P073 AN INTERACTIVE 3D METHOD FOR RESOLVING OF STATICS ANOMALIES CAUSED BY HETEROGENEOUS PERMAFROST

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Summary

In the Western Siberia, near-surface heterogeneous permafrost can introduce large magnitude short- mid- and long-wavelengths statics anomalies. Previous experience showed, that automatic residual statics algorithms as well as first breaks interpretation methods, which are based on constraining the near-surface velocity model, fail to resolve these anomalies due to large magnitude (greater than half a period) of the time delays, poor first breaks and existence of velocity inversion.

These limitations could be overcome by using an interactive approach allowing delineating surface related statics anomalies directly from reflected data on the vertical slices of surface-consistent volumes, which are analyzed in a common-receiver point (CRP), common-source point (CSP), and common-midpoint (CMP) domains. Specific 3D spatially fixed pattern (SFP) stacking technique is used to organize offset-dependent CRP or CSP volumes for spatially fixed sources or receivers, respectively. These source or receiver patterns are located uniformly throughout the 3D survey in order to "illuminate" the near-surface anomaly from different directions and discriminate between the surface- related anomaly and the depth structure. During the analysis, performed within the interpretation system, a geophysicist creates a model of time delays, which adequately reflects the near-surface anomaly. These time delays are considered as source or receiver statics.

Introduction

Vast areas in the Western Siberia are characterized by near-surface heterogeneous permafrost zone, which contains continuous melt regions. It is well known that such kind of near-surface heterogeneities cause considerable artifacts in reflection times and dynamic characteristics of reflectors because of dramatic velocity changes while permafrost zones laterally or vertically interchange with melt ones. These artifacts make geological interpretation of reflected data difficult or even impossible.

Inverstigation of permafrost related static anomalies featuring high density of heterogeneous near-surface and complex nature of heterogeneity boundaries could not be successful if using traditional statics methods, which worked in other, less complicated regions. Organization of integrated field exploration for near-surface study (for example, uphole measurements) is desirable and often necessary, but it leads to considerable raises in the cost of prospecting, because it is impossible to choose the only method, which gives unique results in cases where near-surface velocity variations extents several hundred meters in depth. Discontinuous refractors due to near-surface velocity inversion limit the success of refraction statics methods

(Cox, 1994). Poor tracking of shallow horizons makes impossible application of methods based on reconstruction of these horizons and their velocity characteristics analysis.

All these obstacles, after extensive processing experience, lead to creation of interactive approaches, where a geophysicist plays a significant role in the process of accounting for complex near-surface heterogeneities, analyzing different information and making adequate assumptions. In the method suggested here no assumption about near-surface model is made, Geophysicist delineates near-surface anomalies via analysis of reflected data on and available a priori information and then interactively determines time delays caused by these anomalies. Obviously, the model of time delays require less a priory information or assumptions than near-surface velocity model.

The workflow consists of: delineation of surface-consistent heterogeneities, discrimination between surface consistent anomalies and depth structures, interactive determination of time shifts (i.e. source and receiver statics) and verification of the statics solution. The workflow is realized within integrated interpretation system with the use of multi-panel displays of common-offset, offset-dependent CRP and CSP vertical sections for interactive static shifts estimation. Near and far-offset vertical and horizontal slices and horizon velocity analysis are used for verification.

3D Spatially Fixed Pattern, anomaly delineation and discrimination

In many cases, when quantitative interpretation of first breaks is difficult, it is possible to qualitatively delineate near-surface zones of different types or anomalous zones by analyzing early times wavefield. For such analysis it is convenient to use common-offset sections, which allow looking over whole 3D dataset on the fly. Analysis of first arrivals on common-offset sections shows spatial extent of near-surface heterogeneity and thus starts the interactive statics correction process. For example, Fig. 1 shows a map of first arrivals derived from unfiltered 900m common-offset receiver sections with elevation statics applies. Deacrese in time of first breaks, shown in black, indicates high velocity permafrost heterogeneity.

Concept of SFP stacking (Kozyrev, 1995) is necessary as the only reliable method of generating surface consistent (CSP or CRP) volumes in 3D. A spatially fixed pattern is a group of binned sources or receivers, which are fixed in space and corresponding offset – dependent set of receivers or sources, respectively.

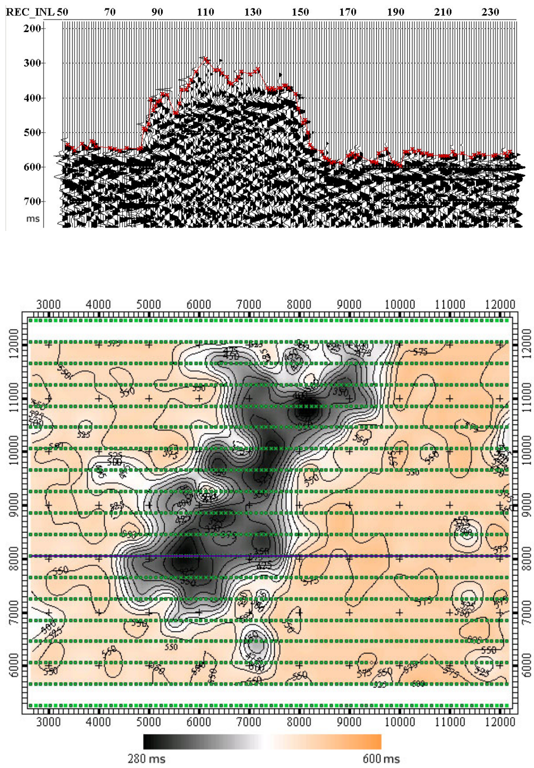

Fig. 1. Common-offset receivers section (top) and first breaks time map (bottom) derived from first breaks analysis over all receiver lines.

Fig 2. illustrates two spatially fixed source patterns "illuminating" high velocity near-surface anomaly from two different directions. After surface consistent stacking along receiver line 2 we have two CRP stacks (in the middle) for two differently fixed source groups. Note, that when we display these sections by receiver position, the anomaly pattern remains stable on both sections. Displaying the CRP stacks by CMP position leads to shifting of each anomaly pattern to their correct CMP position. This type of display referred to as CMP-Matching (Pechols et al., 2001) and serves as a tool for discrimination between surface-related statics anomaly and depth structure (Fig 4).

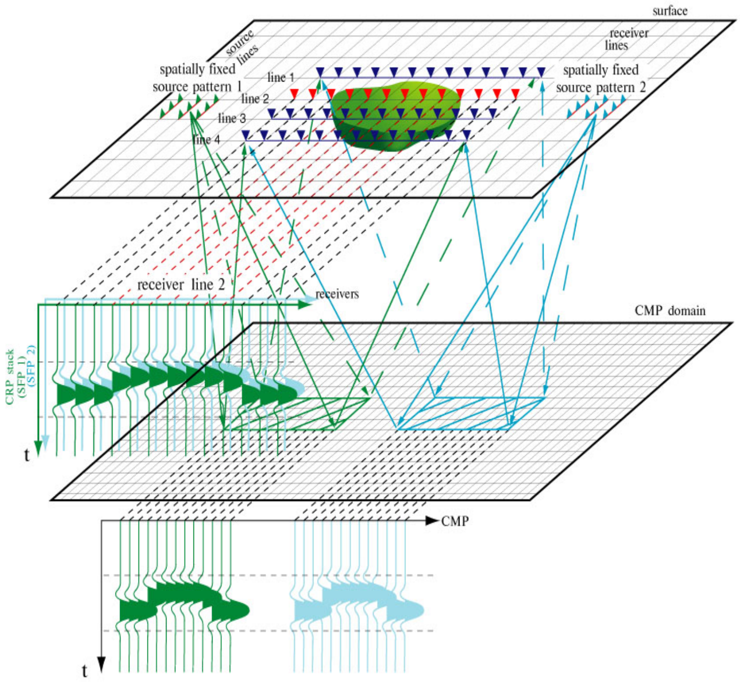

Fig. 2. Two spatially fixed source patterns illuminate near-surface heterogeneity.

Thus, to perform the anomaly delineation and discrimination technique we need at least two sets of SFPs. Such source or receiver SFPs and corresponding receivers or sources are designed using interactive survey map display in order to cover whole 3D survey and then to produce surface consistent volumes.

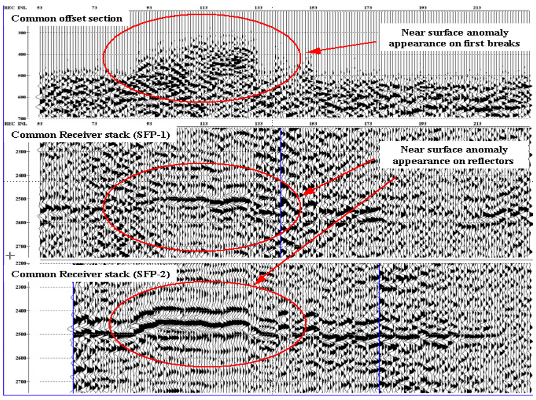

Fig. 3. Multi-panel display of common-offset (top) CRP SFP set1 (middle) and CRP SFP set2 (bottom). The surface – consistent sections are positioned by receivers. The anomaly pattern remains stationary.

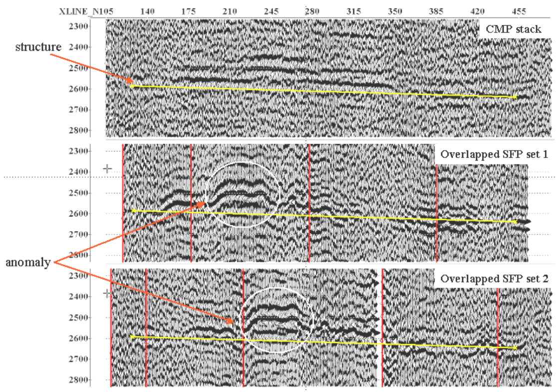

Fig. 4. CMP-Matching. CMP stack (top), CRP SFP set1 (middle) and CRP SFP set2 (bottom). Stacks are positioned by CMPs. The anomaly pattern shifts on the surface consistent stacks.

Each volume then analyzed on line-by-line basis in the multi-panel display, which simultaneously shows different SFP sets. Time delays are estimated interactively on the display providing synchronous time shifts on all SFP sections in order to distinguish between regular and random time delays and to choose the optimal result. Figure 3 demonstrates an example of the multi-display with common-offset section and two CRP section derived from different SFP sets.

QC includes generation and comparison of CMP near- and far-offset partial volumes, horizon and stacking velocity analysis. Statics solution considered satisfactory if t_0 time surfaces on near- and far-offset CMP volumes do not differ and cycle skip velocity anomalies are absent.

3D data example

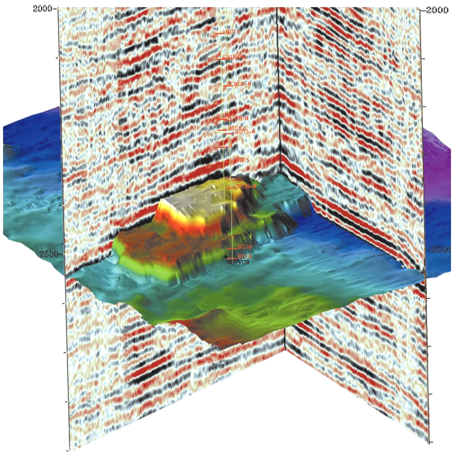

Fig. 5a. Two perpendicular cross sections and horizon time surface. Residual statics applied.

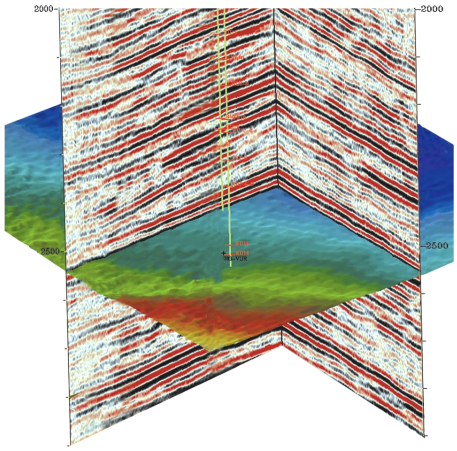

Fig. 5b. Two perpendicular cross sections and horizon time surface. Interactive statics applied.

The method was applied to 3D dataset from area characterized by heterogeneous near-surface permafrost. The data exhibits high magnitude mid-wavelength anomalies. Fig 5a. demonstrates combined display of two perpendicular vertical sections with residual statics applied and interpreted horizon time surface. A false structure, caused by unresolved statics is well observed on the interpretation result.
New interactive statics solution was derived and applied using the method described above. The result, shown in Fig. 5b, demonstrates dramatic improvement in reflectors continuity and removal of the false structure.

Conclusions

The 3D interactive method, described in this paper, gives an opportunity to resolve high magnitude mid-wavelength anomalies caused by heterogeneous permafrost where other standard methods fail. Due to large data volumes in 3D it is necessary to use integrated interpretation system, which allows deriving interactive statics solution in production scale. Since the method includes analysis of reflected data, its success will always depend on S/N ratio.

Acknowledgments

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