Realistic Interpolation of Buried Channel Systems within the New Jersey Geoclutter Natural Laboratory

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LONG-TERM GOALS

To understand, characterize, and predict lateral and vertical, naturally-occurring heterogeneities that may produce discrete acoustic returns at low grazing angles (i.e., "geologic clutter") in a mid-outer shelf test site off the U.S. (New Jersey). Also, conduct precise acoustic reverberation experiments at this site to understand, characterize, and potentially mitigate the geologic clutter, so that the false alarms, or detects, of tactical sonar systems encountered in this marine geologic environment around the world can be characterized properly.

OBJECTIVES

The primary objective of this effort is to conduct geostatistical modeling that will be essential for transitioning from STRATAFORM products to Geoclutter needs. One of my primary STRATAFORM tasks was to develop a means to realistically interpolate stratigraphic architecture from limited data, which resulted in the "SimStrat" algorithm (Goff, 2000). Ultimately this work is intended to facilitate acoustic reverberation modeling in the shallow water environment. With the Geoclutter initiative, a collaborative effort among ONR geophysicists and acousticians to understand signal-like reverberation in the natural environment, this goal is on the verge of being fully realized. The New Jersey STRATAFORM natural laboratory has also been chosen for the Geoclutter field work, in part because of the abundance of data already available, and also because of the complexity of the seafloor and subseafloor environment. In particular, numerous buried channels just meters below the seafloor are probable candidates for "geoclutter"-type returns. This "channels" horizons is very complex in nature, and not readily modeled within the SimStrat framework. The goal here is therefore to expand my STRATAFORM modeling efforts to incorporate channels-type horizons.

APPROACH

SimStrat is intended to work on continuous or nearly continuous sets of stratigraphic surfaces (simple truncations and faults could be handled with some straightforward adaptations). While this is true of most stratigraphic horizons, channeled horizons are notable and critical exceptions. As revealed on the New Jersey margin seismic data (Figure 1), the channels horizon is highly discontinuous, existing only where the channels themselves exist. Furthermore, these channels clearly form a dendritic pattern – which is not reproducible with the usual suite of geostatistical simulation methods, one of which (the Fourier method) is used in SimStrat. A different approach to simulating this type of surface is required.

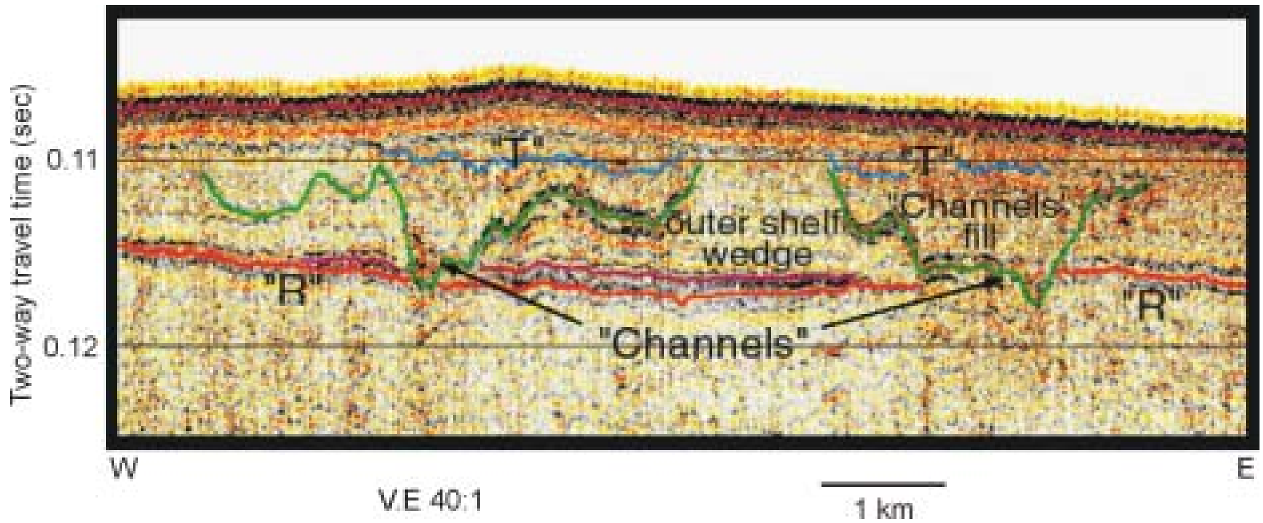

Figure 1. Huntec seismic profile on the New Jersey middle shelf, in ~80 m of water. Horizon interpretations are from Duncan et al., 2000.

A channels-type horizon, with dendritic pattern and patchy existence, is not amendable to the SimStrat algorithm because it cannot unconditionally or conditionally be simulated by conventional geostatistical techniques. An entirely new method for interpolation must be found for such morphologies. Process-based approaches could potentially work, but the goal here, as with SimStrat, is to base the conditional simulation only on geometric and statistical considerations; we seek speed and simplicity as well as realism.

In the New Jersey channels horizon, each channel can be considered an independent surface until it merges with another channel. Owing largely to this observation, the best approach to interpolating a channels horizon from limited sampling (Figure 2 is an excellent example) is to conditionally simulate each channel separately. This approach will greatly simplify the problem by breaking it down into manageable parts, but it will also require sufficient sampling density so that each primary channel can be individually discerned and traced through the interpolating region. On the other hand, with any less data an interpolation of channel morphology would be far too fictitious to merit use.

For each channel that can be traced (e.g., Figure 2), I will transform all seismic data crossing that channel into a new coordinate system consisting of length along and distance across the thalweg of the channel, which itself must be interpolated from limited sampling. This will remove the sinuosity of the channel from the problem, and allow interpolation by conventional interpolation or geostatistical means. Channel definition can be enhanced by separately picking the thalweg and edges at each seismic crossing, and interpolating these along the channel axis prior to full 2-D interpolation. Transforming back into real space will complete the full interpolation of the channel. Merging of channels can be accomplished by a maximum depth criterion. The New Jersey seismic data, which are fully processed and in hand, will serve as the test case for the channel interpolation algorithm. In addition, the “R” horizon will be interpolated, using methods already established, to provide a complete stratigraphic model of the area of importance to the Geoclutter program.

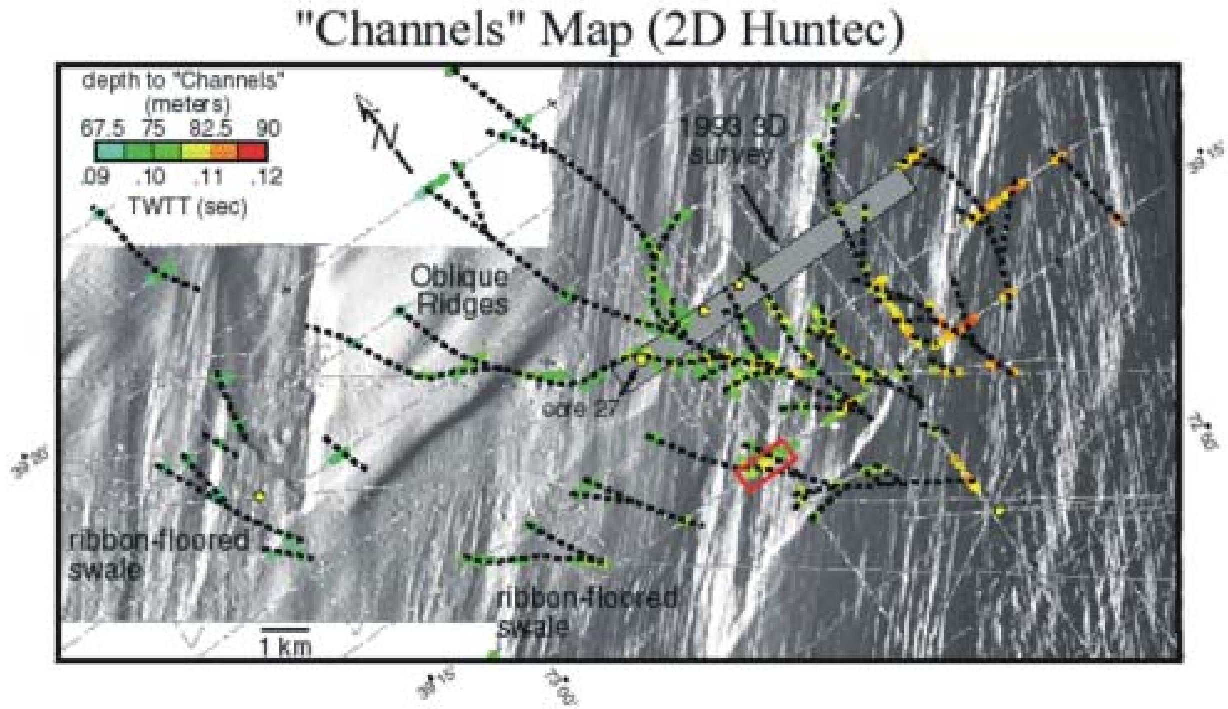

Figure 2: Map of "channels" horizon on the New Jersey shelf overlain on STRATAFORM bathymetry. Dashed lines show interpretation of the drainage system. Note complete lack of correlation between bathymetry and channels morphology. From Duncan et al. (2000)

WORK COMPLETED

The channel interpolation algorithm, conforming to the approach described above, was completed in the Spring of 2001. The NJ shelf STRATAFORM Huntec data in the vicinity of the data shown in Figure 2 were used as a test case to demonstrate the program's utility.

RESULTS

The test case channel interpolation is shown in Figure 3. The interpolation algorithm proved robust in its application, and very successful in interpolating the channel morphology in the manner desired – that is, a continuous channel-form interpolation along the channel axis, and no values specified in the interfluves where no channel surface was identified in the seismic data. This interpolation is considered highly preliminary, and the methodology is still being developed. For example, greater definition of the highest slopes at the channel banks, an important factor in the acoustic problem, can be accomplished by additionally picking and interpolating a top and bottom to the bank on seismic crossings. Additional data will obviously improve the interpolation. However, recent collection of additional seismic reflection in this region demonstrated that the gross structure of the interpolation in Figure 3 was quite accurate.

The "R" horizon was also interpolated through conditional simulation methodology (Figure 4). This horizon has a gap, which separates it into a dipping surface to seaward, and a more flat-lying surface to landward (Duncan et al., 2000). These different extensions of "R" were interpolated separately, and merged into a single grid. In addition, the values were discarded where the channel interpolation (Figure 3) descended below the “R”.

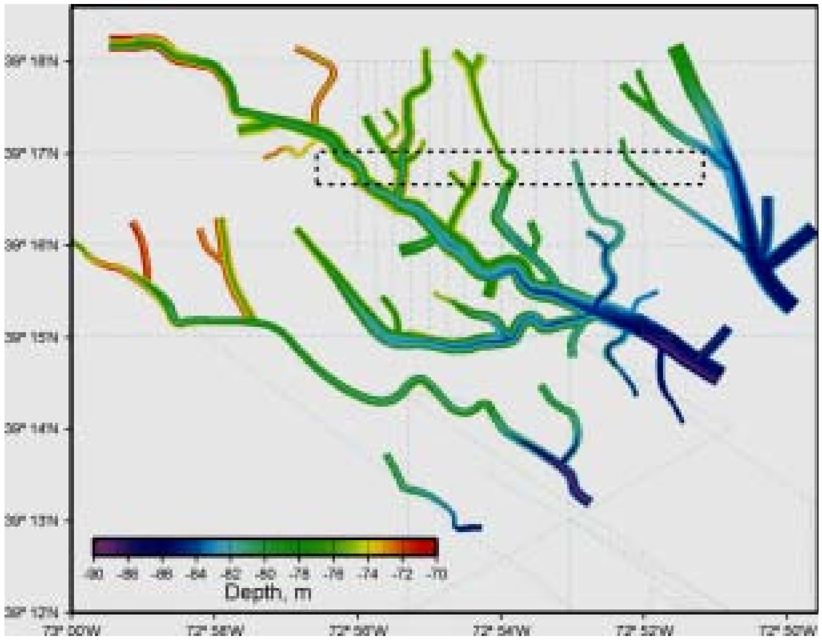

***Figure 3*. Interpolation of channel morphology in the region of densest seismic reflection coverage within the ONR STRATAFORM natural laboratory. Dashed blue lines indicate data coverage. Dashed black lines shows region of 3-D(10 m line spacing) seismic coverage.**

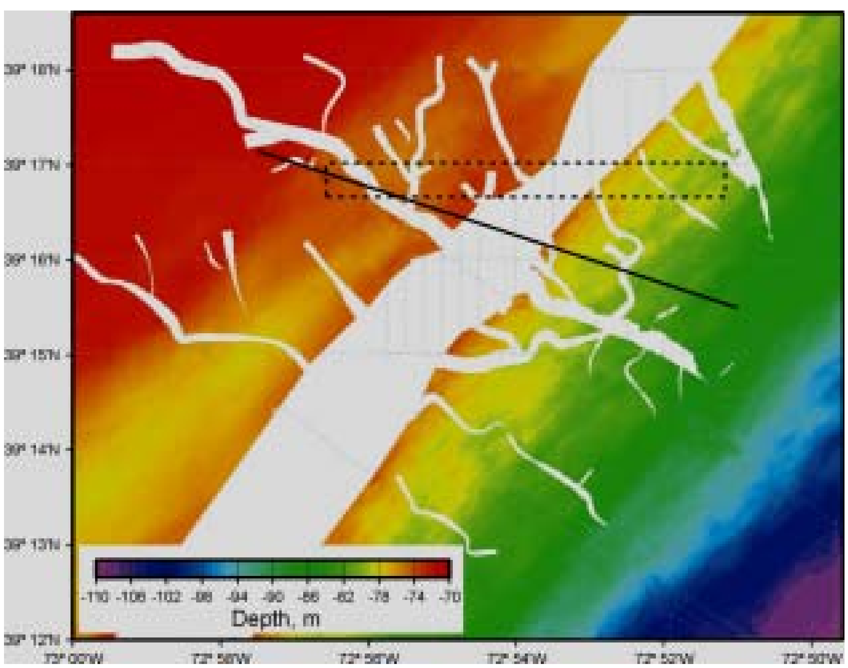

***Figure 4*. Conditional simulation of the ”R” horizon, excluding the gap between seaward and landward extensions, and those areas where the channels interpolation descends below ”R”. Dashed blue lines indicate data coverage. Dashed black lines shows region of 3-D(10 m line spacing) seismic coverage. Solid black line indicates location for Figure 5.**

Along with the multibeam bathymetry, the channels and “R” interpolations provide a complete morphologic model for the shallow stratigraphy within the region examined (the “T” horizon, which is rather ephemeral in the seismic data, will require more data to adequately constrain). Figure 5 displays an example of a cross section through the full model.

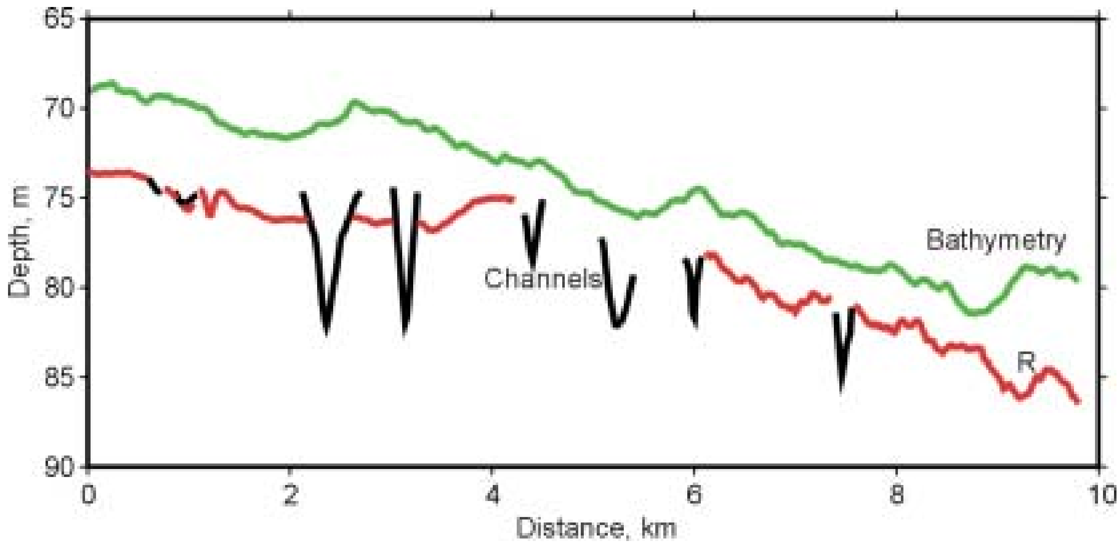

Figure 5. A cross section through the complete stratigraphic model. See Figure 4 for location.

IMPACT/APPLICATIONS

This work has had an immediate impact in the Geoclutter program by fully enabling acoustic reverberation modeling efforts in three dimensions, rather than constrained in 2-dimensions to the orientation of available seismic profiles. These grids were used by Nick Makris in his planning efforts for the Geoclutter acoustic reconnaissance survey in April of 2001. As more geophysical data are collected by the Geoclutter program, these products can be incorporated to produce a refined and more accurate stratigraphic model for the region.

TRANSITIONS

The SimStrat and seafloor conditional simulation programs are being considered by the Navy for applications in minimum data density analysis.

RELATED PROJECTS

The geologic and geophysical components of the Geoclutter program are a direct outgrowth of the ONR STRATAFORM program. Field efforts from the Geoclutter program will also be used as a basis for investigations within the ONR “Uncertainty in the Natural Environment” Defense Research Initiative.

REFERENCES

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