# Flooding the Datum for Land Data with Rugged Acquisition Topography: A Case History in Himalayan Foothills

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## Summary

Flooding the datum overcomes some of the problems present in routine image processing while recording the seismic data on a rugged surface topography. The standard CDP processing algorithms assume that data are recorded on flat surface. The static correction applied routinely to compensate for topography assuming that wave propagation vertically down below and ray trace bending is minimum. The statics calculated with precision statics correction method which envisages stage wise computation of statics correction and its quality check at each stage and the statics applied to upward continue the data to a flat datum above the highest topography. This methodology was applied on 2D seismic data in over thrust area of Himalayan foothills. The image obtained after flooding the datum exhibits better reflector continuity and more accurately represents the true structural image.

## Introduction

Some of the last petroleum prospecting frontiers are in over thrust area where rugged topography and irregular data coverage poses significant processing challenges. The rugged terrain and complex structure makes drilling very expensive, and since there is often little well control or a priory velocity information, it is critical to lower the risk by extracting as much information out of seismic data and provide the best possible sub surface image. Even when good quality of data are recorded in these terrain, processing challenges that arises because of the topography, the presence of high velocity rocks near the surface and complex sub surface velocity can impede conventional processing and subsequent interpretation.

In recent years several advances have been made, not the least of which has been improved the acquisition technology. Increased shot hole depths, shot charge, large offset and enhanced fold, go a long way towards enhancing the data quality. The data processing is generally consisted of early stage of filtering and suppression of noise followed by iterations of statics shift and preliminary velocity information. The final out put datum is selected at an arbitrary flat datum above the highest topography or mean sea level (MSL) depending upon extent of elevation of the area. Field statics are often used to compensate for weathering layer and replacement velocity to correct the data to final flat datum or MSL. Advances in computer technology made great impact in Geophysical industry due to which, computer intensive algorithms have been introduced in seismic data processing. However, these algorithms may not yield good image of the subsurface until and unless the basic data like datum static correction and field geometry are properly incorporated in processing sequence. Many new algorithms presume that near surface irregularities are minimum, whereas in complex geological conditions it is rarely the case. It is a general tendency to view that static corrections are purely an array of numbers with no geological significance. Elevations, weathered layer velocities and rapid variations in near surface layers associated with geological complexity are some of the important factors, which are having bearing on static correction variations. Physical properties of weathered layer in both horizontal and vertical directions are to be taken into consideration while computing static corrections. In fold belt areas the weathered layer itself may be very thin whereas the various rock units beneath the weathered layer may have velocities similar to or appreciably different from one another. The concept of static correction, with its assumption of vertical ray path in near surface layers is likely to be very poor approximation in mountain front topography as per Mike Cox (1999).

The distortion of the raw shot gathers caused by topography and near surface effects can be divided into two components; a high frequency jitter and a low frequency component associated with the topography. The high frequency component can result from local velocity variations, surveying error or any other effects that often plague land data. Flooding the datum and precision statics corrections are intended to remove the long wavelength effect of topography. The high frequency statics degrade the datuming result, if they are not removed. To compensate for high frequency component, surface consistent residual statics programme are used.

The precision static correction process involves different stages particularly in complex geological and undulated areas. The first breaks of a common shot gather are non linear in undulated topographical area (Fig 1a.) without the application of static corrections. After application of Low Velocity Layer (LVL) correction, the shot and receivers are supposed to be on top of high velocity layer and the first break of this Low Velocity Layer corrected common shot point gathers will be linear. The effect of vertical component of LVL velocity will be removed in the process and the first breaks will have effect of horizontal component of high velocity layer, which will be linear in nature (Fig 1b.). In the first stage in static correction computations, the weathered layer (LVL) is removed so that the base of weathered layer becomes the new datum to which surface referenced times are adjusted to give a new set of times which would have been observed if the data had been recorded at top of high velocity layer. The second stage is to adjust the data in a similar manner to simulate data recorded

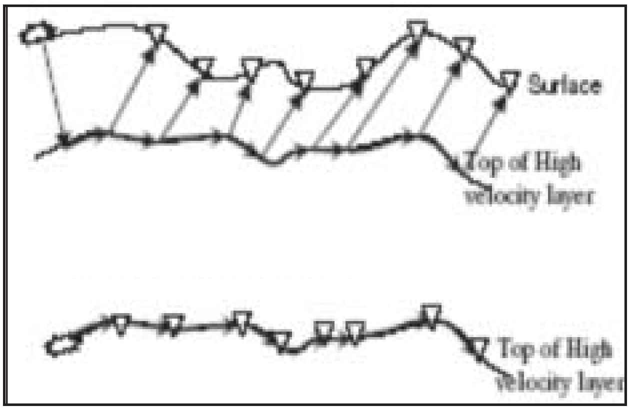


**Fig. 1** : Application of LVL correction

at another surface. Further, the static corrections are applied to brought the data at final datum above the topography in third stage. It has been observed in present study that the distortion caused by the topography can be eliminated more effectively by upward continuation of the data to an arbitrary flat datum above the highest topography in comparison to bringing data to downward at a flat datum or MSL. This is analogous to upward continuation of the marine data from the water bottom back to the original acquisition surface in marine layer replacement application. The proper velocity to use for upward continuation should be close to the near surface velocity. The choice of velocity is made through iterations so that excess ray bending is not introduced by the datuming process. Since near surface velocity often varies along a seismic line, the datuming velocity is generally variable, however, this velocity is optimized by iterative methods. Once the data have been continued upward to a higher datum, conventional velocity analysis can be performed along with other processing sequences of stacking and migration etc. This paper deals with methodology and its application in Himalayan foot hills.

## Methodology

Feng Zeyuan et al, BGP, CNPC came out with a methodology for calculation of static correction stepwise. In his method static correction process is divided into three parts viz LVL static corrections, intermediate reference datum corrections and uniform datum corrections. Taking a lead from this method a methodology was developed by us to calculate the precision statics. The calculation of statics is carried out in three phases with appropriate quality checks at each step ( Fig 2.). After building of near surface model with help of UH survey & SR survey, the LVL statics are calculated. Quality check was carried out after application of LVL statics by examining the alignment of first breaks and convergence of common offset gather. The alignment of first breaks represents the precision of LVL static correction.

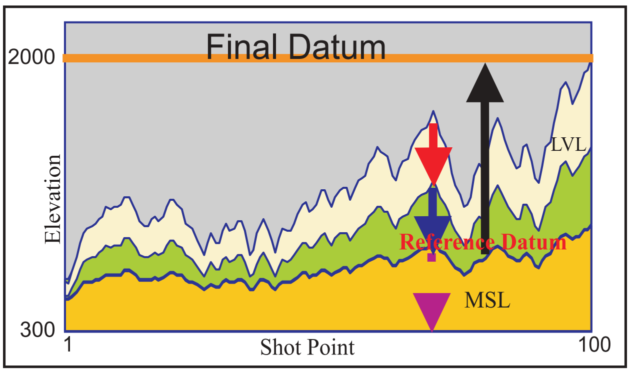


**Fig. 2** : LVL, Refrence Datum & MSL for static correction

After completing stage I, statics are calculated up to intermediate reference datum in stage II with the help of sub weathering velocities obtained through up hole and shallow refraction surveys. The intermediate reference datum statics is the correction between LVL and intermediate reference datum. The intermediate reference datum is selected by considering the depth up to which up hole survey was carried out and shot hole depth and in present case study the depth of datum has been selected 40 meters from surface along entire line i.e. up to maximum depth up to which near surface information is reliably available from shallow refraction or Up hole survey. QC is carried out by examining the stacked section obtained after applying static correction up to intermediate reference datum. In case the stack section is not improved by stage II, Vsw is varied with 200 meters/ sec interval from lowest sub weathering velocity to highest sub weathering velocity along that profile iteratively till we get best stack.

In the 3rd stage statics are calculated up to final flat datum i.e. 500 mts above the MSL and finally at a flat datum above the highest topography. The velocity of the medium between intermediate reference datum and final datum is selected in an iterative way controlled by quality checks. A velocity range ( say 2500-5500 m/sec) is tested with increment of 250 m/sec from lower velocity to high velocity. The velocities which give best stack in a particular portion of profile are the final replacement velocity for that sector. The QC is carried out on stack section after application of final statics up to final flat datum. The details of methodology is given in the paper by authors (A.K. Srivastav et. al.) presented in CGT-2005. However this methodology is not bringing the shallow reflections which are shallower to mean sea level. This is mainly in areas where topographic undulations vary from 500 meters to 2000 meters. To address this problem, the data was brought to a final datum above the top of topography by flooding the datum by a suitable replacement velocity obtained through iteration process (Fig. 2).

## Application

The area under study falls in Himalayan Foothills.Geological map of the area (fig.3) depicts the gross geological feature of the area. The stratigraphy of a well in area, showing thicknesses of different formations is also given in Fig. 4. Main Boundary Thrust (MBT ) has divided the block in two parts . The area NE of MBT which comprises of the outcrops of Pre-Tertiary rocks of Shali, Krol, Infrakrol and Jutogh group of rocks and also known as Lesser Himalaya while the area South and south-west to the MBT is known as Outer Himalaya or Himalayan Foothills, where mainly Siwaliks (early Pliocene to middle miocene), Dharamsala (early Miocene to Oligocene) and Subathu (late Paleocene to middle Eocene) group of rocks are present except few slices of Tunda Pathhar/Sataun / Bilaspur limestone (late Proterozic) coming up with the Bilaspur thrust. The area between Bilsapur thrust and MBT has many thrust sheets overlapping like roof tiles all dipping in the same direction (towards hinterland). Geological cross section (Fig.5 ) shows the thrust pattern in the area. This structural set up has shortened and thickened the Bilaspur and Surajpur units. Most of the thrust at surface are of high to very high dip ( 40-80$^0$ ). Lower Dharamsala and Subathu Formation (Source rock) are the main outcrops in their hanging walls.

The area under study lies between Main Boundary Thrust and Bilashpur Thrust. The geological section (Fig.5) shows many overlapping thrust in same direction. The earlier processed sections, where conventional statics corrections were applied, are not exhibiting the subsurface image clearly, however the processed sections with new precision statics correction method has brought out an accurate structural sub surface features and interpretable also. It was observed that the shallow reflections are missing due to processing these sections at a flat datum 500 mts above the MSL. The processed section with precision statics shows appreciable improvement over earlier processed section with conventional method. However to improve upon this section, the same data was subjected with flooding the datum by bringing data first downward up to reference datum and finally up at a flat datum above the topography by replacement velocity obtained through iteration process. The result of processing the same data from top of topography shows meaningful delineations of sub surface images in shallower portion of the sections in comparison to earlier processed section.

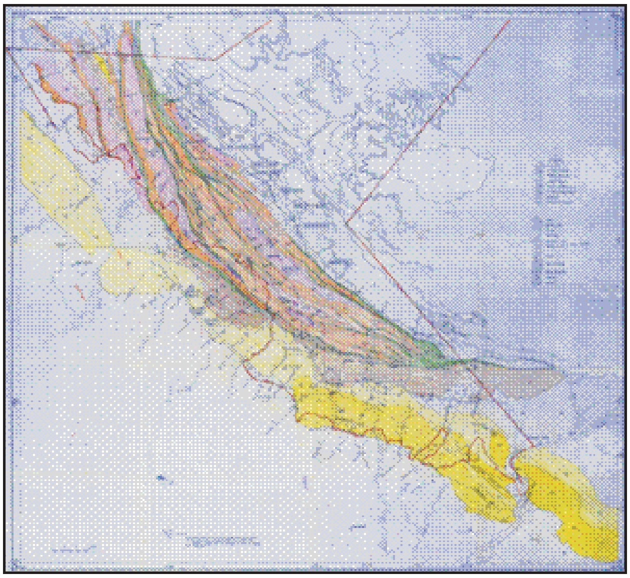

**Fig. 3** : Geological Map of Himalayan Foothills

## Conclusion

The two seismic lines of the Himalayan foothills area, which were acquired with 60 fold, 25 meters GI, and 240 nos. of active channels and 6000 meters offsets, are reprocessed with new methodology.

The earlier processed section (Fig.6 & Fig.8) with conventional method is giving a poor subsurface image and structural trends are not distinctive. The same data processed

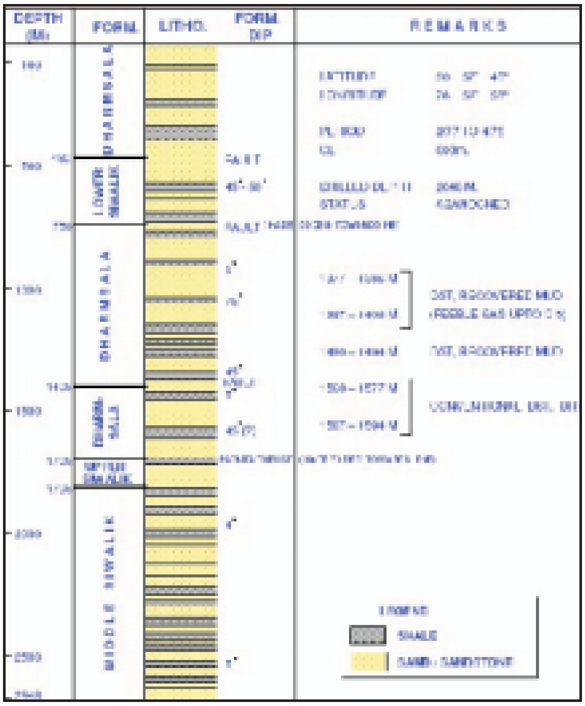


**Fig. 4** : Stratigraphy of a well

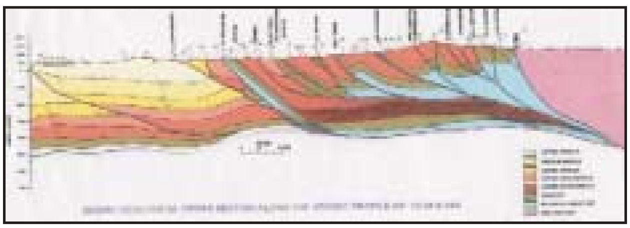

**Fig.5** : Seismo Geological cross section along a seismic profile

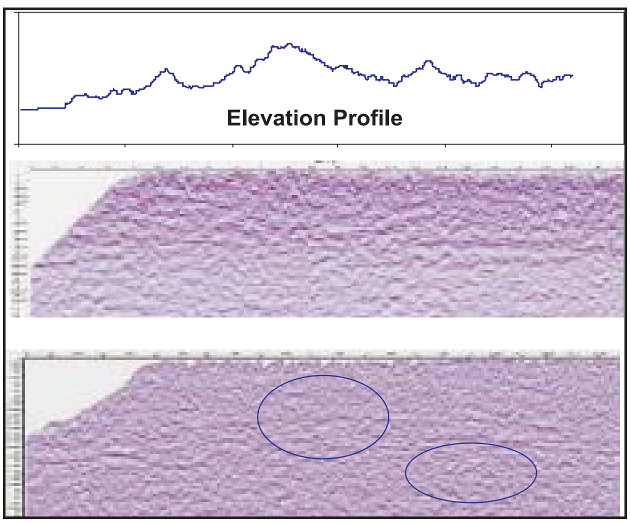


**Fig.6** conventionally processed section and
**Fig.7** processed with precision statics correction along with elevation profile at top.

with precision statics correction method show a remarkable improvement and delineates structural trends clearly (Fig.7 & Fig.9). The both sections were processed at a flat datum 500 mts above the MSL however the maximum elevation of the profile is 1650 mts. Thus a considerable data is being lost by bringing the data to a lower datum. After analyzing the processed section with new methodology it was felt that some more improvement in shallower level will provide a better confidence to interpreter. Again the same data was subjected to flooding the datum above the top of the topography to avoid any loss of data at shallower level and processed section has brought out appreciable improvement in the shallower reflections and sub surface images (Fig. 10 to Fig 15). The seismic sections processed by the precision statics method (Fig. 10) and flooding the datum up to a flat datum above the top of topography (Fig. 11) show the thrust pattern up to surface and some back scattered reflection which may be useful for delineation of fault patterns in the area. Similarly, in another profile, the processed section by the precision statics method (Fig. 12) and flooding the datum up to a flat datum above the top of topography (Fig. 13) show better delineation of structural pattern and thrust plane, a comparison for other portion of the same profile has been shown in (Fig. 14 & 15), the seismic section processed by the flooding the datum up to a flat datum above the top of topography (Fig. 15) show more number of reflection sequences and shallow thrust.

The seismic data acquisition on a rough terrain is always a challenging job. Even when a good quality of data is recorded on these surfaces, it may not yield good subsurface images due to an undulated topography. The same data, when subjected to precision statics correction method and flooding the datum up to top of the topography, yields a better and accurate subsurface image. This method gives an impetus to change the processing procedures to a great extent particularly for applying the statics correction. It can be applied to old data where data quality is very good to extract as much as possible from these data for deriving the geological model with greater confidence.

## Acknowledgements

Authors are grateful to Oil and Natural Gas Corporation Limited, India for providing the necessary facilities to carry out this work and giving permission to publish this paper. The authors express their hearty gratitude to Sh G.Sarvesam, GM-HGS for his valuable guidance to carry out this work. Authors express their gratitude to Sh. D.K.Pande, ED (Exploration) for encouraging us to carry out this work. The authors also express their gratitude to Sh.

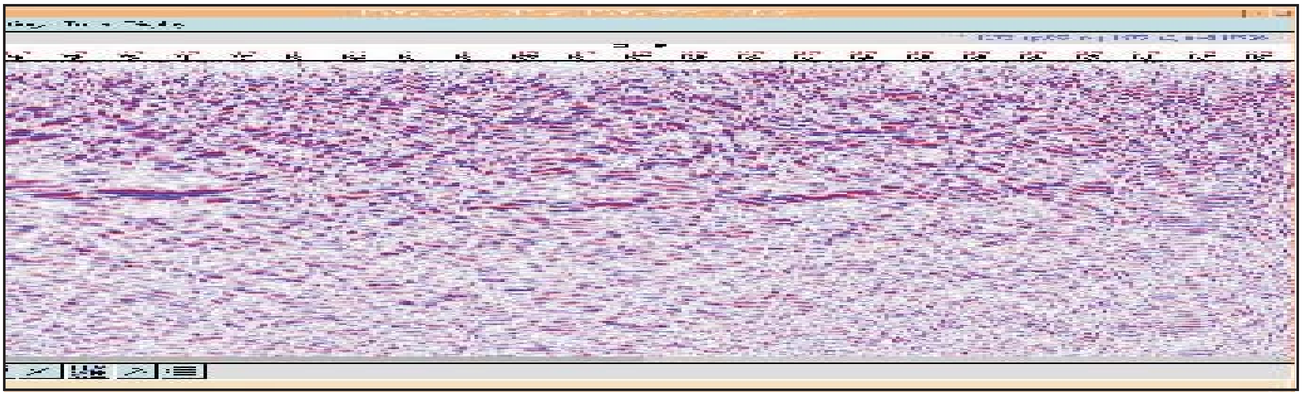

**Fig.8** : conventionally processed section

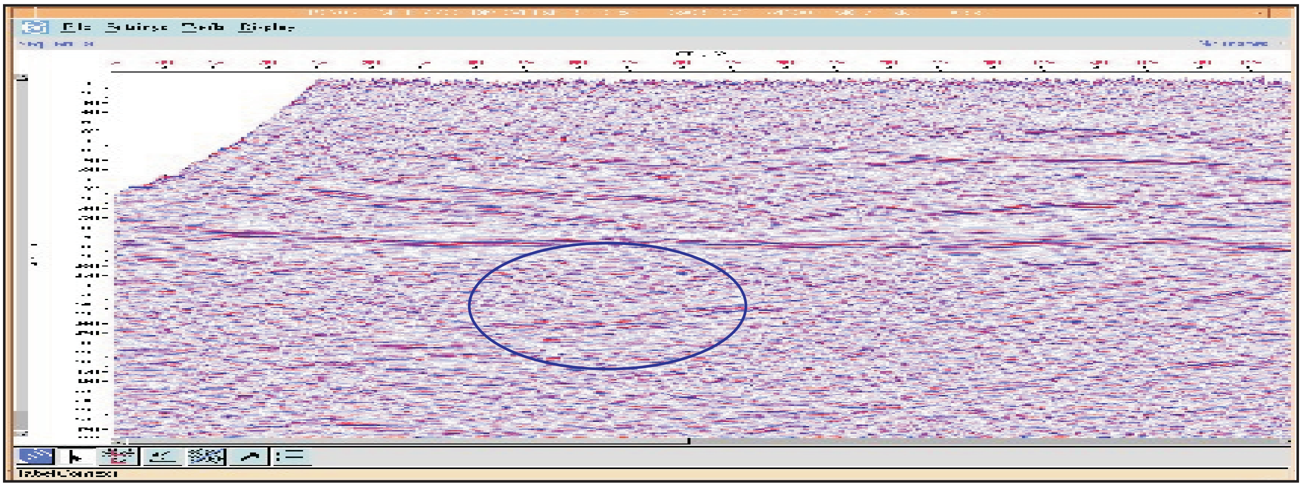

**Fig.9** processed with precision statics correction along with elevation profile at top

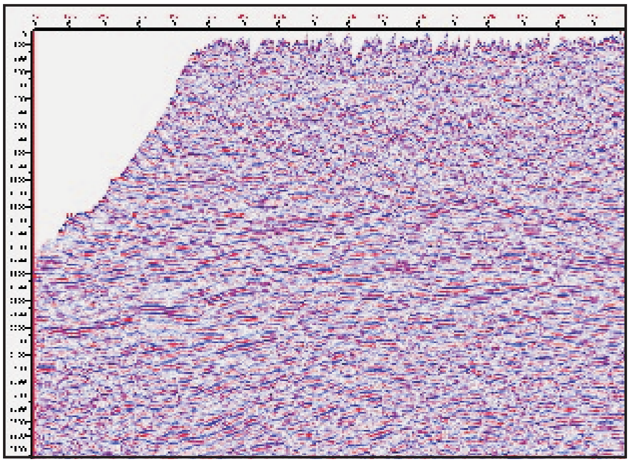

**Fig.10** processed at the MSL

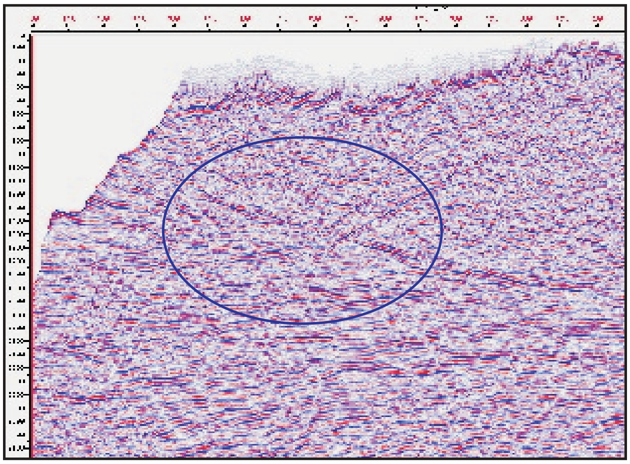

**Fig.11** processed at the top of topography

A. Saha, ED for suggesting this work and Sh. D.P.Sahsrabuddhe, GGM-BM, A&AA Basin giving valuable suggestions for this work. The authors are also grateful to Dr. D.V.R.Murti, DGM (GP) for analyzing the work and providing us facility at RCC.

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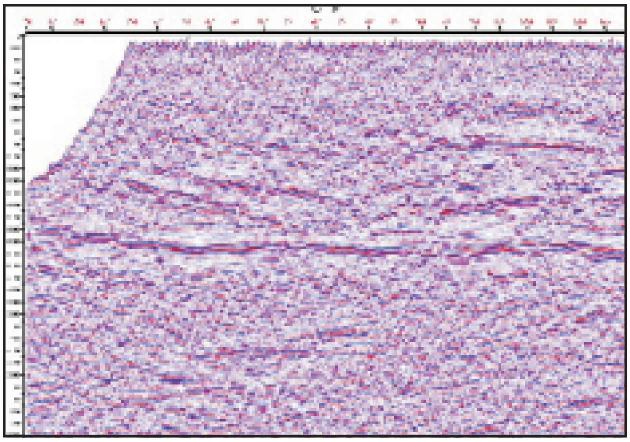

**Fig.12 :** processed at the MSL

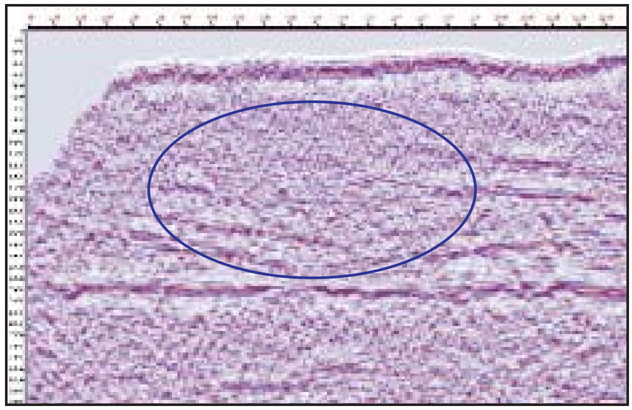

**Fig.13**: processed at the top of topography

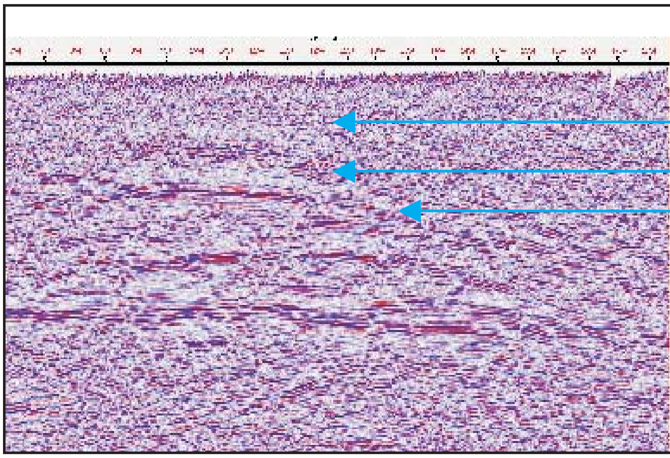

**Fig.14 :** processed at the MSL.

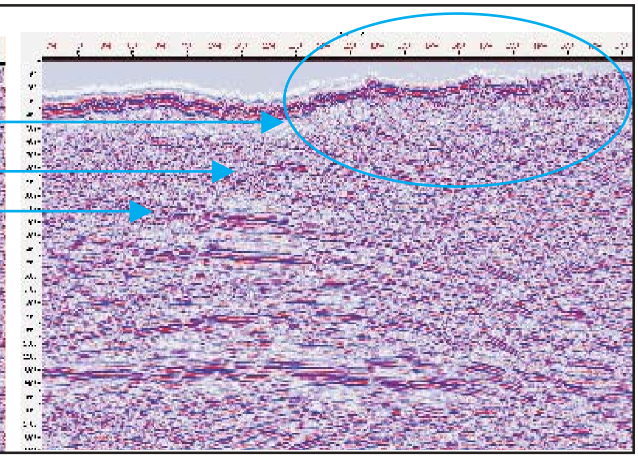

**Fig.15** processed at the top of topography

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