P-146

Static corrections in challenging cases

Seweryn Tlalka, Geofizyka Torun, *Poland*

Summary

Seismic data processing in challenging areas such as sand or rock desserts of Asia, North Africa, or Middle East needs various technologies to remove distortions caused by complex near surface structures, frequently of large, irregular thickness.

Methods of removal such distortions include vertical static shifts and wave equation datuming. Initial static corrections are solved usually by low velocity layer modeling and deterministic or tomographic inversion of refraction arrival first breaks. For residual corrections, proprietary software modules based on interactive static estimation proved to be efficient in cases when automatic approaches fail. For that kind of solutions, when geophysicist's patience, and experience of his/her team are crucial, procedure the quality control is very important issue. Discussed are interactive tools, unique on the market, which assure correct and homogeneous solution of static corrections, interactive static corrections, first break correctness and velocity coherency. Moreover, interpretive procedure to calibrate static corrections is discussed.

Introduction

To resolve the issue of static corrections at the initial step of seismic data processing is the key to success of subsequent processing.

In regions where near surface structures exist, frequently of large thickness and complex structure, processing needs various technologies to remove these deformations from seismic data. To guarantee high quality processing, what frequently depends on type of the desert (sandy, stony), many different methods had to be employed.

Static corrections can be classified in the following types:
 - surface consistent static corrections,
 - non surface consistent static correction,
 - wave equation datuming.

Surface consistent static corrections are: elevation, modeled, field, refraction, tomographic, or residual. Non-surface consistent static corrections are estimated either in offset domain (usually 3 or 4 intervals), or in common depth point consistent manner. Datuming based on wave equation is used in areas with thick near surface velocity layer where straight rays approximation cannot be hold. Two proprietary solutions complement discussed set of methods: interactive static corrections come into play when deterministic or statistic methods do not give satisfactory result, and calibration is the process obligatory to get reliable static corrections.

Method of estimation depends on region and on near surface geology in areas of prospection. Sand dune desert, stone desert, permafrost, transition zone, periodical river, buried ravine or chott, each area needs dedicated approach to computation of static corrections and to creation of near surface velocity model. In some areas standard methods are combined with advanced ones.

In most cases, selecting refraction static is enough. In this case first breaks are used, and near surface model is built with, for example tomography, or deterministic inversion, so high quality of first breaks is needed. Semiautomatic first break picking methods make compromise between quality and execution time. LVL is frequently modeled in sand deserts and areas where dunes exist and where other methods cannot be accepted. Old, proven methods, combined with proprietary software lead to the best solutions of static corrections.

Selected methods of statics computation

Model of LVL is sometimes created in cases where static corrections are related to terrain elevation. When surface elevation changes rapidly and the shallowest layer of LVL has low but almost constant velocity, then it is possible to design such model which moves shot point and receiver point to the final datum. There are two main types of modeling: simple and advanced.
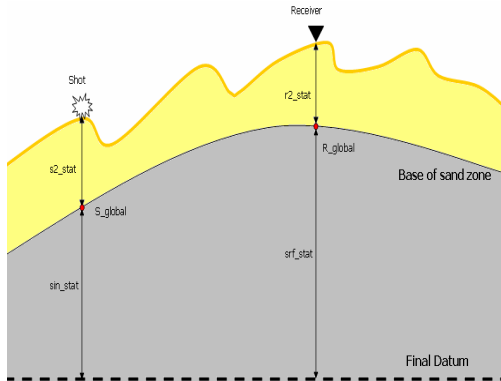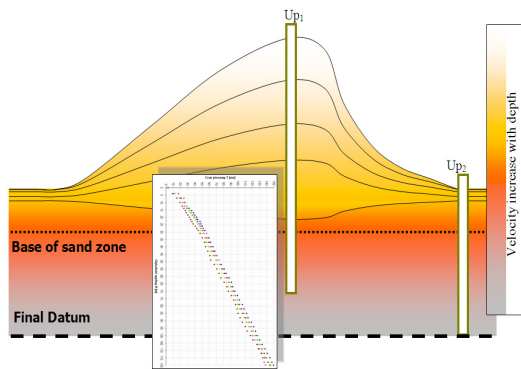
Fig. 1 Simple modeling method

Fig. 2 Advanced modeling method

Where modeled statics do not give as acceptable result as was expected, solution is usually provided by **refraction method** based on the first breaks.

Effectiveness of first break picking depends on quality and suitable preparation of seismic data. There is often noise which does not allow to recognize correct phase of seismic signal. When combined with complex geology and tectonics, first breaks in the seismic data could make complex pattern, and sometimes are hardly recognized at the background of noise. Then in production, dedicated processing is applied, e.g.: filtering, noise reduction, scaling. These operations allow to get proper quality of first breaks to pick.

The latest proprietary software solutions allow to carry out automatic and semi-automatic first break picking. In

case of large 3D areas, this methods (especially semi-automatic) significantly cuts computation time while maintaining high quality. Dedicated toolkit for semi-automatic first break picking was created (see Fig.3).
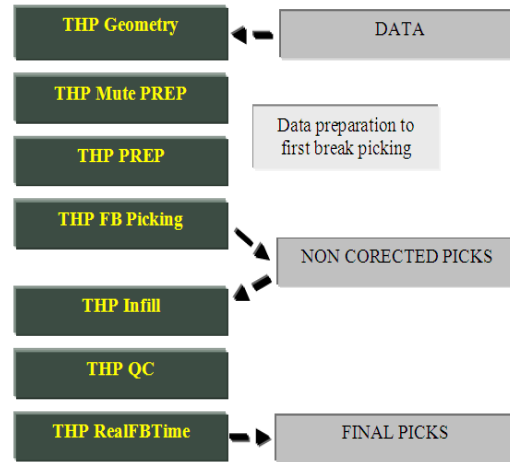

Fig.3 Semiautomatic First Break Picker " Thunder Pick – layout of structure scheme"

Generalized Linear Inversion (GLI) is one of methods commonly used to compute static corrections. This method is based on times of first break picks and allows to compute static corrections. Model building is done by linear approximation of first break picks' pattern.

Tomographic inversion is used in cases of vertical velocity gradient in shallow layers. Diving wave appear, and straight line approximation to first break pattern is not valid.

There are few cases when no automatic method gives acceptable result. In these cases crucial supplement of statics' workshop is **interactive static correction**.

This method on the contrary to automatic methods allows to avoid cycle skips, and introduce interpretive, non-seismic information. User can correct interpretation of selected horizons (common shot gathers, common receiver gathers and CDP gathers) with reference to modeled horizons. This interactive correction is iterative and process convergence is determined by correctness of horizon picks and quality of seismic data. Snapshots from application of dedicated, proprietary software for interactive static correction in 2D and 3D data (ISC),

where data are examined and corrected in shot, receiver and common depth domains, can be seen in Fig.4 and Fig.5.
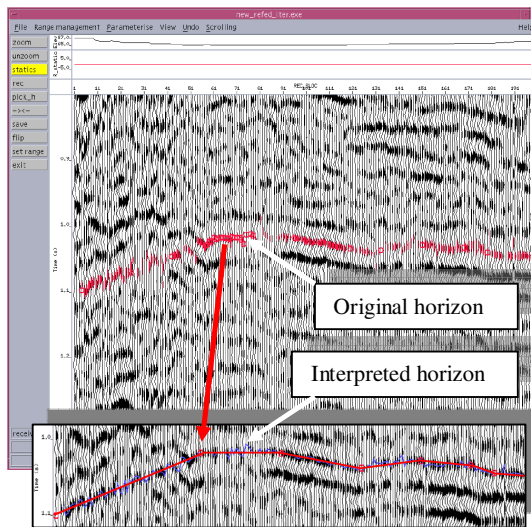

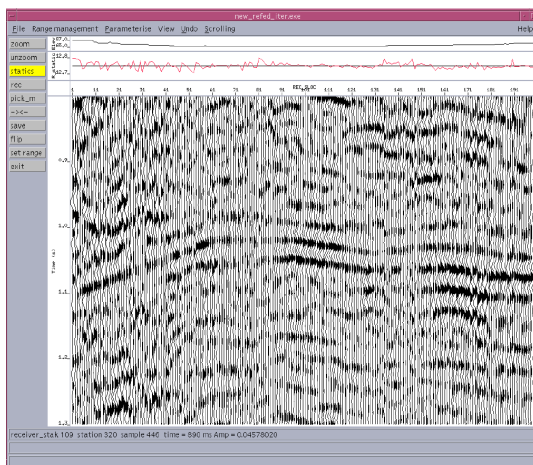Fig.4 ISC – Stack in common receiver domain

Fig.5 ISC – Stack in common receiver domain after first step of interactive static correction

Creation of coherent static solution is important issue in case of multiline 2D surveys. Unique, proprietary software (Mistie Analysis) allows to get homogeneous surface consistent solution for projects which contain big quantity of 2D lines. Essential condition is presence of mutual intersections of 2D lines, and application of match filter to seismic signal.
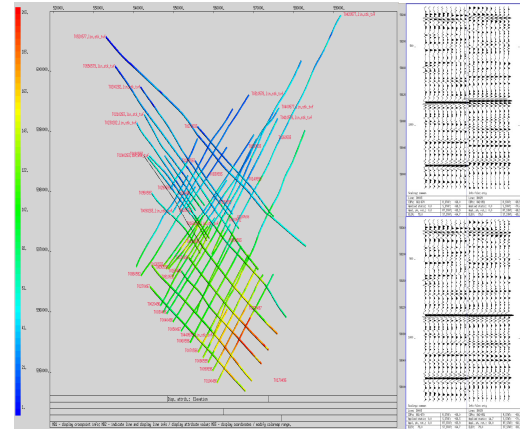

Fig.6 Mistie Analysis – tool for interactive static correction of 2D project

Low – frequency component of statics cannot be solved within surface seismic workshop. Case when different static methods were used is even more troublesome. Remedy for that is **calibration** of statics.

Static are relative qualities so they have to be calibrated to reference measurements.

These are main reasons for that:
- usually, for practical reasons, a signal phase being shifted from actual first break is picked (let say about 1/4, 3/4, 5/4 wave period.),
- inaccuracy and limitations of measurements caused sometimes by too large distance between stations, what leads to imprecise estimation of shallow layer parameters,
- refraction method can model only boundary where velocity increases with depth. It omits velocity inversion: inserted low velocity layers.
- limitations of refraction method. Refraction wave refract below ceiling part of the layer but not directly in the ceiling. Layers are observed somewhat deeper in this case.

Correction of this irregularity is done by direct measurements of near surface layer with upholes. Final static corrections are split into low and short wavelength statics. Slow component of statics is calibrated to uphole data and in the next step is added to short wavelength statics which together give calibrated final static corrections.

One of the procedures of **static corrections quality control** is controlling data after stack. Another step is observation of trend and maximum and minimum deviation of statics map in processed area. By velocity field monitoring we can detect places where static corrections are not resolved. Afterwards we make correction of statics where decided.

The most important thing in seismic data processing is application of stable velocity field during first iteration. This velocity stabilization allow to find zones where statics need corrections.
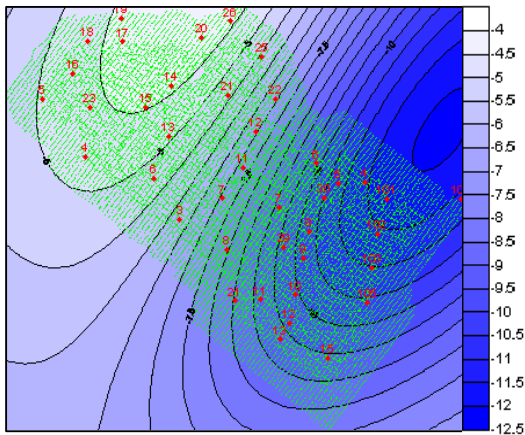

Fig.7 Calibration map for 3D data

Data Examples

Fig.1 and Fig.2 present simple methodology of computation of modeled static corrections. Two types of modeling which are used, often depend on region and client's requirements: simple modeling and advanced modeling. In the first method constant velocity is applied in the shallowest near surface layer. In the second one statistical velocity gradient is computed from uphole data in dune area and is applied to the shallowest layer.

During refraction statics calculation important elements are first break picks. Fig.3 describes simple scheme of

proprietary tool kit Thunder Pick (THP), and Fig.9 shows respective interface. This software is semiautomatic first break picker, commonly used in areas where automatic first break pickers fail. Picks are moved and tuned from one group of seismic data to another one. User can modify picks if needed and decimate receivers or sources to be picked in the dataset.

Fig.4 and Fig.5 show example of propriety software used to compute interactive static corrections (ISC). Both pictures show software interface with loaded stack sections in common source domain. In the first figure a section before interactive static corrections is shown, and in the second one it is after that. Fig. 8 presents sample of stack sections before and after interactive corrections in CDP domain. There is cycle skip in the first section which was eliminated in the second one.

Fig.6 shows software used to correct misties between 2D lines from one area. Misties between 2D lines and 3D data are computed by cross-correlation of data. Whole set of tools is complemented with velocity viewer allowing to check and correct coherency of velocity fields.

Fig.7 shows calibration map based on the uphole data.

Fig.10 and Fig.11 show an xline from 3D area where modeled static corrections were applied. First seismic section shows result of elevation statics applied, and the second one is after simple statics modeling method. First breaks were so ambiguous that finally refraction statics were not used in that area.

Fig.12 and Fig.13 show 2D line where static corrections in dune area were computed. In the first section field statics were used. In the second section refraction static with first iteration of automatic statics correction were used.

Conclusions

- Selection of appropriate static computation method allow to build and correct for near surface layer even in case of very complex structures.
- Areas such as sand or rock deserts need special approach to computation of static corrections.
- Static calibration, modeled and interactive methods are important components of static corrections workshop.
- Commercial software used in seismic data processing, in many cases is far not enough to get satisfactory solution of static corrections.

- Proven methods which are combined with proprietary approach lead to the best solutions of static corrections.

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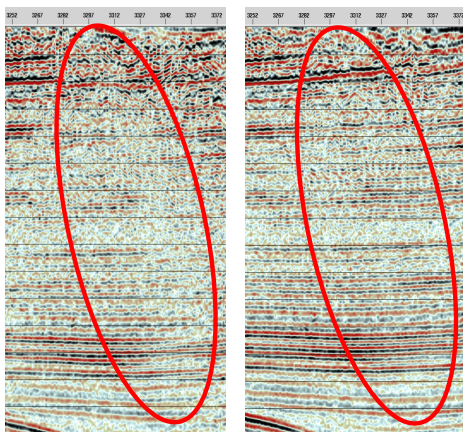
Fig.8 Stack before and after interactive static correction with ISC software.
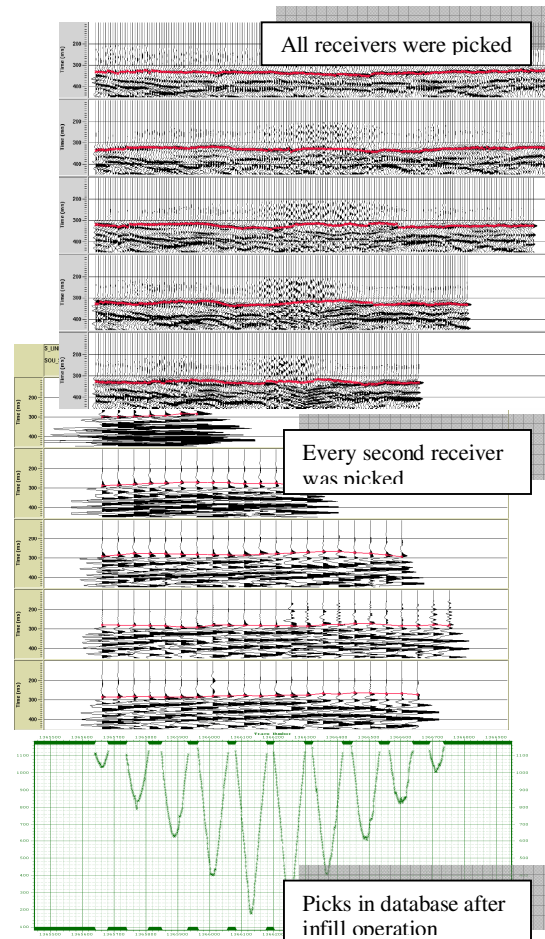
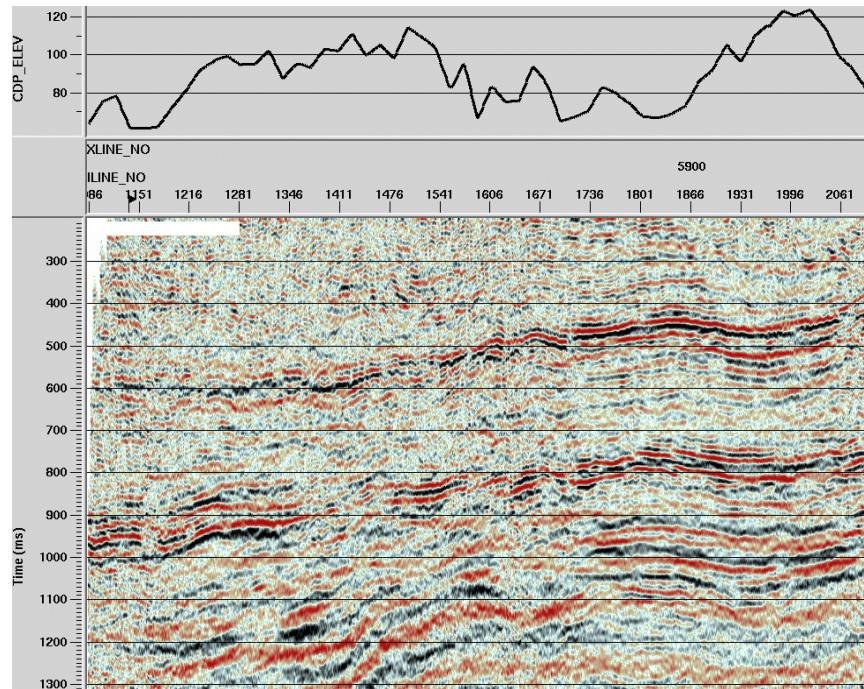Fig.9 THP – first break picking user interface

Fig10 Elevation static corrections were used – dunes in Asia
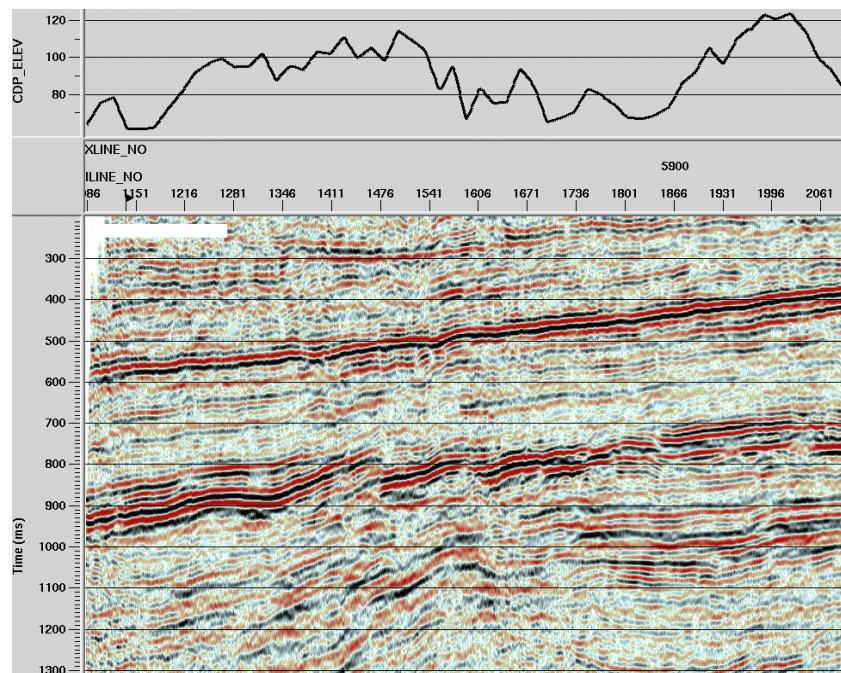
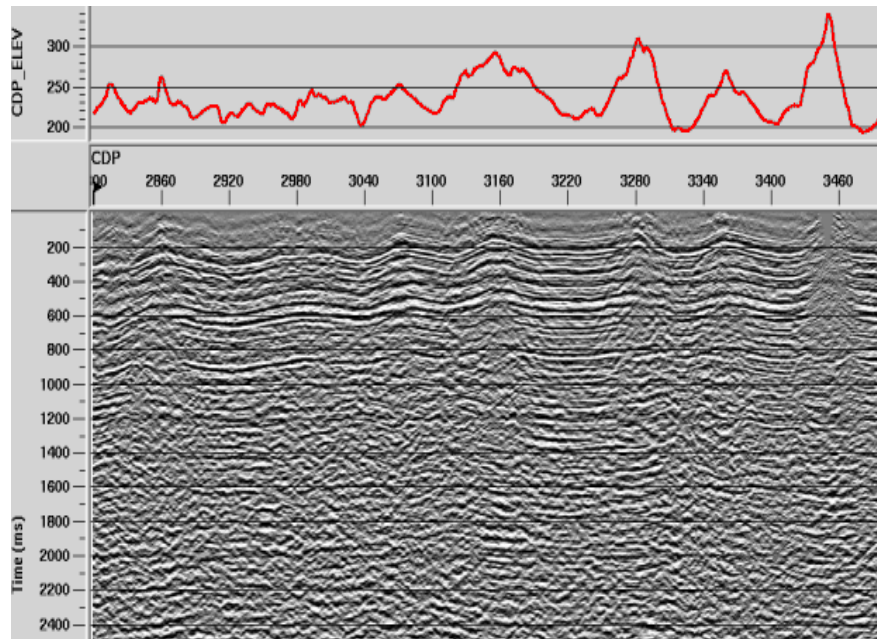Fig11 Modeled static corrections were used – dunes in Asia

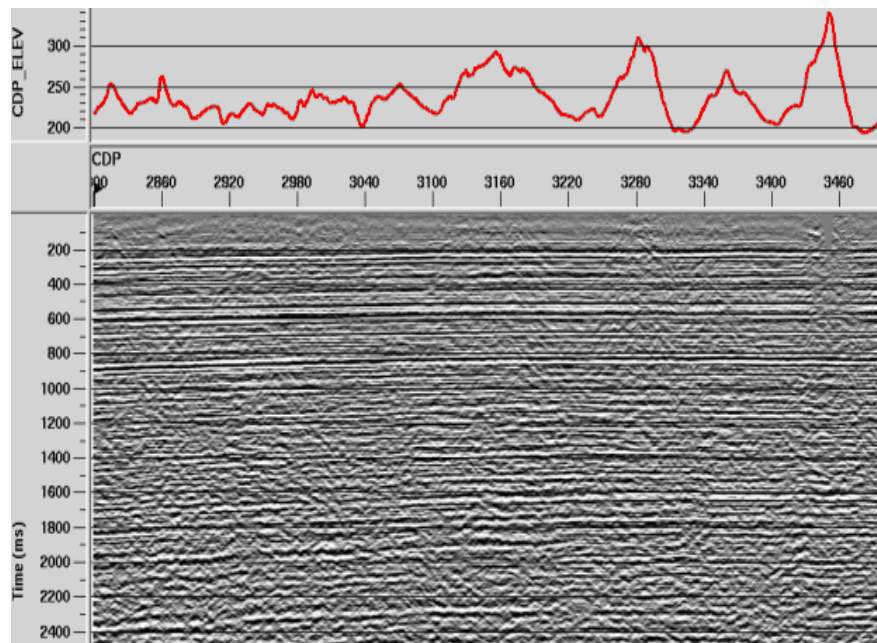Fig12 Field static corrections were used – dunes in Africa

Fig13 Refraction static corrections were used – dunes in Africa