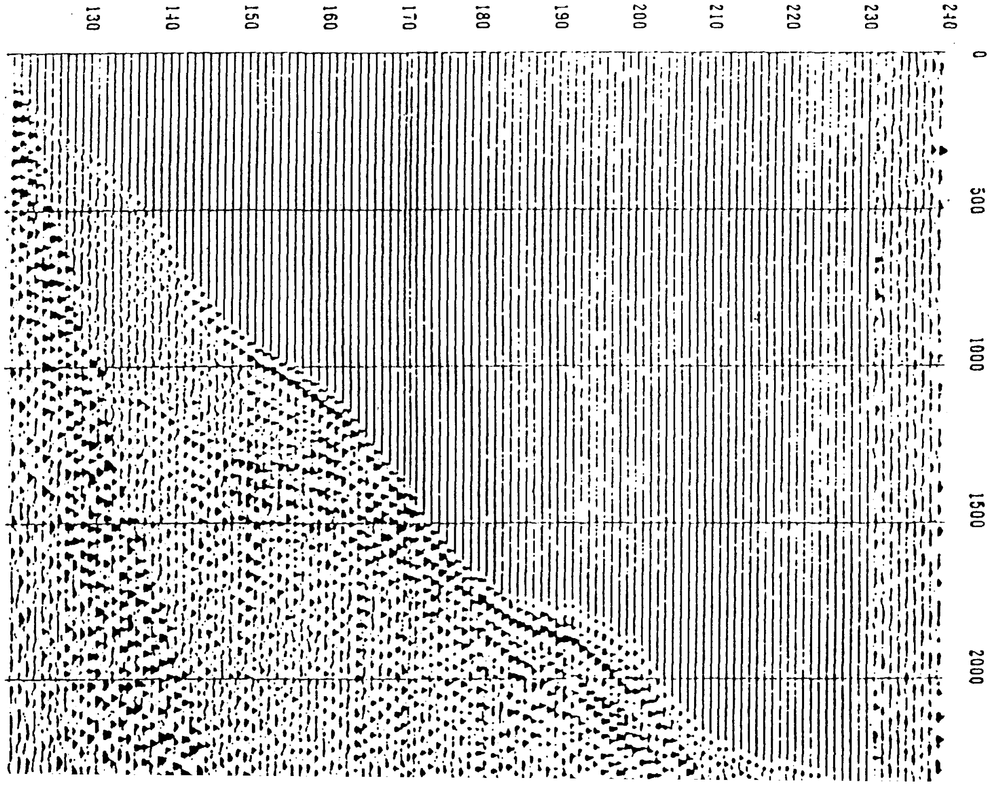


(b) (a)

Figure 1, A shot gather seismic data in a rugged loess plateau area, Northwest of China.

(a) field seismic data. (b) same data processed with static correction.



Figured 2. A field shot gather seismic data of line MZ in a mountain area of Tarim basin, Northwest of China.

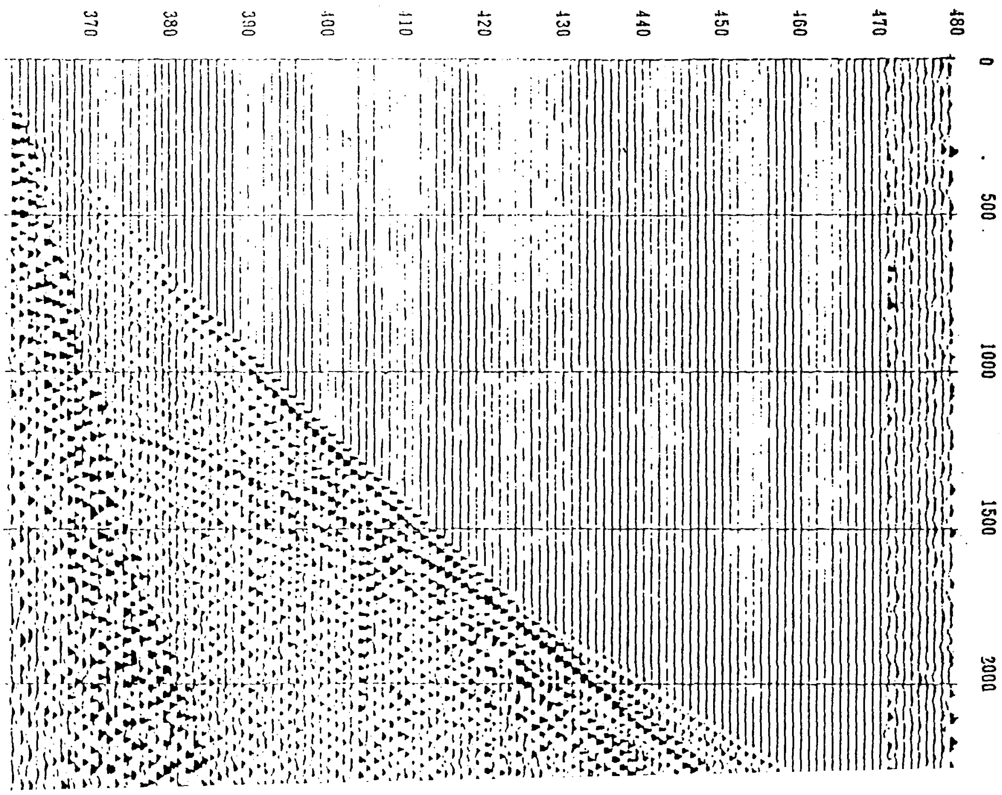


Figure 3. Same data of Figure 2 processed with static corrections.

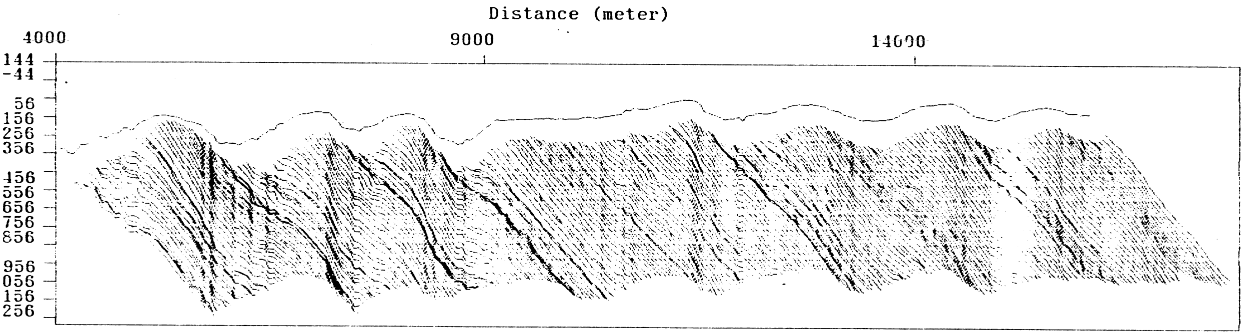


Figure 4. First arrival curves of part of shots in Line MZ, Tarim basin, Northwest of China,(In the top of first arrival curves there is a elevation curve, and the coridinate for curves is downword. So the elevation curve is reverse with actual topograph).

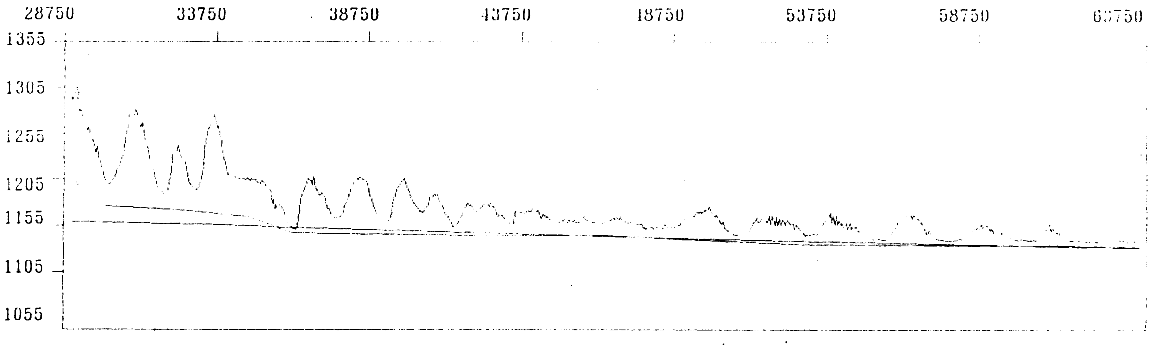


Figure 5. Elevation water table and floating datum of Line MZ, Tarim basin, Northwest of China.

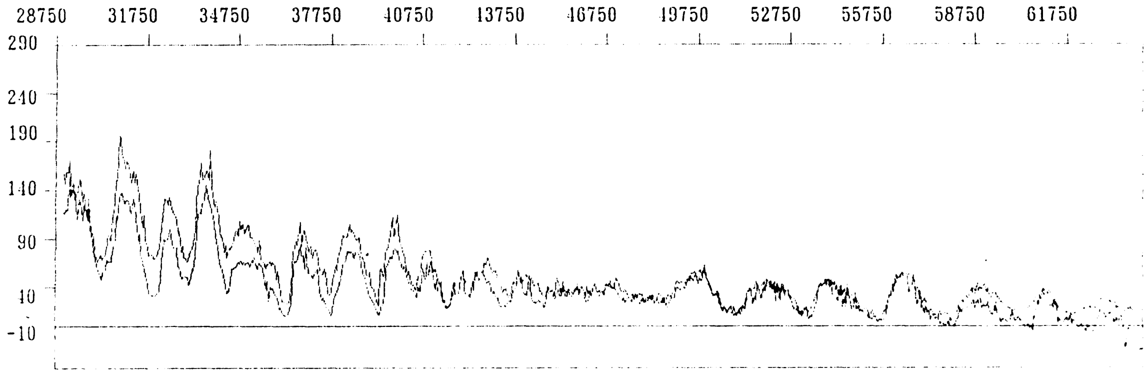


Figure 6. Static corrections of receiver and shot points of Line MZ, Tarim basin, Northwest of China.

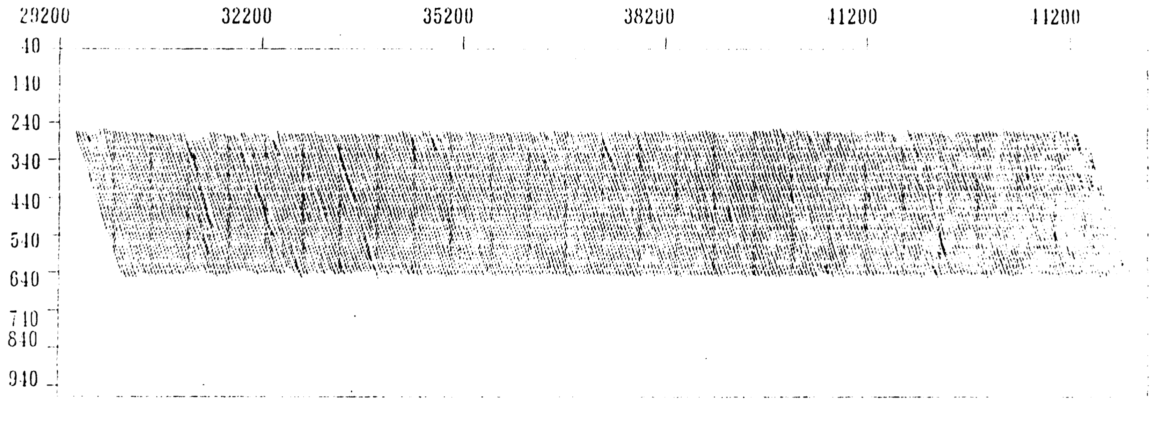


Figure 7. First arrival curves processed with static corrections of the same part of shots in Line MZ, Tarim basin, Northwest of China

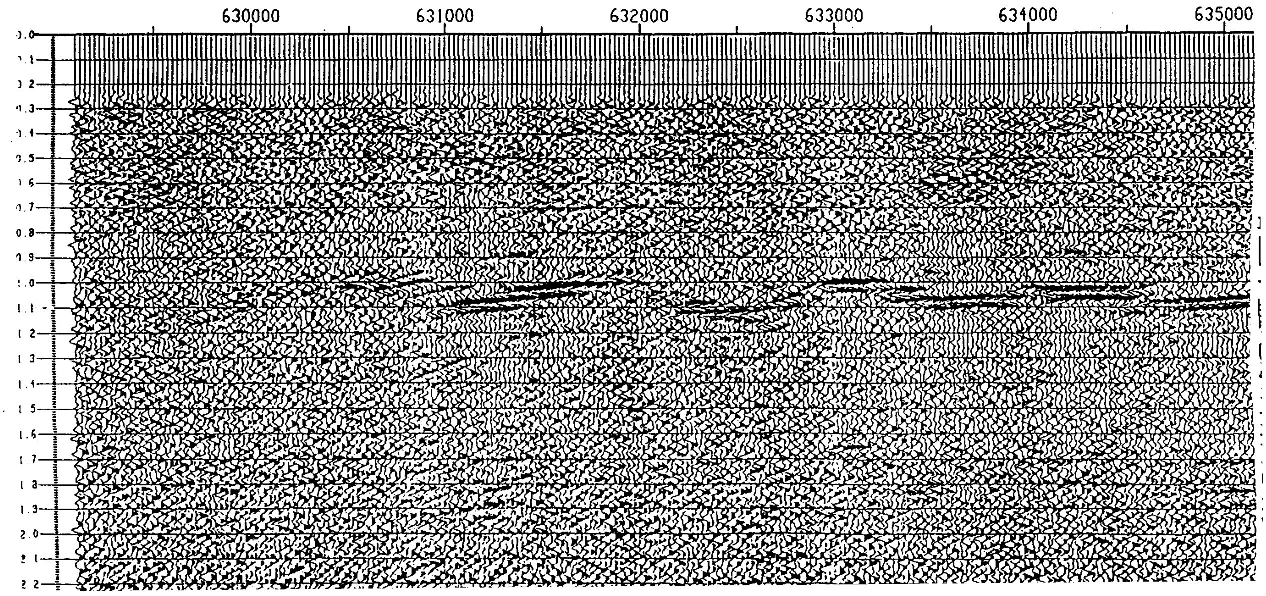


Figure 8. Part of preliminary stack seismic section of Line MZ processed with conventional static technique.

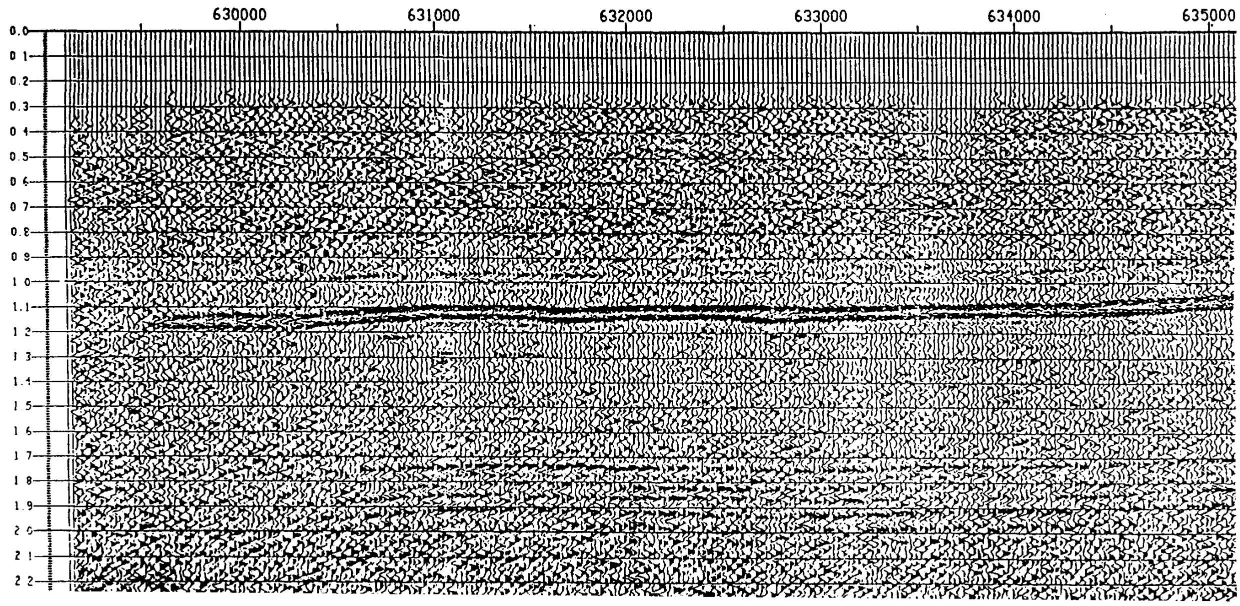


Figure 9. Same data of Figure 8 processed with static technique proposed in the paper.