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Significance of Statics and Noise Attenuation in Low S/N scenario - A Case Study from NE part of India

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Summary

Thrust belt seismic data from NE part of India has always been constrained by topography, near surface heterogeneity and energy penetration issues. Out of these, shallow sub surface complexity and topographical variation have direct impact on the alignment of reflection events and frequency content of the stacked sections. Seismic data from Naga thrust area posse strong challenges such as statics correction, noise elimination and velocity estimation to the processing geophysicists. An effort has been made in this paper to improve the S/N ratio to produce geologically conformable image of the subsurface. This paper delves on the processing strategy employed. The processing efforts were challenged by the scarce geological information available for the area. Meticulous analysis of the dataset and application of fit for purpose noise attenuation algorithm, better static & residual static solutions and CVS velocity picking helped in realizing the objective of seismic imaging in the area.

Keywords: *Thrust, subsurface, Shot, Energy, Groundrolls, Guided Waves, CVS, Stack*

Introduction

Hydrocarbon entrapment in the naga schupen belt and Assam-Arakan fold belt is strongly structurally controlled. A series of discoveries have been made along the naga thrust belt and thus proves the high prospectivity of the area (Figure 1). 2D seismic data of Split spread geometry was acquired at one of such area in the north Cachar hills of Assam bordering Nagaland at west in the vicinity of Naga thrust. Seismic survey over the area was heavily limited by logistic challenges including rugged topography, bamboo bushes and wind, apart from the issues of energy penetration due to overlying boulder beds and outcropped hard rock surface at most of the places, all these leading to poor S/N ratio in the data.

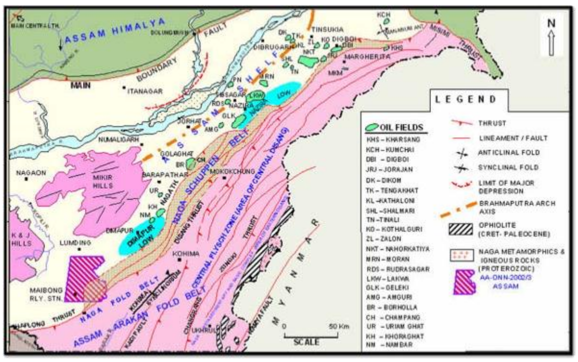

Figure 1. Location of the study area and its closeness to the oil fields discovered along the Naga thrust.

Noise contamination of the data was strong due to surface and subsurface related problems. Primary objective of processing the data was to align coherent events through better static computation, apply good noise attenuation solution to enhance the S/N ratio and increase frequency content of the stacked section through close grid velocity analysis and residual statics. QC plots and displays were extensively used to judge the effectiveness of each algorithm on the dataset.

Geology of the Area

The block area is covered by outcrops of Tertiary sedimentary rocks and characterized by the presence of NE-SW trending thrust fault at its southern part. A notable structural feature present in the block is that the Naga and the Disang thrusts merging into one about 15 km southeast of Maibong Railway station and then runs towards southwest as the Haflong thrust. From Haflong, the fault runs westward as the Dauki fault (Figure 2).

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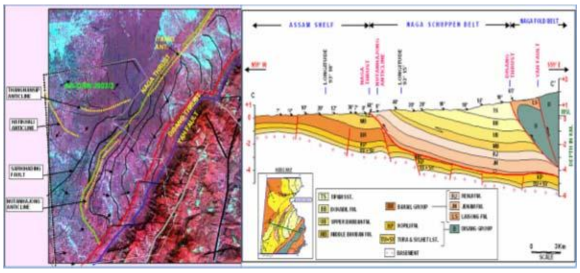

Figure 2. Satellite imagery and cross section through the study area showing major tectonic elements.

These behaviours of the structural elements have been responsible for the occurrence of outcrops of shelf and geosynclinal facies very close to one another in the southwestern part of the block and in Haflong area. A tentative cross-section of south-western part of the block shows the sub-thrust configuration. There are three exposed anticlines, of which two, namely, the Hatikhali and Thangnangsip anticlines occur within the Upper Assam shelf part of the block and one, namely, the Nutan Hajong anticline occurs in the Naga Schuppen part of the block, grazing the Naga thrust.

Processing strategy

Analysis of shot records and brute stacks indicate strong contamination of coherent & random noise and problem of alignment due to sever statics issues. Near surface velocity model generated using uphole survey also indicates lateral variation in near surface velocity. Following are the main challenges which were of prime importance.

- Abrupt variation in topography and lateral velocity.

- Surface related noise- Guided waves and dispersive groundrolls

- Random noise- Noise due to cultural activity and wind.

Considering the noise prevalent on the shot records & in general poor energy penetration first and foremost objective of this study was to improve the S/N ratio specifically for structural imaging only. Extensive testing and quality control were exercised to reduce the processing artifacts which may get induced during the course of processing and harm the basic character of the dataset. Key steps employed in the processing sequence are as follows.

- Aligning coherent events for better cancellation through statics.
- Removal of coherent noise using combination of filters to enhance S/N ratio.
- Iterative velocity estimation using CVS and interactive velocity analysis and residual statics to improve quality.

Navigation, First Break QC & Near surface Velocity Model Building

Seismic data and navigation information was rigorously checked, merged and analyzed thoroughly to identify shots and receivers having issues in positioning and labeling. First break based source positioning and LMO analysis was carried out to graphically QC the geometry merged seismic data (Figure 3).

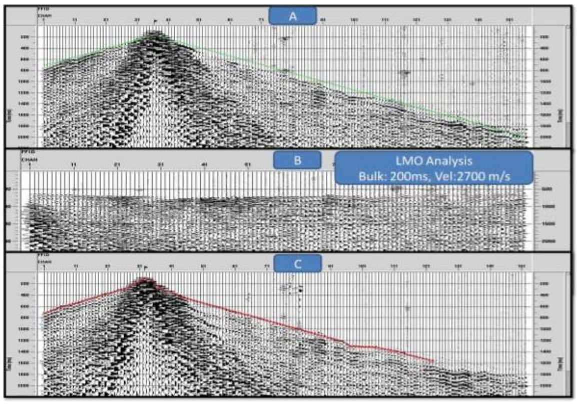

Figure 3. Graphical QC of shot records based on offset LMO and FB picks.

Moreover, QC of first breaks picked over the shot records were done to remove the outliers. Information from Uphole survey acquired along the 2D lines was compiled to generate the near surface Velocity variation map of the area (Figure 4). Consequently the data was mildly filtered and a velocity analysis of 1Km grid was carried out over the line. This brute velocity was used for stacking the gathers to test three different kind of statics correction. Following are the types of statics computed and compared to see their effectiveness over the study area.

- Elevation statics using uphole times recorded during shooting.
- Elevation statics using Velocity depth model of the near surface derived from Uphole survey.

- Offset optimized refraction statics using Velocity depth model of the near subsurface derived from Uphole survey.

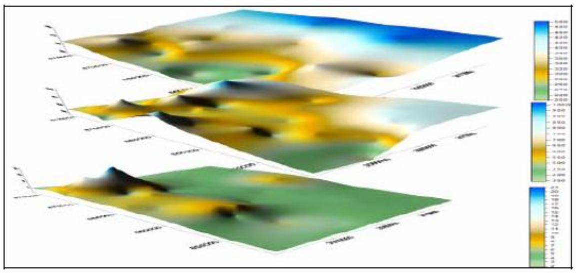

Figure 4, Variation of Elevation (Top), V_0 (Middle) and Z_1(bottom) over the study area.

Random/surface related noise attenuation

Spectral analysis of seismic data indicates the dominant surface related noise to be of 11 Hz with ground rolls dispersing with variable velocity. An FK based surface wave noise attenuation was tested on the data for frequency range below 14 Hz and velocity from 180m/s to 700 m/s. SWNA was found to be effective in addressing this issue. Spiking Deconvolution with mild pre-whitening was found giving good result.

Elevation statics using uphole times recorded during shooting

Shot hole depth and uphole times recorded while shooting were used to compute the elevation statics (Figure 5). Statics values ranges from 10 ms to -58ms.

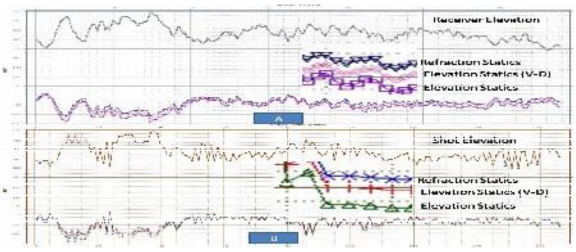

Figure 5. Comparison of Elevation statics using uphole times, Elevation statics using V-D model and Refraction statics using V-D model derived from uphole survey. Figure 5A is comparison of shot statics where as figure 5B is for receiver statics.

It can be observed from Figure 6 that elevation statics is not effective for the dataset. Reflection events could hardly be seen on the stack section and the appearance is chaotic with lot of random low frequency energy scattered at place of the stack section. This randomness is primarily attributed to the non-alignment of events resulting into destructive interference between the wavelets.

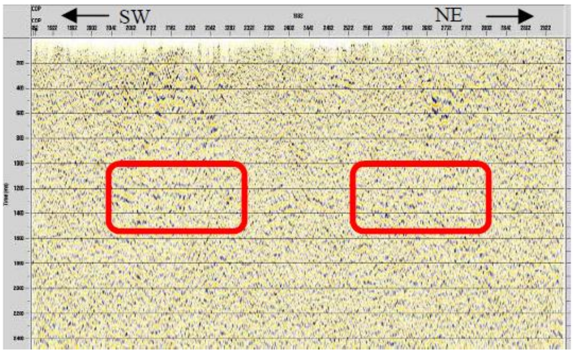

Figure 6. Stack generated using elevation statics, 1KM interval velocity and mild noise removal. Red polygon indicates stacking of reflection energy but the strength and alignment is low.

Elevation statics using V-D model from Uphole survey

A moderate amount of alignment is observed in the stack section as depicted in Figure 7, however the overall strength of the reflector remains less, indicating scope for improvement. Assuming that shot hole depth values are perfect it can be concluded that uphole times are not effective in representing the shallow subsurface.

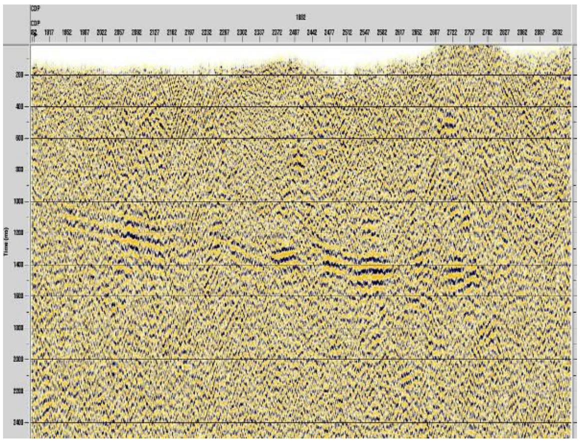

Figure 7. Stack with elevation statics using V-D model, noise attenuation and 100m interval velocity analysis.

Improvement in the stack section with the use of V-D model in statics calculation can be observed.

Offset optimized refraction statics using V-D model from Uphole survey

V_0 and refractor offset. The near offset traces were discarded as they represent the direct arrivals. Moreover, first breaks having multiple refractors also complicate the refraction statics solution. Therefore, the refractor offset and V0 were perturbed to compute static solutions. These perturbations were bounded within the limits of the near surface velocity model derived from uphole survey. Figure 8 shows the difference of application of noise attenuation and statics correction on the data.It can be observed from Figure 9 that refraction statics solution using V-D model derived from uphole survey gives much better result than the other two schemes employed.

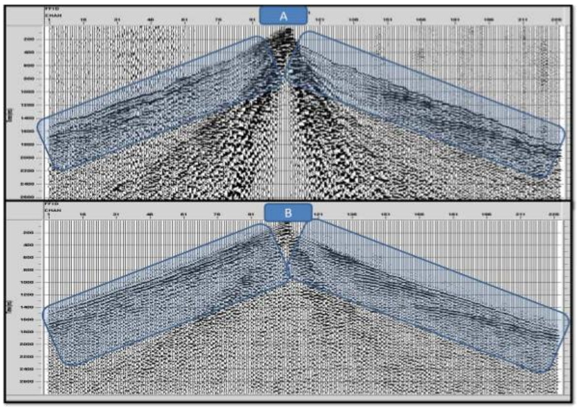

Figure 8. Figure 8(A) is shot with elevation statics and 8(B) is shot with refraction statics and noise attenuation. Effectiveness of noise attenuation and static correction can be observed over the highlighted portion.

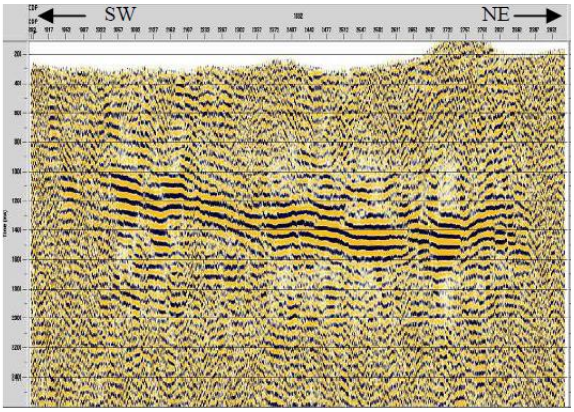

Figure 9. Stack with refraction statics using V-D model and offset optimization. Strong alignment can be observed due to application of proper statics, velocity and noise attenuation.

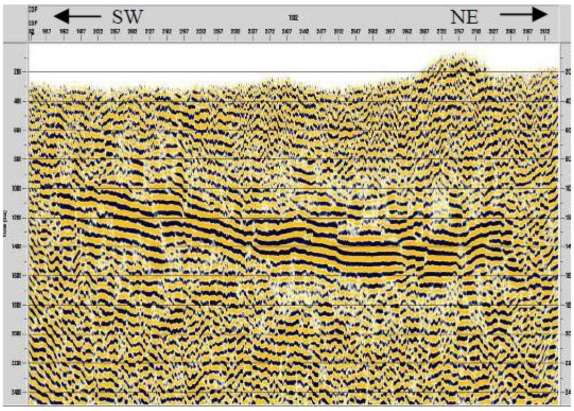

Figure 10. Further improvement can be observed after migrating the data. Close interval velocity analysis and QC of velocity using migration velocity analysis scheme is the key to improve the section.

Stacking velocity estimation and residual statics computation.

Geologically complex area necessitate specific attention in estimation and application of static solutions, coherence of velocity panels can be improved if the same are accounted for appropriately. After optimization of the static solution the next focus was to estimate the stacking velocity which results in the best stack response. An iterative approach was adopted to strengthen the estimation of velocity and residual statics. CVS based velocity analysis was found to be very effective in this case. A broad velocity range from 1700 m/s to 6000m/s with stepping of 20ms was selected to identify subtle changes in the geometry of the reflector due to minor velocity change. To map the lateral variation in velocity, velocity analysis was performed every 100 m interval. With every iteration of static correction and velocity analysis, QC migration was run to see its effects on the data. An iterative approach of velocity picking and residual statics was taken to improve the stack. Residual statics algorithms were tested on the data and maximum-power based statics algorithm was found to be giving good results.

Results

Judicious picking of first break, optimization of V0 and refractor offset improved the residual statics solution. It can be observed from Figure 8 that proper accounting of statics enabled significant improvement in the alignment of gathers which was not possible with elevation or uphole statics. Moreover, attenuation of coherent noise using FK for dispersive ground rolls and Tau-p for guided waves improved the S/N ratio thus improved confidence in structural mapping. Iterative velocity estimation and residual statics improved the frequency content of the signal. Alignment of reflectors improved with every iteration of velocity and residual statics. Finer velocity analysis helped to capture subtle variation in geometry of the reflectors.

Conclusions

Imaging in thrust belt area will always pose significant challenges to the processor; however effective planning and implementation of acquisition design along with the use of advanced processing technique can result in faithful reconstruction of the subsurface. The importance of statics solution and optimization of the same for thrust belt data is once again re-established in the case study presented herewith. Application of latest seismic processing techniques which can take care of lateral variation in the characteristic of surface related noise will generate superior results.

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