'Dynamics' of Statics: An Illustration of statics pull-up

S. P. Das, K. Pal and Arjeesh Gupta

Keywords

Near surface, Refraction based non-linear tomography, floating datum, statics pull-up.

Summary

Statics corrections play a 'dynamic' role in the land data processing. Improper computation of the same can lead to false structures and bad quality of reflection events. Long wavelength or low frequency statics are prone to create such structural anomalies whereas the short wavelength statics largely affects the reflection quality. A good statics solution should address the challenges posed by the elusive near-surface and topography. The authors elucidated through case studies how statics computed from different methods affects the imaging of sub-surface geology.

Introduction

From the advent of seismic data processing the statics is quite an essential step in processing specially land data. The land data throws challenges in this regard as because the acquisition is carried out in a relief which is not flat and the character of the near-surface is not very simple. In fact adding to the complexity of the near surface, it is also very difficult to comprehend and compute or model them.

Statics involve giving constant shifts to the reflected events on a surface-consistent manner. Statics contribution can be broken down into mainly three parts depending upon the magnitude of shifts and the feature it is trying to resolve. These are long wavelength (low frequency) statics, short wavelength (high frequency) statics and very short wavelength (very high frequency) statics (Jones, 2012). Long wavelength statics produces a large scale impact in the subsurface structures, whereas proper computation of the short wavelength and very short wavelength shows major impact in enhancing the quality of the reflection.

In the shallower part of the seismic section the fidelity of the seismic refraction is more than that of the seismic reflection. The seismic refractions are acquired as a by-product from the reflection survey, and their information is contained in the first-breaks. From the refracted arrivals it is possible to model the near-surface velocities and heterogeneities. Starting from an initial model and minimizing iteratively the residual errors between computed and observed travel-times we obtain a good estimate of the near-surface using nonlinear refraction tomography (Zhang and Toksov, 1998).

The author here presents case studies of two 2D lines which elucidates the necessity of a comprehensive near surface model to compute the statics. In the data set, the static problem is due to varied topography and a high velocity regime, the scale of velocities which is encountered is in the sub-surface is quite high compared to the sedimentary velocities.

Methodology

The case studies referred to in this paper the authors intend to show that how sensitive a static issue can be. The static computation can be divided into two parts,

1) Static computed from refraction (first-breaks)
2) Static computed from reflection

From the refracted arrivals (first-breaks) a model is estimated which gives us the long-wavelength statics and the short wavelength (refraction residual) statics.

The auto-statics (very short-wavelength statics) calculation carried out by stack-power maximization of the reflected events is not emphasized in this particular article.

Computation of Long-wavelength & Short-wavelength statics from First Breaks

The computation part of the refraction tomography derived statics basically consists of six steps

- Picking First Break times
- Creating an Initial model
- Using Non-linear refraction traveltime to derive the Final Model
- Choice of datum
- Computation of tomo-statics (long-wavelength statics)
- Computation of the refraction residual statics (short-wavelength statics)

First Break Picking:

The first break picking is carried out by automated picker designating first breaks from energy ratio. This is often guided by a Linear Move-out Velocity. The auto-picker fails where the ambient noise level is quite large, making the first breaks indiscernible. Several techniques such as using a minimum phase band pass filter and offset restricting did produced good results. Sometimes synthetic traveltimes computed from the tomography is used as guide to the auto-pickers. And within some iteration the outliers are minimized and picks are refined.

Initial Model Building

The gridded initial model is the starting model which is the best representative of all the picks. Since the final traveltimes picks were guided from the synthetic picks, so there were few outliers. The choice of the initial model was not critical in these two case studies. The author found that starting with a lower velocity trend for the first layer is actually a good option to start, as then the convergence is seen to occur faster.

Model Estimated through Refraction Traveltime Tomography

The non-linear refraction tomography is used to invert the picked traveltime. The errors between the observed (picked) traveltimes and the calculated (synthetic) traveltimes were minimized with iterations and within around 10 to 15 iterations the convergence of rms-misfit errors were achieved.

Since the authors have used the synthetic picks to guide the automatic picking therefore tomography aided model building was done as an interim process. The workflow is designed in such a way that we start with an initial model and then we run the tomography to obtain smooth velocity trend in the model. The synthetic picks generated from the model served as good guide for the auto-picker to pick the first breaks and most of the erratic picks were minimized.

In the final phase when the first break picks seemed satisfactory the picks were offset restricted to find the best model for the statics calculation. Since for the statics we only need the shallower part of the model. Mostly we find the heterogeneities occurring in the top of the model and the model is very smooth as we go deeper. For the authors the final accepting criterion for the model is that it should be smooth with a regular RMS-error distribution over the profile.

Choice of the Datum

The floating datum is created by smoothing out the topography variation. Fixing this floating datum is quite crucial, as migration and velocity analysis will be carried out from this datum. Also it is mandatory to keep the floating datum as running average of the topography with the spread length. There is also another datum to be chosen which is called the intermediate datum. This can be assumed as the hypothetical layer below which the geological consistencies are observed. The layer bounded by the floating datum and the intermediate datum is the near surface. This layer takes into account all the near-surface heterogeneities conditions such as elevation changes, sand dunes, buried river channels, buried glacial scours, permafrost, evaporites, variable water table, leached zones, volcanics, peat deposits, and coal seams (D, Marsden, 1993) which are known to pose potential challenges in land data processing.

Computation of Long-wavelength Statics

This comprise of the first-part of the statics computation. This is a sort of layer replacement wherein the heterogeneous near surface is replaced by a layer of constant velocity which is the velocity of the layer just below the near-surface. After application of the tomo-statics, it is assumed that all the near-surface irregularities such as the elevation difference and the velocity heterogeneities are being addressed and corrected.

Computation of Refraction Residual Statics

The computation of the statics is done to address the minor time shifts after applying the tomo-statics in the earlier steps. The gathers within a particular offset zone is flattened and the minor divergence in the first-breaks are the residual corrections. The residual statics calculations have to be suitably tuned to a smoothing radius. The choice of the smoothing radius is very crucial and alignment of reflections and stacking further is a good way to investigate the quality of the residual statics computation.

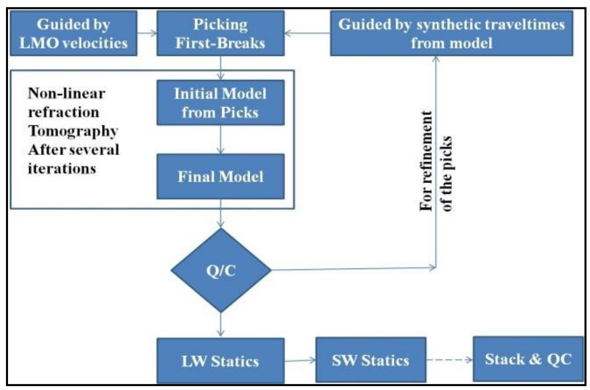

Figure 1 Flow diagram for obtaining the refraction based long and short wavelength statics computation

Stack-Power Residual Statics

The stack-power residual statics is computed by giving surface consistent static shifts on the traces so as to maximize the stack-power (Ronen & Claerbout, 1985). In this case study a single pass residual statics did quite commendable job and further shift was not necessary.

This statics data are compared with the field statics data and when plotted together we find a major change deviation at places and that's where the false structures were formed in the section.

In addition to the efficient static computation, the velocity analysis and the migration were carried out from the floating datum. Constant migration velocity stacks to pick reflectors and define velocity across the strands.

Kirchoff’s migration was performed with the migration velocity and the result was compared to the earlier section. On comparison with the earlier processed section, a clear case of static pull anomaly was perceived.

Examples

Case Study-01

This particular case study is taken from the Vindhyan Basin. This is a Proterozoic Basin, characterized by very high velocity of order of 4000-5000 m/s. And such velocities are encountered in the near-surface. The imaging challenge was further intrigued by the presence of the rugged terrain. The solution is of course a comprehensive statics solution which addresses the issues of complex near-surface. The near-surface model is conceived from the refracted arrivals or first-breaks in the method described above.

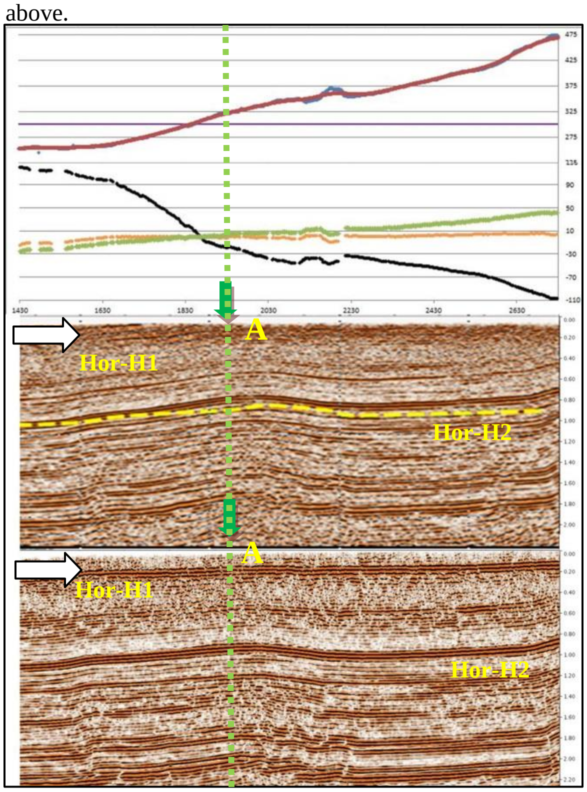

Figure 2 (a) Plots of Elevation (blue) and Floating Datum (red), SRD (purple) (b) Plots of cumulative *(shot and receiver at zero offset)* tomo-statics (orange), floating datum to SRD shift plus tomo statics (green) and cumulative field statics (black), (c) Earlier Processed K-PSTM Section (Field Statics & Flat Datum; (d) (Below) Reprocessed K-PSTM addressing ‘near-surface’ solution through non-linear refraction tomography and floating datum velocity analysis and migration.

The section shown aside (Fig. 2) is from a 2D line. The section was initially processed using the field statics. Fig. 2 (c) is a K-PSTM stack, wherein an anticline like feature is quite apparent at the location A (marked in the Fig. 2 (c)). Also the shallow horizon (H1) shows an upward tendency. This is a clear case of static anomaly (or pull-up), (right-side of A (also annotated with a dividing line)). This has led to an illusion of an anticline.

From the geology of the area, the top-most horizon marked in our section, horizon H1 is expected to be flat. But when the elevation of the area is plotted (Fig. 2 (a), it is seen that the horizon has followed the topography, and hence this apparent ‘pull-up’ has resulted. The field statics (black) computed from a flat datum (SRD) shown just below the elevation plot (Fig. 2 (b)) also increases to the right. This has resulted in disappearance of the horizon H1, from the sections processed with field statics.

This is quite obvious in the right side of the old section the values of field statics were of larger magnitude, and the total statics applied is actually more than the value of the first breaks, this is why the horizon H1 shows an upward tendency and ultimately disappears to the extreme right. The pull-up shown in the right side of the section, distorted horizon H2 and thus we can see an anticline like structure forming.

The second section (figure 2 (d)) is processed with tomo-statics that is the long wavelength statics derived from the tomo-model. The tomo-statics (orange) is calculated to compensate the effect of topography and near-surface varies more or less uniformly. And hence the horizon H1, which was poorly imaged in the old section, is brought out with much clarity after consideration of floating datum and tomo-statics. The green color line shows the cumulative of the tomo-statics and the floating datum to SRD shift. The horizon H1 is also rendered flat, and is quite obvious from the geology of the area. The flat horizon H1 has also reduced the prominence of the false structure forming in horizon H2. The apparent anti-cline is reduced to a minor hump. And thus it becomes quite conclusive seeing the comparisons that tomo-statics has compensated the near-surface problem and honored the geology.

Case Study-02

On another line a similar sort of anomaly is observed on reprocessing. This line lies alongside the line explained in Case Study: 01. In this profile, (Fig. 3(a)) the elevation is rising towards the right side and this impression is felt in the computed field statics. The top section (Fig. 3 (c)) represents a data processed with field statics and flat datum velocity analysis and migration.

In this data the shallowest horizon H1 follows the topography. As the topography increase towards the right hand side of the section just across the green line the horizon H1 tends to disappear, as it did in the earlier case. This static anomaly also tells upon the entire section deteriorating the image quality as a whole. The bottom section the same data re-processed through a comprehensive statics calculation involving low frequency, high frequency and very high frequency statics, provided a better section in all regards.

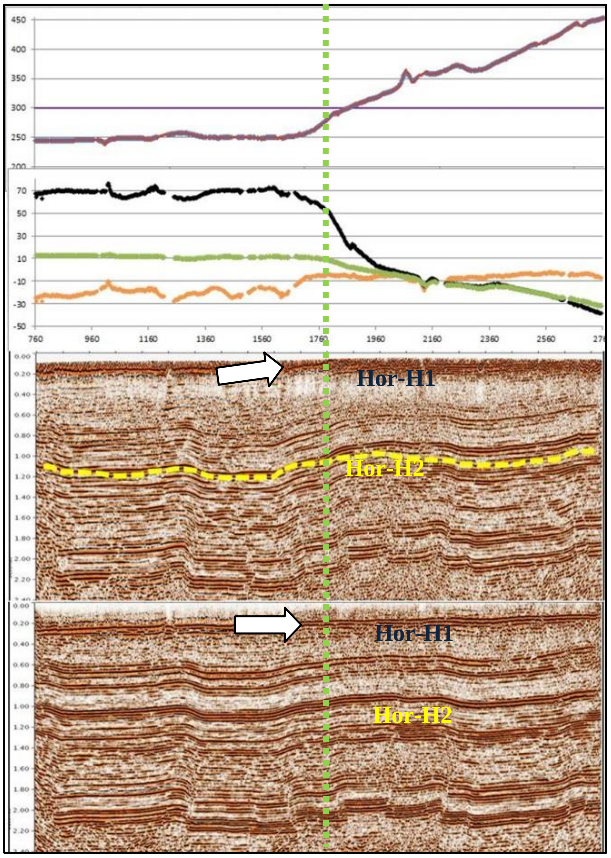

Figure 2 (a) Plots of Elevation (blue) and Floating Datum (red), SRD (purple) (b) Plots of cumulative *(shot and receiver at zero offset)* tomo-statics (orange), floating datum to SRD shift plus tomo statics (green) and cumulative field statics (black), (c) Earlier Processed K-PSTM Section (Field Statics & Flat Datum; (d) (Below) Reprocessed K-PSTM addressing 'near-surface' solution through non-linear refraction tomography and floating datum velocity analysis and migration.

As seen in the earlier case the tomo-statics (plotted in orange) vary almost smoothly whereas the field statics (plotted in black) shows an abrupt increase in magnitude once the elevation rise. Therefore the tomo-statics again compensate the near-surface problem, which in this case is the topography change and subsurface heterogeneities. Following from the area geology again the horizon H1 is flat in the re-processed section. The deviations seen in horizon H2 is also clearly apparent from the point the acclivity increases. Also on comparing the image quality in both the cases, it is seen that the faults in the deeper part of the reprocessed section are much clear and crisp. Therefore, it is quite evident that the reprocessed section showed a significant improvement compared to the earlier processed section and the reason can be attributed to better statics calculation and floating datum processing.

Conclusions

- The concept of near-surface is not always restricted to a mere weathering and sub-weathering layers, there are many other complex forms of buried heterogeneities which can pose imaging challenges.
- Field statics calculated from uphole surveys does-not always give a clear picture of the near surface features. Also the length scale of heterogeneities might be small compared to the density of uphole surveys performed along a profile therefore there is always a chance of missing them.
- The refraction based statics calculation amasses information from all the shot locations can be helpful in areas with complex near surface problems, which include varying topography, buried small-scale heterogeneities in the shallower part of the section.
- For an area with varying topography, velocity analysis and migration carried out from the floating datum produces better results. This also ensures that the long-wavelength statics calculated from the near surface model is small in magnitude so that scale of errors in estimation of the model also remains small.

The impact of statics can never be underestimated as a wrong statics calculation can totally disrupt the quality of image especially in land data processing. Impressions of false structure may also take place and can lead gross interpretation errors. Therefore it is advantageous to use refraction based statics calculation. Also statics computation and velocity analysis may be treated as an integrated approach to solve problems involving complex near-surface.

References

Dave Marsden (1993). "Static corrections—a review, Part 1", The Leading Edge, 12(1), 43-49

Ian F. Jones (2012). "Tutorial: Incorporating near-surface velocity anomalies in pre-stack depth migration models", First Break, Volume 30 (March), 47-58

Zhang, J. and Toksoz Nafi, M., 1998, Nonlinear refraction traveltime tomography; Geophysics, 63, 1726-1737

Acknowledgements

The authors are thankful to Dir. (E), ONGC, for permitting the publication of this work. The authors acknowledge the contributions of Sh. Anil Sood, ED-HOI, GEOPIC, ONGC his support and cooperation to carry out this work. The authors also express the heart-felt thanks to Sh. T R Muralimohan, GM-Head Processing, for his constant suggestions and motivations to carry out this work. The authors also acknowledge the support and advice received from colleagues of interpreters and data acquisition team throughout this project.

The views expressed in the above article are entirely of the authors and not the organization.