Quality Control of Residual Statics on an Interactive Processing System

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Summary

Residual statics usually are discussed in terms of applications to land data. It has produced dramatic improvement in fold belt area where terrains have rapid variations in elevation. However residual statics have provided satisfactory results in irregular sea-floor in shallow waters and areas with rapidly varying velocity in the sediments near the water bottom. In complex near surface setup where single pass of residual statics falls short of expectations the processor is tempted to apply multiple passes of the same to ameliorate the stack response. Application of repetitive passes of residual statics rakes up a few queries like amenability of the seismic data towards residual statics, adequacy of number of passes and the benchmark to be achieved as far as residual statics' quality control is concerned. These observables are qualitatively assessed by the processor most of the time before graduating to subsequent processing stage. In the backdrop of these genuine queries in mind a program "Residual Statics Quality Control (RSQC) " has been developed by authors to provide tangible parameters in this respect. The discussions impart some insight into the overall development of quality control measures in residual statics.

Introduction

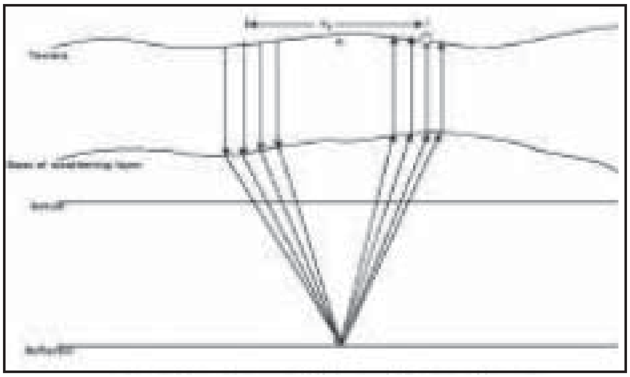
Reflection times often are disturbed by irregularities in the near surface. Although such travel time disturbances can be caused by structural complexity beneath the surface more often they result from near surface irregularities. Application of field statics corrects to a large extent such travel time distortions in the seismic data. These corrections still fall short of adequate compensation in terms of static corrections due to rapid changes in elevation, the base of weathered layer and weathering velocity. It puts onus on picture perfect Near Surface Model (NSM) and static shift accounting for it. Static shifts from an ideal hyperbolic travel time trajectory is not very uncommon in seismic gathers. After NMO correction is applied the misalignment of the waveform across the CDP gather results into a poor quality of stack. The immediate need is to estimate time shifts from the time of an ideal alignment then compensate for time shifts by using automatic picking . It requires a model for the move out corrected travel time from the source station to a depth point on a reflector then back to receiver station. The model adopted here assumes that the static shifts are dependent on source and receiver locations not on travel ray- paths in the subsurface. This assumption holds well if all ray-paths irrespective of source receiver offset are vertical in near surface layers. As the weathered layer near surface has low velocity and refraction at its base making ray-paths vertical, the surface consistent assumption usually yields reasonably good results. The assumption may not hold any longer for a high velocity permafrost layer which has a tendency to bend the wave away from the vertical.

In some areas where S/N ratio is poor, multiple passes of residual statics are usually run to correct the static shifts. The basis of the idea is that the previous pass of the residual static correction improves the signal to such a level that the subsequent pass should remove the remaining residuals. Of course velocity analysis intervening two passes of residual statics will help revalidate the subsurface geology of the area in-turn accurate time picking in the subsequent residual static pass. While working on IBM-RS6000/SP-3 loaded with Geovecteur software, the authors came across a few wrangles of residual statics which raked up a set of salient points (i) adequacy of number of passes to be applied to achieve reasonably good residual static correction (ii) amenability of seismic data set to be put up to the rigor of residual statics (iii) achievability of a level of residual static application (iv) diagnostic of large static correctio n. The authors wrote a program "Residual Static Quality Control (RSQC)" which provides some insight on the salient points already covered. The program RSQC is an initiative to evaluate the performance of an ongoing residual statics application in an interactive processing system.

Theory and method

The residual travel time t_{ijh} that corresponds to the ith receiver station ,the j^{th} source station and the k^{th} mid point along h^{th} horizon can be modeled as (Ref. Figure1)

$$t_{ijk}=s_i+ r_i +G_{kh}+M_{kh}x^2_{ij}\text{-----------------}(1)$$



where sj and ri are residual static shifts corresponding to source and receiver stations. G_{kh} is structural term with reference to k^{th} mid point – h^{th} reflector. $M_{kh}x^2_{ij}$ imperfect moveout correction. The coeff. M_{kh} has the dimensions of time/distance2.x_{ij} is offset between ith receiver station and j^{th} source station.The number of time picks is equal to NG.NF .Where NG is number of CMP locations and NF fold. It gives rise to NS +NR +NG+NG unknowns corresponding to four terms of equation (1) stated above. The number of picks are more than the unknowns (NG.NF>NS+NR+NG+NG) indicating towards least squares fitting case . The least squares error energy between the observed picks $t_{,ijk}$ and the modeled times tijh :

$$E = \Sigma (t_{ijk} - t'_{ijk})^2 \text{--------------------------} (2)$$

has to be minimum for the best suitable model. We have to substitute for t_{ijk} from eq.(1) and minimize the error energy E by requiring

$$\delta E/\delta s_j = \delta E/\delta r_i = \delta E/\delta G_k = \delta E/\delta M_k = 0 \text{-----------} (3)$$

which yields (NS+NR+NG+NG) equations.

The process of residual statics correction involves three phases (i) picking of observed time values t'_{ijk} (ii) it's decomposition into source, receiver, structural and moveout residual static components. (iii) application of computed source and receiver residual static corrections to travel times on the pre-NMO corrected CDP gathers .The starting values for solving the normal equations (3), can be chosen as $s_j = r_i = G_{kh} = M_{kh} = 0$.The iteration normally in use follows computation of structural term G, the residual moveout term M,the residual static term associated with source s_j and the residual static term associated with receiver r_i.The process recycles to G in the next iteration and continues until convergence is satisfactory . After computing the residual static shifts for each source and receiver stations, these shifts are applied to the pre-NMO corrected gather traces. In noise prevalent seismic data set multiple passes of residual static are inevitable for proper alignment of events.

Geovecteur CGG software computes residual static corrections using TDSAT (2D equivalent SATAN) an option which allows residual NMO to be taken into account.The program claims to improve seismic data without modifying dips or creating erroneous continuities.In the first phase of the program, it picks the best events of the section in the stack ("REMI-picking") these events are chosen on the basis of their amplitude and spatial continuity. In the second phase ,program computes the residual correction for each source station and receiver station which optimizes the picking of phase1.The computation is iterative in nature providing accuracies to the quarter of the sampling interval.

The output of residual static program(TDSAT/ SATAN) is residual receiver correction (CS) and residual shot correction (CP) along with Maximum-Minimum of corrections(Refer Figure-4).In a seismic data set where there is scope of improvement of S/N ratio a number of residual static passes are applied to the data .In Figure2 a cross plot is shown between Residual Static Corr. Range (I Max.- Min.I) and Number of residual static passes .Residual Static Corr. Range is declining with the increase in number of residual static passes .These residual static passes are punctuated by velocity analysis to help revalidate the model. It is

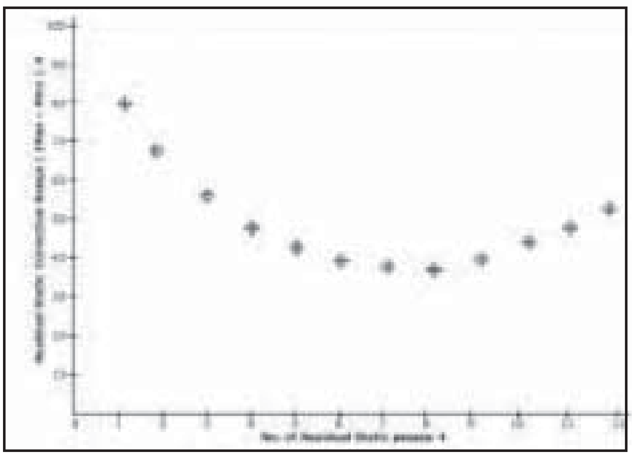


Fig. 2 : A cross plot is shown between residual static corr. range

observed that the 8th pass is having the lowest value of the Residual Static Corr. Range. Thereafter the Residual Static Corr. (I Max.-Min. I) increases with increasing number of residual static passes. In some cases it may stagnate around the lowest value of the Residual Static Corr. Range. The data corresponding to the pass having the least value of Residual Static Corr. Range is subjected to RSQC software.It has been developed using Motif and C++ programming languages. It

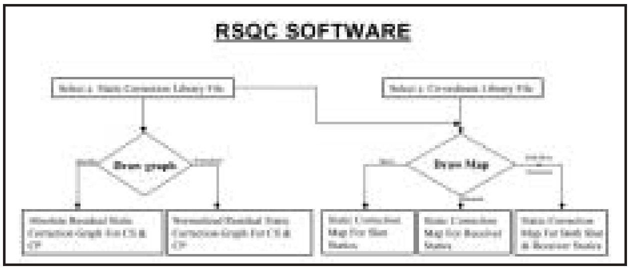


Fig. 3: Flow Chart of RSQC Software

is portable to any UNIX system(Ref.Figure3).The software comprises of four options in the main menu. File menu is subdivided into Select and Quit.The Select submenu has again two options (i) Library File for selecting residual static correction library file (Ref.Figure 4-5) . This file contains residual static correction values (in milli seconds) of the shot and receiver points . This file has to be selected via a file dialogbox that is displayed when the " Library File " option is selected (ii) Coordinate File for selecting coordinate library file (Ref.Table1).This file contains of X and Y coordinates of the shots and receivers stations in the residual static correction library file . These two files mentioned above

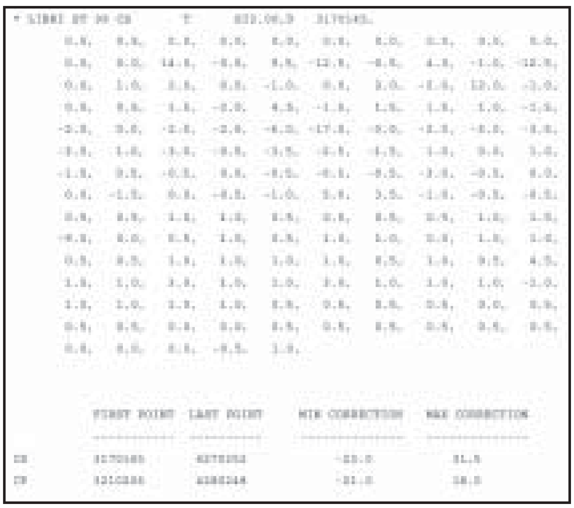


Fig. 4: Sample Residual Static Correction Library File

comprise of the basic input to the program. Graph menu has two options (i) Absolute Graph for displaying a color coded histogram representing absolute frequency distribution of residual receiver static correction (Ref. Figure 6) and absolute frequency distribution of residual shot static correction (Ref.Figure 7). The residual static correction library file has to be selected using "File->Select->Library File" option before invoking the the option. (ii) Normalized Graph for displaying color coded histogram representing normalized frequency distribution of residual receiver static correction (Ref.Figure8) and normalized frequency distribution of residual shot static correction (Ref.Figure9).Map menu is

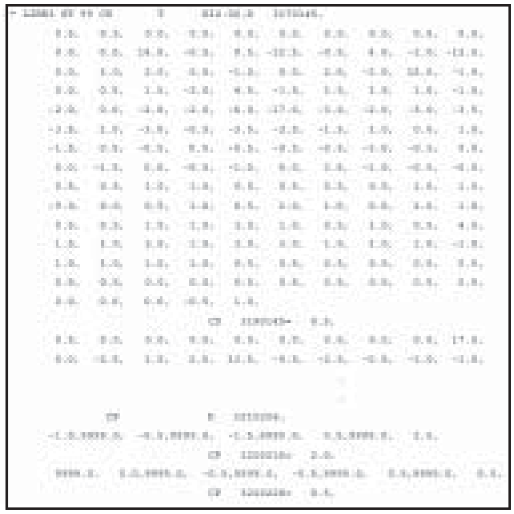
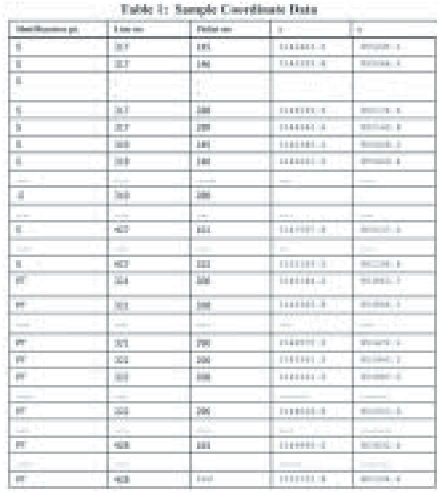


Fig. 5: Sample Residual Static Correction Library File

Table 1: Sample Coordinate Data



subdivided into two sub menus (i) Draw Map contain of three submenus " For Shots Only ", " For Receivers Only " and "Both Shots and Receivers" for selecting the type of the map required to be displayed (Ref.Figures10-12). The function of the "Draw Map" menu is to display residual static corrections' overlay either for shots or receivers or both of them on the base map. Plot option is also included to print or plot the graph or maps respectively.

The experience in real data situations imply that we cannot be liberal on upper bound of maximum shift in residual static correction.In the background of short period multiple or reverberation energy or high noise level or data with narrow bandwidth, cross correlation can yield multiple number of peaks and cause uncertainty in the estimated time shifts (cycle skipping). We may think of applying a good number of residual passes intervened by velocity analyses instead of single step large shift solution.The current approach has the effectiveness of the Large shift solution, while avoiding the chances of cycle jump. In the present data set we see that there is steady decline in Residual Static Corr. Range upto 8th pass of residual statics (Ref. Figure2).Beyond this pass the Residual Static Corr. Range takes an up-turn . It implies that The efficacy of residual static program is conducive upto 8th pass . Imposition of further passes of residual static program will not yield any improvement in S/N ratio . In this case we can confidently assume that 8 passes of residual statics are adequate to deal with this processing stage. The cross plot shown in Figure2 helps the processor to decide the adequacy of number of residual static passes to be applied to obtain the best results from the residual static program.

The data of 8th pass of residual statics is input into the RSQC program. The output is shown in Figures 6 &7. in the form of a histograms. It is the absolute frequency distribution of residual receiver and shot static corrections. It's normalized version is shown in Figures 8&9 which indicates a level of 93%&99% of residual receiver and shot static corrections respectively falling in the minimum value I0-5Ims. It becomes a level of achievability in residual statics for reprocessing job of the investigation undertaken at some later stage on the same seismic data set. In noise prevalent seismic data set the Residual Static Corr. Range maintains high value, say 70-80ms.The application of RSQC program yields histogram having 50% frequency for I0-5I ms residual corrections , remaining 50% frequency is distributed among I5-10I ms, I10-15Ims,I15-20Ims,I20-25Ims, I25-30I ms values of residual static corrections.It is also observed that repetition of residual statics passes does not improve the percentage (or level) of I0-5I ms residual static correction any further. We can very well question the amenability of such seismic data set towards residual statics. The processing of such data may require some additional follow-up e.g. refraction residual statics.

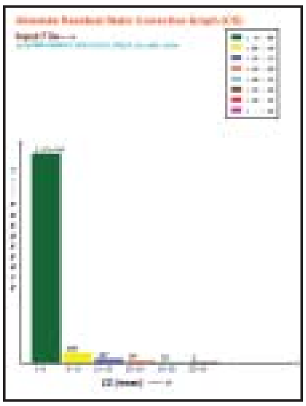


Fig. 6: Absolute frequency distribution of residual receiver static correction

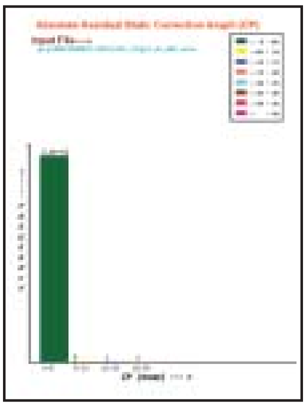


Fig. 7: Absolute frequency distribution of residual shot static correction

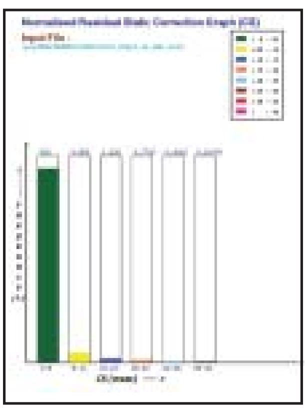


Fig. 8: Normalized frequency distribution of residual receiver static correction

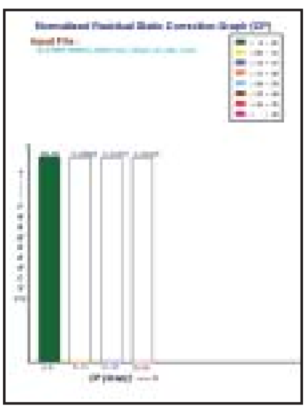


Fig. 9: Normalized frequency distribution of residual shot static correction

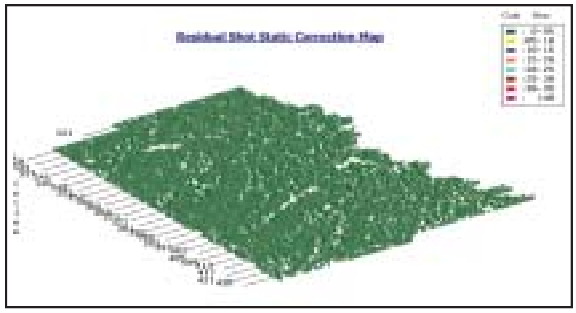


Fig. 10: Residual shot static correction overlay on base map

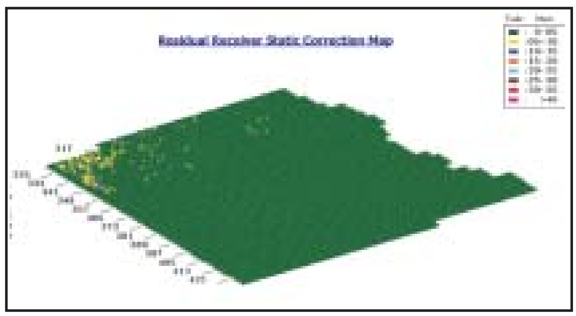


Fig. 11: Residual receiver static correction overlay on base map

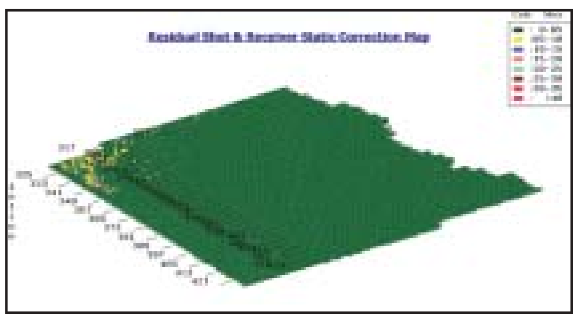


Fig. 12: Residual shot and receiver static correction overlay on base map

In the utility part of Geovecteur software a number of overlays are provided on the base map e.g. elevation , foldage , terrain and field statics etc. These overlays may be studied in conjunction with Figures 10-12 to have a feel of residual static correction deviations. It provides causatives to the large scale shifts in residual static correction . It is imperative that such residual static failure areas draw attention of survey crews to map near surface model intensively and rigourously.Thus residual static correction overlay on base map provides overall residual static quality control measure on seismic data set.

Conclusions

The ultimate judgment of residual static application is made by examining the stack response by human eye. Neverthless the present paper provides some insights into the significant step called residual statics:

⇒ Adequacy of number of passes of residual statics to be applied to achieve reasonably good residual statics.

⇒ Achievability of a level of residual statics application .

⇒ Amenability of seismic data set to be put up to the rigor of residual statics.

⇒ Diagnostic of residual static correction deviations with the help of residual static overlay on base map in conjunction with static / terrain /foldage overlays.

All above parameters help structure the hitherto considered an abstractedly assessed process called residual statics application in seismic data set.

The authors sincerely acknowledge constant encouragement by Shri S.K.Majumdar, the then Basin Manager, Shri R.K.Khanna the then Head Geophysical Services , A & A-A Basin ,Dr.D.V.R .Murti Dy.G.M (Geoph.) and Dr. R. C. Iyer Dy.G.M(Geoph.) for value addition in the available software resources. The paper would have not become reality without a word of suggestion from S/Shri P.K.Srivastava, P.K.Bose, Y. Satyanarayana, M.K.Mathur and P.R. Bora.

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