A 3-D GIS and Quantitative Backscatter Analysis in Support of STRATAFORM

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LONG-TERM GOALS

Our long-term goal is to provide the fundamental mapping information and visualization tools necessary to support STRATAFORM's multidisciplinary effort to develop a more complete understanding of how short-term oceanographic and geological processes interact to produce the preserved geologic record on the shelf and slope portions of the continental margins. This effort began with detailed mapping of the bathymetry and backscatter of the STRATAFROM survey areas and is now continuing with the integration of the many data sets collected in the northern California STRATAFORM region into a GIS system that will allow all STRATAFORM researchers (and others) to interactively explore the complex relationships amongst seafloor, water-column, and subsurface parameters in an easy and intuitive fashion.

SCIENTIFIC OBJECTIVES

The fundamental objective of the STRATAFORM Swathmapping Program is **to provide complete (100%) bathymetric and sidescan imagery coverage of the Northern California and N.J. Margin STRATAFORM field areas**. This has allowed STRATAFORM investigators to evaluate the geologic processes of the shelf and slope over a continuum of scales. Complete coverage also has provided STRATAFORM investigators with the knowledge that their studies are based on a complete picture of morphological relationships rather than the interpolation of sparsely spaced data. In doing this, we have produced a bathymetric, geomorphological, and potentially lithological framework upon which all subsequent work can be built. Building on these base maps we are now focussing our efforts on the development of a fully searchable GIS system that will allow us to interactively explore the inter-relationships amongst the many data sets collected by STRATAFORM investigators (as well as others). In particular we are using this approach **to further develop techniques for the remote classification of seafloor materials from swathmapping data** and, **to develop techniques for the interactive 3D visualization of co-registered surficial and subbottom data**.

APPROACH

The original mapping of both the northern California and New Jersey margin STRATAFORM regions was conducted with an EM1000 (95 kHz) multibeam sonar. As compared to conventional echosounders, multibeam sonars provide increased source level, lateral resolution, and a substantial increase in data density and areal coverage. Most importantly, the newer systems also provide the ability to simultaneously produce high-resolution sidescan sonar imagery. We have developed a full suite of real-time and near real-time multibeam sonar processing tools to assure that only high-quality data is collected and that this data can be processed in the field. These tools also allow for the

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interactive 3-D visualization of multibeam data sets and derivative products (Mayer et al, 1997) We are also developing a range of seafloor classification algorithms with particular focus on techniques that look at the characteristics of the returned waveforms as well as the change in backscatter as a function of angle of incidence (Hughes Clarke et al., 1997). We are also exploring the application of the wavelet transform as a means of removing unwanted artifacts from seafloor backscatter data as well as a means of estimating seafloor type (Hou, et al., 1998).. In order to compare the results of these analyses to ground truth data collected by other STRATAFORM scientists and to explore the limits of extracting quantitative seafloor property information from multibeam sonar data, we have, for the northern California survey area, created a very large and graphically explorable data base made up of the wide range of data sets collected in the region.

The data base of information in the northern California STRATAFORM region is immense and disparate, ranging from physical oceanographic time series collected by moorings, to multichannel seismic data to backscatter and bottom photos. Our approach to understanding the complex inter-relationships of these data (and thus the potential for using remotely derived data sets like acoustic backscatter to understand the distribution of lithologies and seafloor processes) has been to treat each data set as an individual layer or theme and bring the data into a Geographic Information System. Once each layer is fully georefenced and all geodetic corrections (projections, datums, etc) applied, we then have the ability to interactively select, explore, retrieve and display the data sets in any combinations we desire. For example we can easily look at the relationship of sediment porosity as measured on cores (or many, many other parameters) to acoustic backscatter. We have also extended the ability of the standard GIS environment to allow us to not only import data layers but to link these layers to the actual data sets (i.e. down-core property plots or even seismic data). Finally we have begun to develop a true 3-D environment for this data base so that this same sort of interaction can be done in 3-D and thus interproperty relationships can be explored within the complex of the 3-D morphology.

WORK COMPLETED

In 1995 and 1996, we completed mapping of the Calif. and most of the N.J. survey areas. In 1997 we completed the remaining deep-water portion of the N.J.study area, processed these data and merged them with the shallow water data. We also processed additional multibeam (Hydrosweep) data from the Eureka area collected by Clark Alexander. We merged this data with the earlier data sets and made the new maps available to all STRATAFORM investigators. Our more recent efforts focus on data integration, visualization and particularly on the question of remote seafloor classification. We have finalized interactive 3-D fly-throughs of both the N. J. and California margins (Mayer, et al., 1997) and have developed a suite of automated algorithms for extracting and parameterizing the backscatter as a function of angle of incidence (Hughes Clarke, et al., 1997). We have completed the software necessary to bring fully georeferenced high-resolution seismic data into our 3-D visualization package. Our focus for data integration and sediment classification studies has been the Eureka margin. Our GIS data base now includes 62 layers (including several types of seismic data, gas abundance data, core and camera station data, geologic, tectonic and hazard maps, bathymetry and backscatter from a number of systems, satellite imagery, mooring data, etc.) (Fig 1). It will be distributed to STRATAFORM investigators on CD in December; graduate student Miguel Pancheco has developed software that will allow all those receiving the CD access to all features needed to explore the data base without the need to purchase a GIS system. We have completed the algorithms for the application of tree-structured wavelet transforms to multibeam sonar backscatter data and applied these transforms to data from the Eureka margin (Hou, and Mayer, 1998); we have begun to bring the various data layers (including seismic data into the 3-D environment (Fig 2). We have also supported the efforts of other Strataform investigators (Flood, Nitterour, etc.) by providing installation and operating advice as well as software for the processing and visualization of data collected by the new DURIP-purchased EM3000 multibeam sonar. This system has now successfully been used for a variety of programs including shallow water mapping in both the N.J. and California STRATAFORM field areas and off Panama City Florida in support of a Navy DRI.

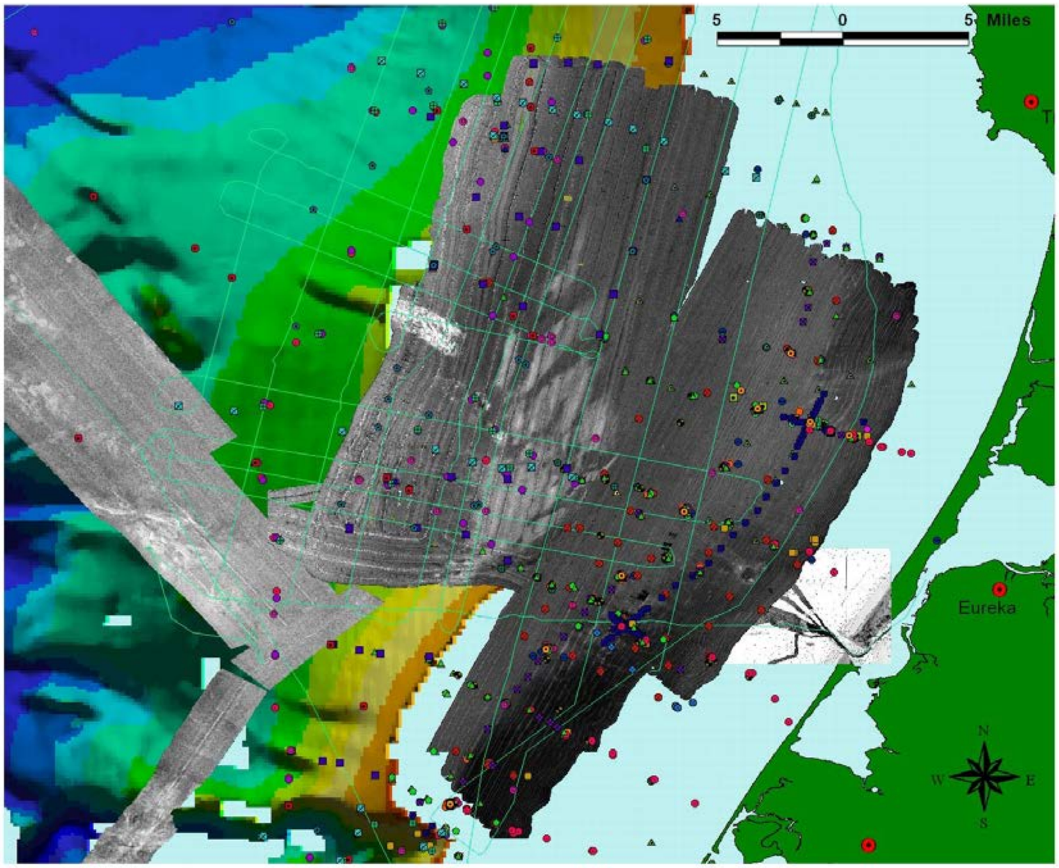

Figure 1. Example of a small subset of the Eureka area GIS. Layers displayed are Seabeam bathymetry, EM1000 backscatter, EM300 backscatter, core sites, photo locations, Huntec seismic lines.

RESULTS

Numerous insights have been derived and papers written from the multibeam data. Our parameterization of the angular backscatter response curve appears to be a sensitive indicator of changes in seafloor type or texture. In particular, the shape of the curve below 40° is especially revealing as response in the vicinity of the critical angle may be observed. The wavelet transform has proven to be a robust technique for the removal of artifacts from backscatter data. Backscatter data characteristically is degraded by ship-track parallel artifacts that are the result of the incomplete correction for specular energy at nadir (i.e., the lack of sidescan at nadir). These artifacts are easily identified as "channels" at certain levels of the wavelet transform and thus easily removed. Once the artifacts are removed we can continue to use the wavelet transform to identify regions of characteristic backscatter statistics that we then relate to changes in seafloor roughness. We are using quantitative roughness data provided by other Strataform investigators to ground truth these studies. The 2-D and

3-D GIS approach has allowed us to rapidly and efficiently explore the inter-relationships amongst seafloor properties and backscatter. The work of graduate student Jose Vicente Martinez is demonstrating that mean backscatter may be a relatively good predictor of grain size and the work of graduate student Sean Galway has demonstrated the feasibility of using interactive 3-D exploration to evaluate the relationship of subsurface features (from seismic data) with surficial morphology (Fig 2).

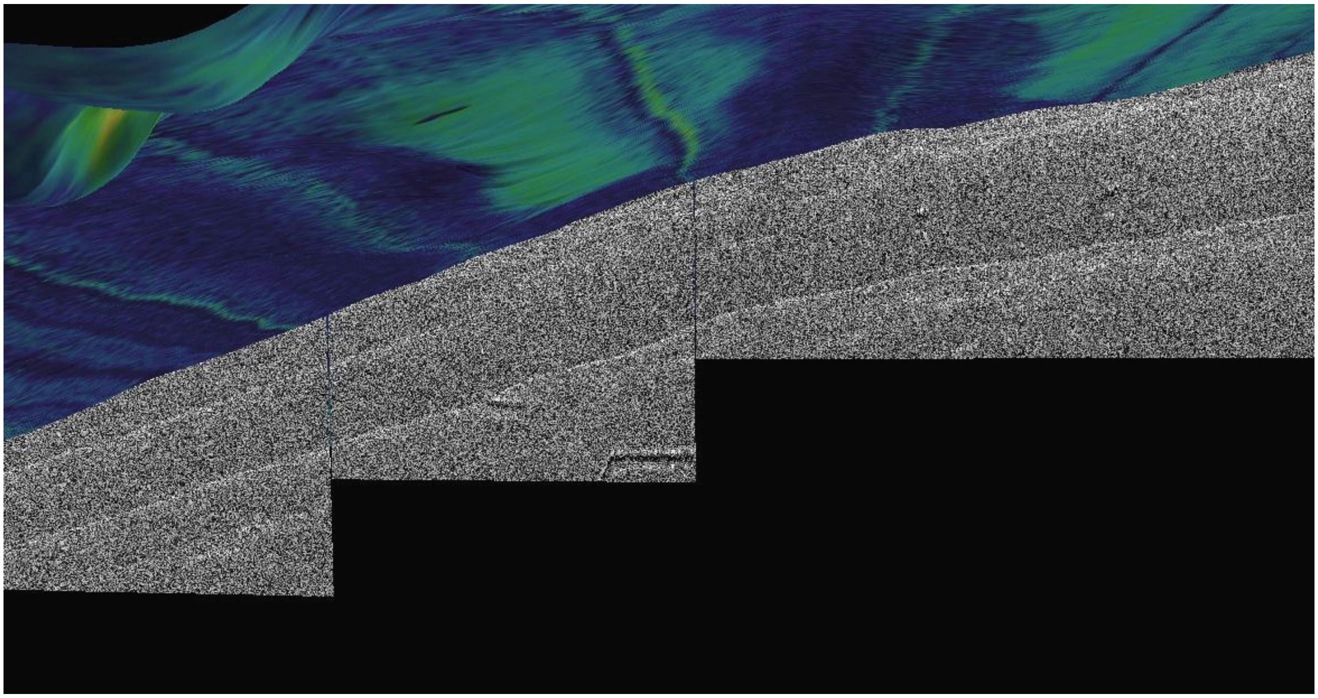

Figure2. Huntec seismic profile as seen in interactive exploration of 3-D scene viewed from below the surface. Surface is seafloor bathymetry with acoustic backscatter (light color represents high backscatter) draped on it.

IMPACT/APPLICATIONS

The swathmapping results from the Eureka and the N. J. margins provide all STRATAFORM investigators with an unprecedented, detailed look at both the bathymetry and distribution of sediments on the shelf and slope. These results have already been used in planning the deployment of a series of long-term moorings, seismic profiling and coring cruises, as well as for planning ROV, submersible work, and ODP sites. The GIS that we will distribute will allow all investigators to integrate a massive data set in an intuitive and interactive manner and should be a building block for many future studies. Quantitative measurements of slope and sediment-type distributions will inevitably lead to improved models of shelf and slope development, the primary goal of the STRATAFORM program. Our initial results from the New Jersey margin indicate that pervasive ice scouring is evident further south than previously reported and may have impact on our overall understanding of the evolution of shelf stratigraphy. The ability to interactively explore large and complex data sets in a 3-D GIS will greatly facilitate our understanding of the seafloor processes at work in the Strataform areas and particularly their relationship to seafloor morphology. In addition, through the use of backscatter as a function of angle of incidence and wavelet transforms we hope to provide a new and rapid means of exploring lateral changes in seafloor roughness and composition.

TRANSITIONS

Our maps and data have been used by numerous investigators both in and out of STRATAFORM, including several other Navy programs (e.g., SWARM, NRL). Our processing and visualization software is being used by NAVO, NRL, NOAA, USGS, the Canadian Hydrographic Service, the Royal Australian Navy, as well as a number of universities and private sector companies (Shell, Exxon, Woodside Petroleum, WAPET Petroleum).

RELATED PROJECTS

NSERC Chair in Ocean Mapping – a consortium of 14 sponsors that provide base support for general research in the field of ocean mapping. DURIP sponsored multibeam sonar at SUNY Stony Brook (with Roger Flood – SUNY Stony Brook and Dale Chayes LDEO). “High-resolution Bathymetry and Backscatter of a High-Frequency Acoustics Test Area” – work of Panama City with Roger Flood.

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