Interactive static corrections to avoid mis-interpretation of seismic data in case of complex near-surface velocity changes.

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Summary: Static correction computation is an important step in the seismic processing of land and transition zone data. Complex near-surface overburden velocity changes do hamper proper imaging. Geological and physical features (like: permafrost, pinch outs, swamps, sand dunes etc) may introduce irregular travel time delays. Automatic residual static algorithms sometimes fail to resolve these static corrections and thus may give rise to serious mis-interpretation of the subsurface structuration. Costly dry holes have been drilled based on false tectonic structures visible on non-optimal processed seismic data. These errors can be overcome by introducing an interpretation / modeling phase in the determination of the static corrections, using receiver and shot partial-offset stacks. The Interactive Static computation method uses diagnostic partial stacks in various domains to distinguish anomalies caused by drastic lateral velocity change in the shallow subsurface. Case studies illustrate the benefit of such a static correction method.

1. Introduction

Determination of reliable static corrections on seismic data is an important step in the processing of land and transition zone datasets (e.g. Veeken 2007). Complex near-surface overburden velocity changes may hamper proper imaging of the subsurface. Geological features - like buried valleys, sedimentary channels, lithological facies changes, pinch-outs, sand dunes, swamps, igneous intrusions, karsts and permafrost – may introduce irregular large magnitude short-wavelength travel time delays. These delays can be greater than half a period and their wavelengths larger than half an effective spread length. Uphole surveys give detailed velocity information to a shallow depth (e.g. Al Mahrooqi et al., 1999). But some of the anomalies may be situated out of reach of the uphole survey. Vertical and horizontal resolution of these surveys play an important role to resolve the encountered imaging problems (Veeken et al., 2005). Discontinuous refractors due to near-surface velocity inversion limit the success of refraction statics methods. Poor tracking of shallow horizons makes it impossible to reconstruct these horizons and is hampering a proper velocity analysis (Figure 4).
Automatic residual static algorithms sometimes fail to resolve these kind of static corrections, leading to serious mis-interpretation of the earth's structuration and as a result unnecessary dry holes have been drilled. Figure 1 shows a false tectonic structure on the reflection seismic data that is an artefact introduced by limitations in the conventional residual statics computation. The partial stacks in the bottom of the figure illustrate the sections resulting from the Interactive Static computation method presented here. The large statics corrections are due to the presence of a shallow permafrost layer. Problems in such case are various: poor first break determination, existence of velocity inversion, large magnitude of the static corrections and erroneous cycle skips (Korotkov et al., 2003). Therefore additional geologic and geophysical information is needed to constrain the near-surface model. These errors can be overcome by introducing an interpretation phase in the determination of the static corrections, using receiver and shot partial-offset stacks which are analyzed in different domains distinguishing a surface anomaly from real structure as will be demonstrated below (Figure 2).

2. Methodology

The interactive statics interpretation system (IST) uses multiple forward and reverse partial-offset stack displays in the common-receiver point (CRP), common-source point (CSP), and common-mid

point (CMP) domains to delineate and estimate surface-consistent source as well as receiver statics. However, it is only possible to decouple the source and receiver statics, when the offset distance is greater than the anomaly width (i.e. under-shoot). Special stacking technique – variable offset Spatially Fixed Pattern (SFP) is used to avoid source and receiver statics coupling and this is the only reliable surface – consistent stacking method for 3D (Pecholcs et al., 2001; Korotkov et al., 2003).
Some basic, as usually for static correction, are made:

- Low velocity anomaly influences only time shift.
- Static correction does not depend on oscillation frequency.
- Static correction does not depend on propagation direction.

Analysis in the shot and receiver domain is essential to discriminate between shallow surface velocity anomalies and a structural cause of the seismic feature under investigation. The interactive static determination methodology has proven already its merits in Russia as well as in Saudi Arabia (Korotkov et al., 2003; Kozyrev et al., 2004; Pecholcs et al., 2001). Several case histories demonstrate the effectiveness of the method for data acquired under different conditions (e.g. arid/humid, polar).

3. Zones of inhomogeneities

Inspection of first arrival energy in the common – offset prestack domain, after elevation or refraction statics applied, gives already some idea about the presence of significant shallow velocity anomalies. More detailed information is obtained when the behavior along various raypaths is examined. Stacked common receiver and shot data (or SFP stacks), sorted by their surface positions with separation of positive and negative offsets, supports the possible shallow origin of velocity anomalies.

4. Partial stacks and determination of anomaly origin

Visualisation and interpretation of various seismic dataset aspects is required to obtain a correct velocity model of the shallow subsurface. In this approach time consuming velocity model building step is avoided and instead a time delay model is analyzed. Extra information from seismic in alternative domains gives a better grip on the cause of the anomaly (Figure 2,3). The principle of surface anomaly determination is shown on figure 2 on modeled data: the anomaly image is observed on the same position when partial CSP stacks are compared by their surface positions and it is shifted laterally when the same stacks are compared in CMP domain. Similar comparison of real CRP partial stacks in receiver and CMP domains is shown on figure 3. Thus, the data is sorted in the shot, receiver, CMP domain and according to offset or differently fixed SFP. It is now interesting to compare the expression of the seismic anomaly on the partial CMP stacks. On the CMP partial stack a structural cause will influence the raypaths more or less in similar way, whereas a shallow velocity anomaly would gives rise to a different expression on the near and far offset stacks. The differences in the anomaly appearance on the partial CMP stacks is shown on figure 1. Different shape of an anomaly on partial CMP sections is a good indicator for the presence of statics effects in the dataset. One more indicator of the near-surface velocity anomaly is a corresponding sing-changing stacking velocity anomaly (figure 4.). Here low-velocity near-surface anomaly causes increasing of both reflection times and stacked velocities. Once the origin of the anomaly is detected, the processor can proceed with statics correction using the tools provided by the IST system. Although the workflow is labour intensive, it will lead to a better seismic stack section and drilling of costly wells on 'false' structural closures is avoided (Figure 1). Application of the interactive static correction methodology has a proven positive track record in land data processing. But also in the shallow marine transition zone, surveyed with bottom cables, static problems may play an important role and can be satisfactorily addressed with this technique.
Thus, the methodology consists of:

- preliminary analysis of prestack data and preliminary stacking for delineation of possible near-surface heterogeneous zones,
- choosing of partial stacking strategy for CRP, CSP (as well as SFP), CMP,
- partial stacks analysis in different domains and estimation of time delays on determined near-surface anomalies.

5. Conclusions

- Reliable determination of seismic static corrections is important for correct imaging of the subsurface. It avoids mis-interpretation of subsurface data and unnecessary mis-location of proposed exploration wells.
- The interactive statics method allows to discriminate between anomalies caused by a shallow velocity anomaly and a genuine structural deformation. The approach can also be applied to the shallow marine transition zone data.
- An interpretational step is necessary, whereby the behavior of the anomaly on partial CRP, CSP, CMP stacks is diagnostic for the actual cause of the seismic anomaly.
- A shallow origin for the anomaly is expressed by a lateral shift on the near offset compared to the far offset CRP, CSP, CMP section. Such phenomenon needs to be compensated by the static correction of the seismic traces. If there is no lateral shift observed, than a structural cause is present and hence only small static corrections should be introduced.
- The interactive static correction method works in absence or lack of costly uphole surveys for shallow velocity calibration and avoids time consuming ambiguous velocity model building.

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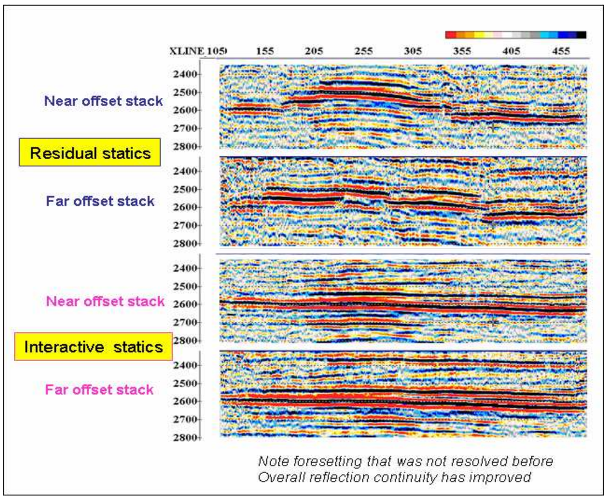

Modified after Kozyrev et al. 2004

Figure 1

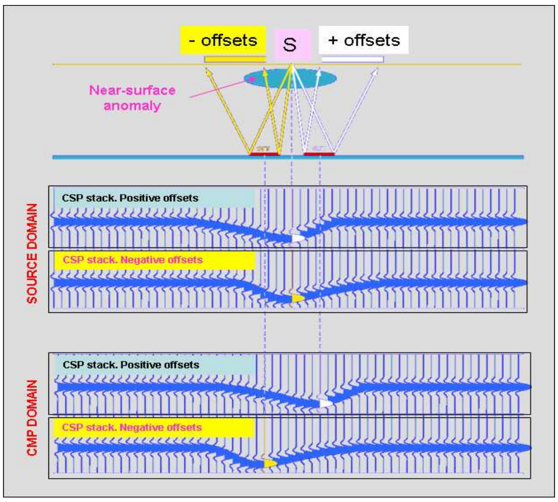

Figure 2

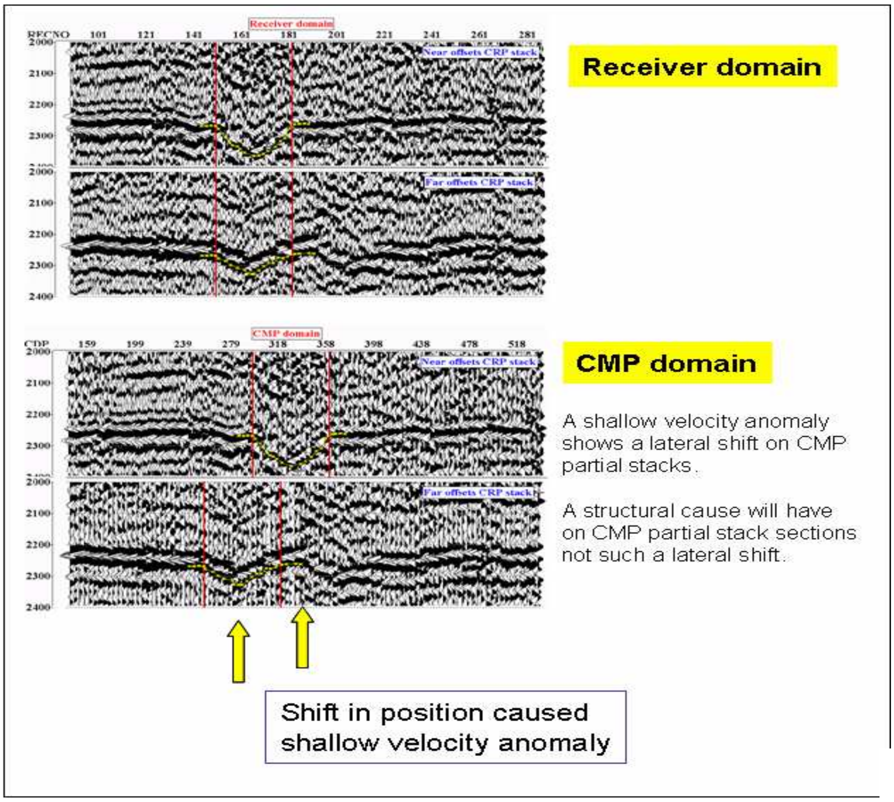

Figure 3

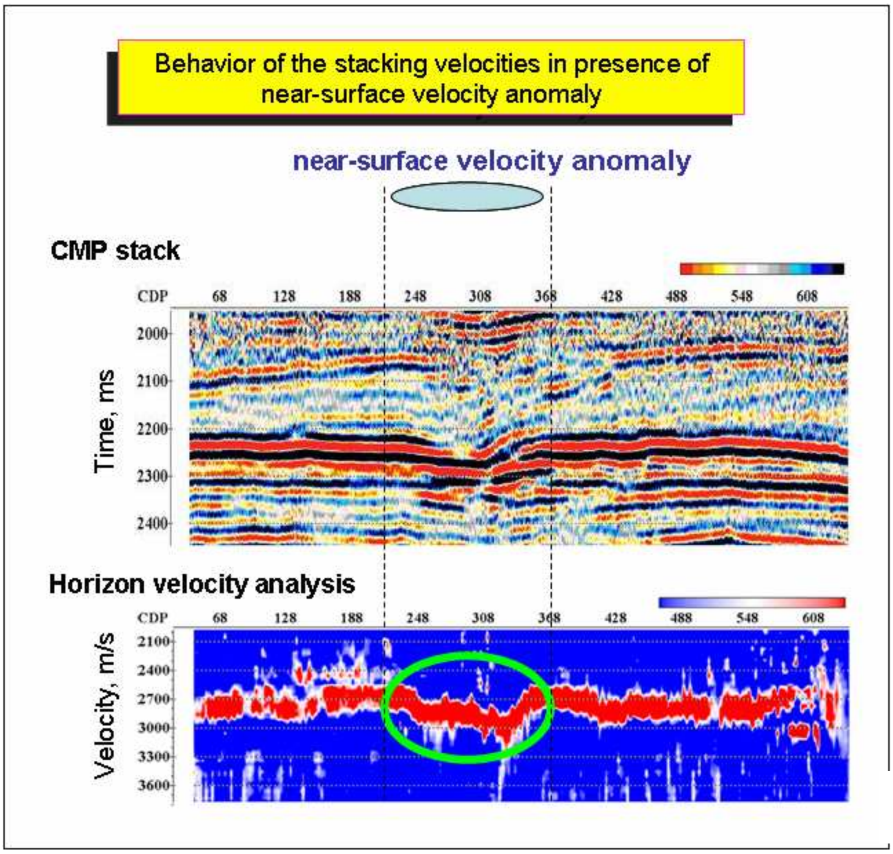

Figure 4