Near Surface Anomalies and Solutions

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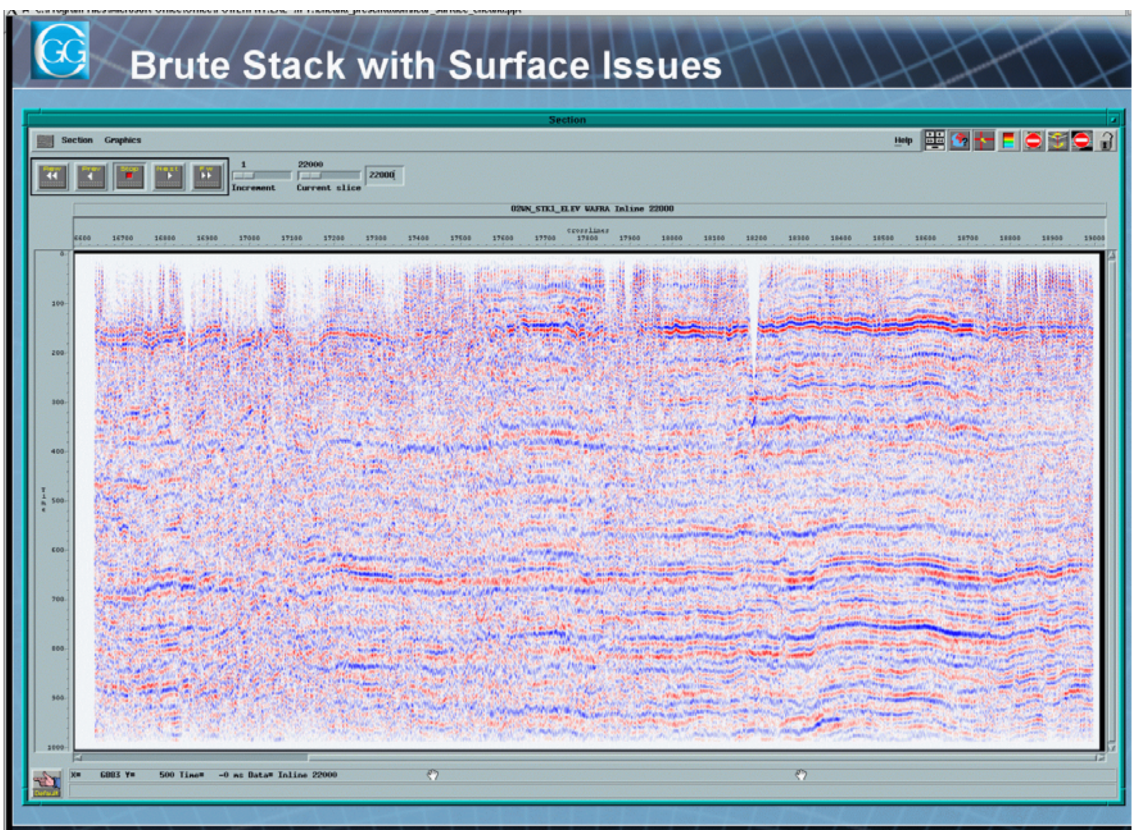
Abstract

Introduction

Near surface anomalies are at the root of virtually all of the problems associated with land seismic data. In particular, these surface conditions (weathering, bogs, swamps, limestone outcrops, rapid changes in elevations, permafrost, dunes, wadis...) introduce large changes in travel times, creating massive distortions in the seismic images.

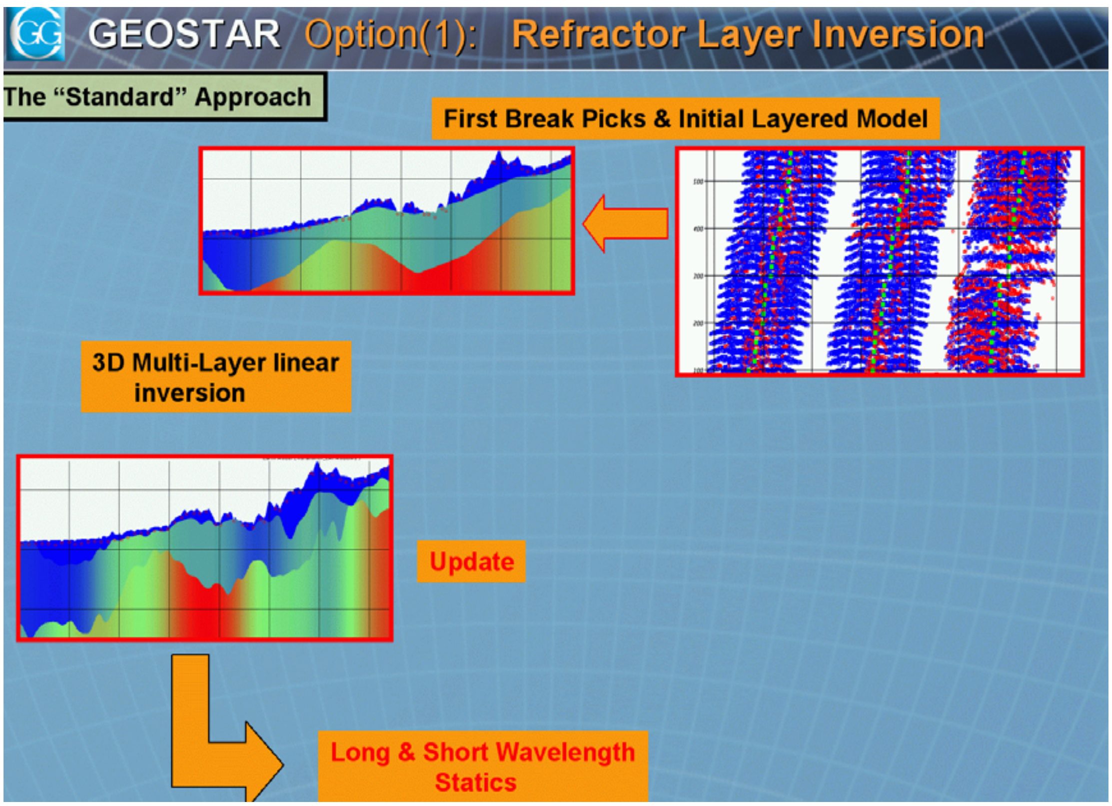


The purpose of this poster paper is to present some of the newer (and older) developments that CGG has been using to resolve these complex problems.

Weathering solutions

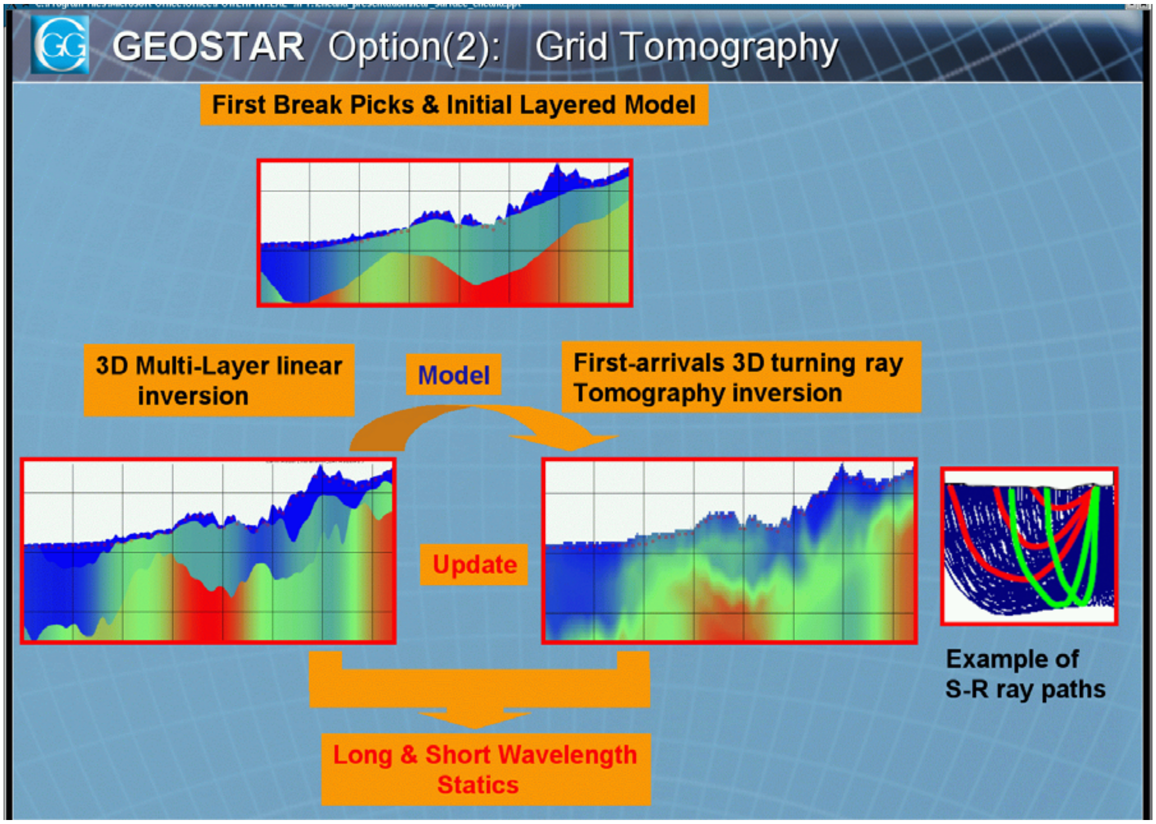
1) Refraction Methods

Surface consistent static solutions are key in these situations. Typically, refraction statics are derived from the picking of first arrivals (first breaks). Relative to the noise-contaminated shallow reflectors, first arrivals are pickable in most situations, and a near surface model can be derived quickly using most "standard" refraction algorithms (GLI, GMG,...). These assume a layered model of the earth, with refractor head waves propagating along locally continuous boundaries. In more complex settings, of course, these simple assumptions break down.



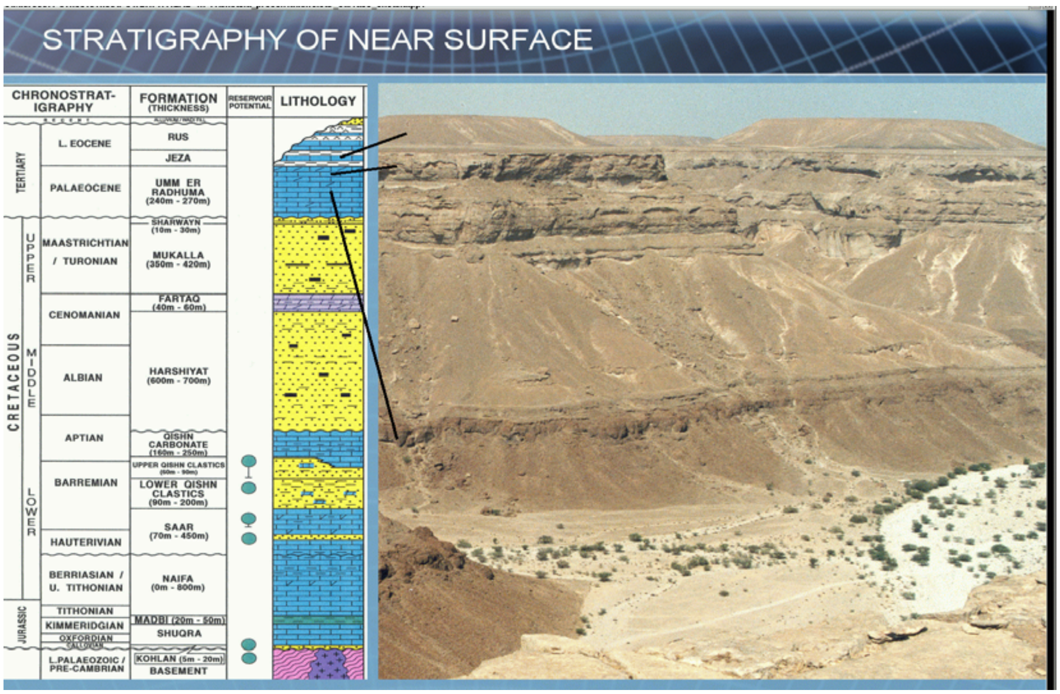
2) Tomographic Methods

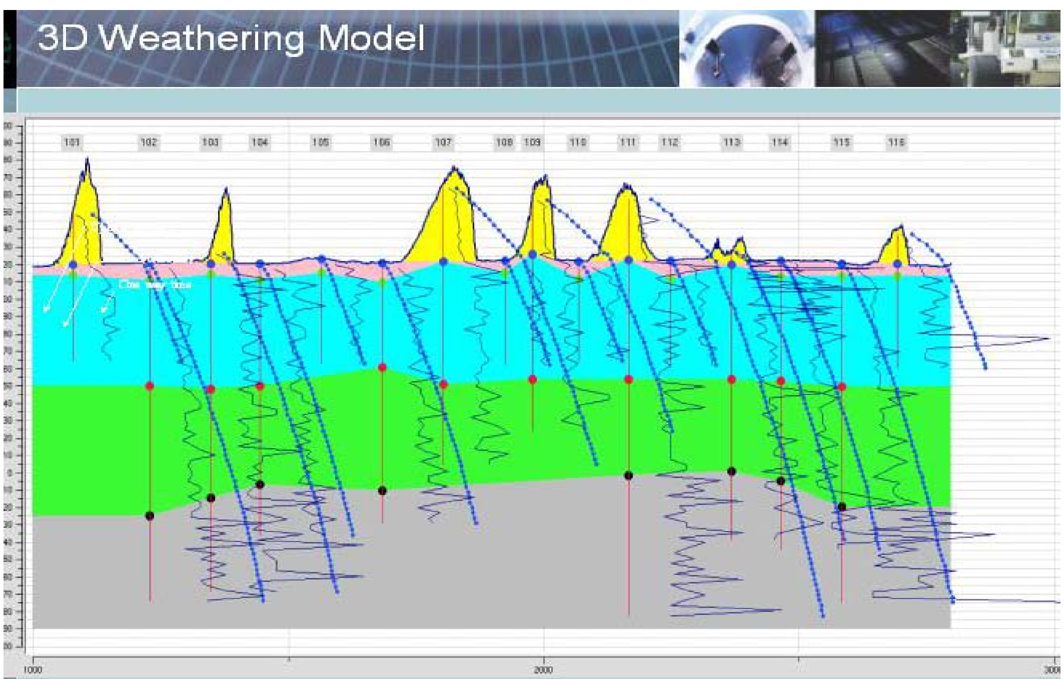
I'll introduce our new Geostar statics package, which incorporates turning-ray tomography into its inversion engine. The near surface medium is divided into cells (grids), and a velocity is inverted uniquely at each location. The methodology is similar in concept to a PSDM depth inversion. These methods essentially try to predict the observed travel times (of the first arrivals in this case) with the generated model. A finite-difference Eikonal solver allows fast and accurate estimations of first-arrival travel times for transmitted, diffracted, or head waves, even for a very complex medium. The accuracy of this near surface velocity inversion is especially important for PSDM, where it can become the starting point for its velocity field. Of course, for time processing, static corrections are done simply by applying the vertical time difference between that inverted surface model and a single constant velocity layer.



3) Surface Modeling Methods

In a lot of situations, unfortunately, first breaks can be virtually impossible to interpret and pick. To correct for these cases, CGG has developed a unique way of creating a weathering model based on the combination of all available information at the time of processing. The geological information (such as outcrops), satellite maps, up holes, check shots, and well information are all used to create an accurate model of the near surface. Examples from around world will be shown.


STRATIGRAPHY OF NEAR SURFACE
CHRONOSTRATIGRAPHY
FORMATION (THICKNESS)
RESERVOIR POTENTIAL
LITHOLOGY
TERTIARY
L. EOCENE
RUS
JEZA
PALAEOCENE
UMM ER RADHUMA (240m - 270m)
SHARWAYN (10m - 30m)
CRETACEOUS
UPPER
MAASTRICHTIAN / TURONIAN
MUKALLA (350m - 420m)
FARTAQ (40m - 60m)
CENOMANIAN
MIDDLE
ALBIAN
HARSHIYAT (600m - 700m)
APTIAN
QISHN CARBONATE (160m - 250m)
UPPER QISHN CLASTICS
LOWER
BARREMIAN
LOWER QISHN CLASTICS (90m - 200m)
HAUTERIVIAN
SAAR (70m - 450m)
BERRIASIAN / U. TITHONIAN
NAIFA (0m - 800m)
JURASSIC
TITHONIAN
KIMMERIDGIAN
OXFORDIAN
MADBI (20m - 50m)
SHUQRA
L.PALAEOZOIC / PRE-CAMBRIAN
KOHLAN (5m - 20m)
BASEMENT


3D Weathering Model
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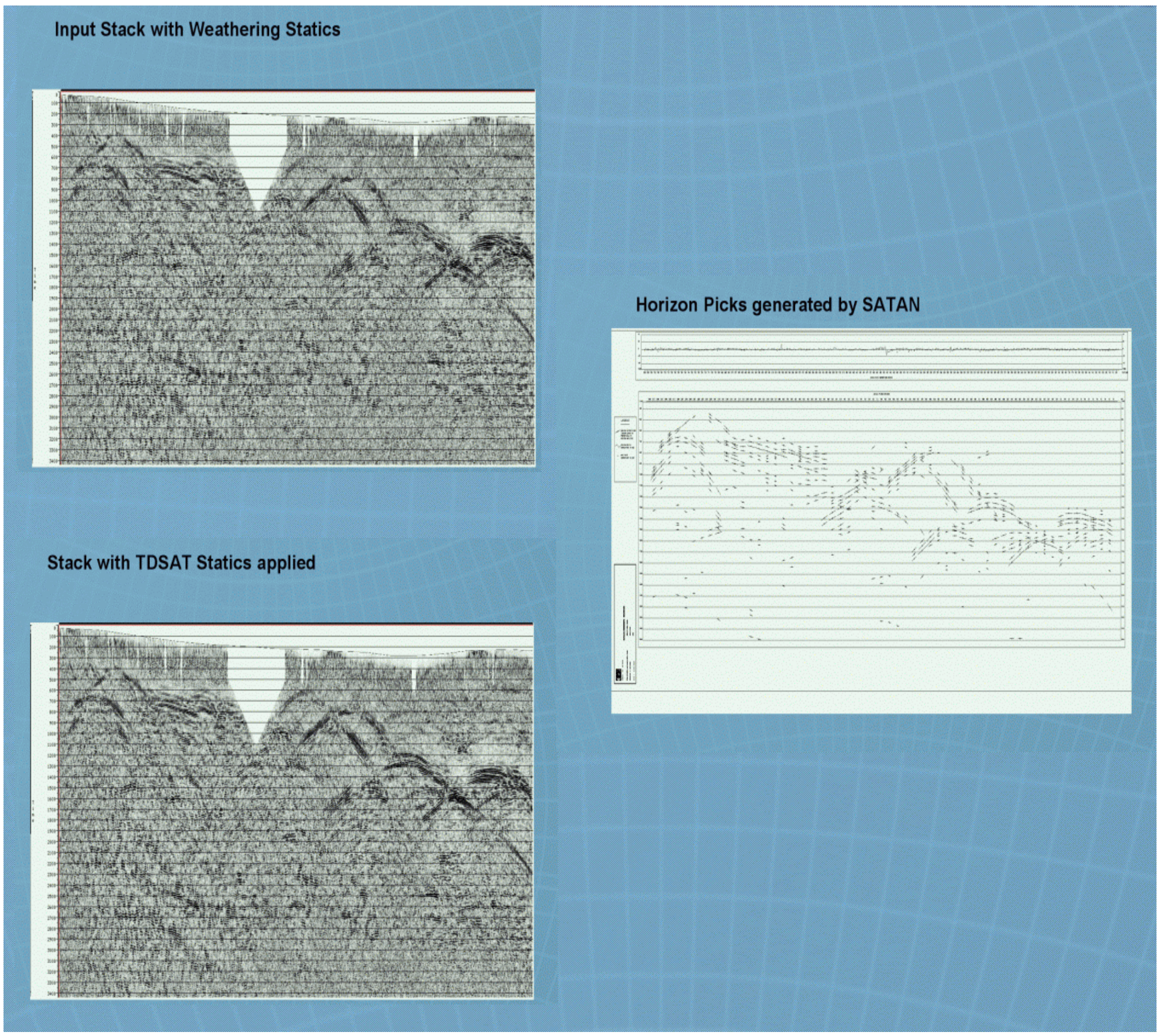
116
1000
2000

Reflection statics algorithms:

1) TDSAT

For years, CGG's standard residual reflection statics package has been a rather unique one called TDSAT.

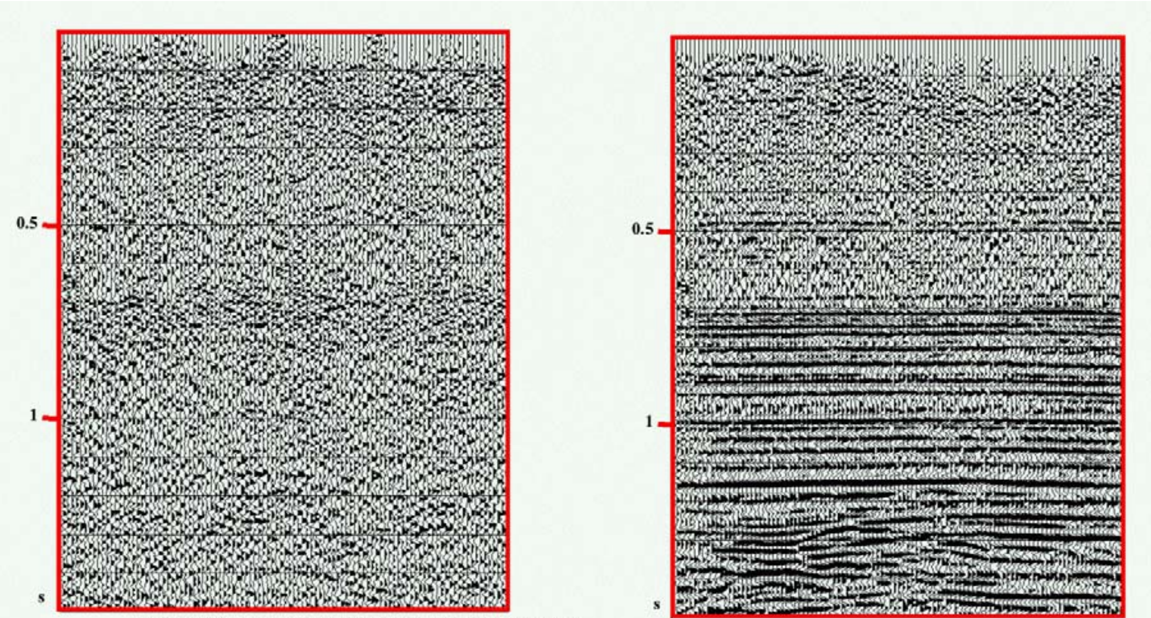
This algorithm automatically picks out the most coherent horizons in the section and windows them for statics analyses. These horizons can cross each other, disappear, reappear; it's essentially what's made CGG so effective in the foothills and other areas with complex structures. However, the program is not designed to correct for large static anomalies or long wavelength statics.



2) GeoPACS

Long wave and large magnitude statics require a new algorithm. NMO errors, the influence of acquisition geometry, and even the statics themselves limit the span of the search for large statics, generating `cycle-skips'. As part of the new statics workstation mentioned above (Geostar), a rather unique approach has been developed for residual reflection statics. Instead of a pilot trace model, cross correlations are computed trace to trace around a dynamic horizon tracing. Perhaps more importantly, not just S.C. residual source and receiver statics but also velocities are resolved simultaneously. These properties result in the possibility of reaching large and stable static values (2-3 times the inherent wavelength of the seismic data).

Geostar has been used successfully to solve for large statics anomalies; cases studies from permafrost, glacial overburden, heavy oil projects (including converted wave data), dunes, and swamps will be shown.



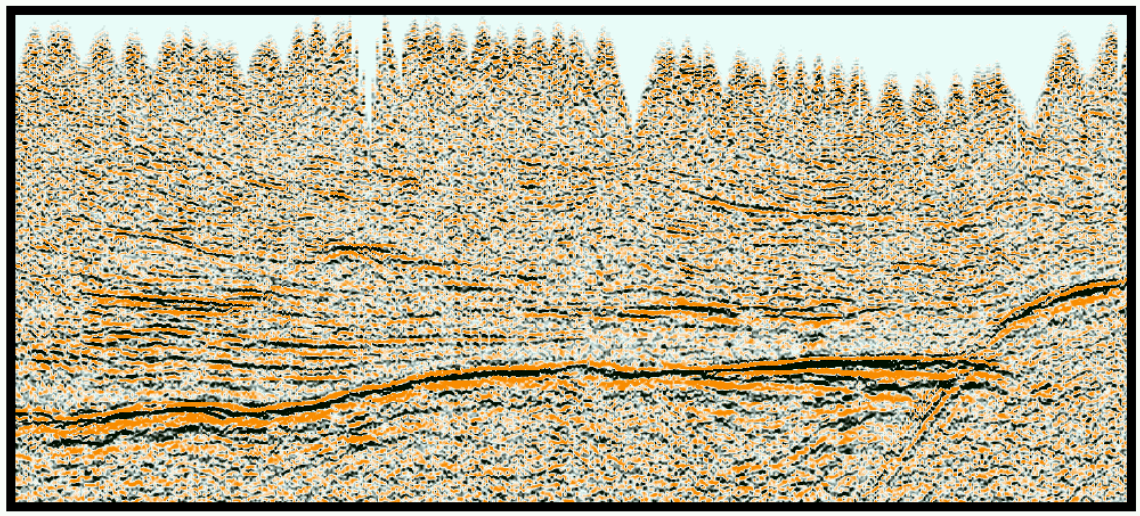
Stack after the application of a random perturbation on shot and receiver statics (from –50 ms to +50 ms).

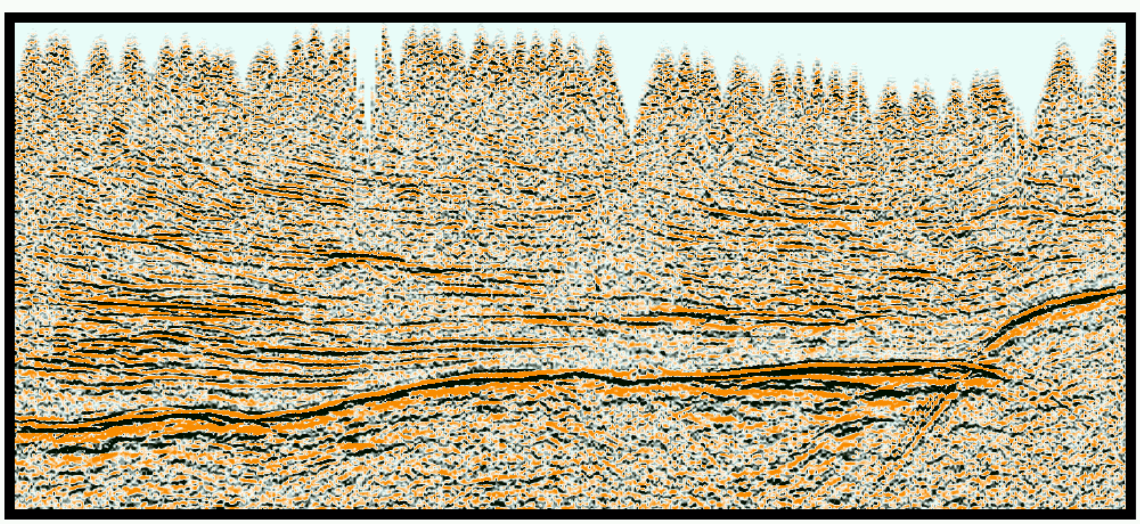
: Stack after the estimation of the random perturbation on shots and receivers .

3) Monte Carlo Statics

This is a very new approach to S.C. residual statics, developed recently here in Calgary. Virtually all current residual statics programs attempt to “tweak” the data via linear inversions to produce a better quality stack. This new approach instead uses a non-linear Monte Carlo engine in an attempt to find the best stack via simulated annealing. It’s been over fifty years since Metropolis first introduced the basic concept for a chemistry problem. The low cost and fast computational speed of today’s PC racks makes this finally an economical possibility. David LeMeur will present a paper at this convention detailing his research and results: “Monte Carlo Statics: The Last Frontier”.

Stack with conventional statics





Stack with Simulated Annealing, Monte Carlo-Derived statics

References

Improta L., Zollo A., Herrero A., Frattini R., Virieux J., Dell'Aversana P., 2002. Seismic imaging of complex structures by non-linear traveltime inversion of dense wide-angle data: application to a thrust belt, Geophys. J. Int. 151, 264-278

Marsden, D.,1993, Static corrections – a review, partIII: The Leading Edge, 12, 210-216.

Metropolis, N., Rosenbluth, A., Rosenbluth, M. Teller, A., Teller, E., 1953. Equation of state calculations by fast computing machines, J. Chem. Phys., **21**, 1087-1092.

Rothman, Daniel H., 1986. Automatic estimation of large residual statics corrections, Geophysics, Vol 51, No. 2 (February 1986); p. 332-346.

Sheriff, R.E, 2002, Encyclopedic Dictionary of Applied Geophysics, fourth edition, SEG.

Taner, M. T., Koehler, F., and Alhilali, K. A., 1974, Estimation and correction of near-surface time anomalies: Geophysics, 39, 441-463.

Wiggins,R. A., Larner,K. L., andWisecup,R.D., 1976, Residual statics analysis as a general linear inverse problem: Geophysics, 41, 922-938.

Vasudevan, K., Wilson, W. G., and Laidlaw, W. G., 1991. Simulated annealing statics computation using an order-based energy function, Geophysics, VOL. 56, NO. 11 (November 1991); p. 1831-1839.