Further Investigation of the Eel River Shelf Resistivity Structure

Rob. L. Evans
Department of Geology and Geophysics
Woods Hole Oceanographic Institution, Woods Hole, MA 02543.
phone: 508-289-2673 fax: 508-457-2150 e-mail: evans@hades.whoi.edu

Award#: N00014-98-1-0507

LONG TERM GOAL

Maps of sedimentary physical properties are essential to a complete understanding of processes shaping the continental shelf. We have demonstrated that measurements of electrical resistivity can provide exciting new insights into shelf structure. But there is more work to be done in tying results of electromagnetic (EM) studies to those of more conventional surveys such as the extensive coring efforts on the Eel River shelf, high resolution seismic reflection profiling and surficial acoustic backscatter measurements. Through these efforts we can increase the amount of information extractable from an EM data set and therefore improve our understanding of sedimentary processes.

OBJECTIVES

- Providing insights into inverting seafloor EM data through a comparison of in-situ resistivity profiles and cores: approaches to inversion, choice of norm and misfit criteria.
- Understanding the cause of anomalously high resistivities seen in one area of the Eel River shelf
- Understanding the links between the present day surface expression of the Eel River subaqueous delta and a spatially coincident buried resistive layer seen in EM surveying.

BACKGROUND

An EM data set was collected in the Eel River shelf STRATAFORM region. The methodology of the EM experiment and the data collected have been presented in Evans et al., (in press). Briefly, the survey used a seafloor frequency-domain EM system developed by the Geological Survey of Canada. The system is a 50m-long array which is dragged along the bottom. Three receivers measure the magnetic field generated by a transmitter at the front of the array. Each receiver (4m, 13m and 40m behind the transmitter) provides structural information over a depth interval approximately one-half the distance between source and receiver. As the system is towed, it measures resistivity profiles to a depth of 20m beneath the seafloor. The resistivity profiles measured along a tow-line can be interpreted in terms of sedimentary porosity, identifying structures with horizontal length scales on the order of 100m.

Continuous resistivity profiles to 20m below the seafloor were measured along 120km of tow-line, from water depths of 100m to around 30m. The shallow structure along the shelf was seen to be highly variable and three distinct environments based on the recorded resistivities were identified.

Cores collected across the shelf coincide with two of the regions, a mid-shelf depocenter, and the subaqueous delta of the Eel River. The depo-center is characterized by a thin (~2m), moderately high

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **1998**	2. REPORT TYPE	3. DATES COVERED **00-00-1998 to 00-00-1998**

4. TITLE AND SUBTITLE **Further Investigation of the Eel River Shelf Resistivity Structure**	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Woods Hole Oceanographic Institution,Department of Geology and Geophysics,Woods Hole,MA,02543**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR’S ACRONYM(S)
	11. SPONSOR/MONITOR’S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES
See also ADM002252.

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**4**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

porosity (45-60%) surface layer which overlies a less porous (35-45%) and homogeneous substrate, uniform both laterally and vertically. This region is roughly coincident with recent flood deposits (Wheatcroft et al., 1996). The subaqueous delta features a buried resistive layer at a depth of about 5m and with a thickness of between 5-10m, beneath which resistivities decrease. A third region was seen close to the shore (in water depths of less than about 65m) and contains extremely high resistivities for a marine sedimentary environment with extremely variable structure, on wavelengths of a few hundred meters.

The extensive coring that has been carried out in this region, also as part of STRATAFORM, allows us to directly compare the non-invasive field data with porosity profiles from cores. Particular issues we can evaluate are: (1) How well do EM data represent the seafloor structure seen in cores? (2) How is this representation influenced by choice of model norm in the inversion? And (3) what misfit criteria between the model response and the data provide optimal agreement between the model and the core profile?

APPROACH

There are several approaches adopted by the geophysical community when faced with providing resistivity profiles from field data. These include finding minimum norm, or structure, models that satisfy the data by choosing to fit data to a pre-specified tolerance level. In practice, we rarely have ideal error statistics on field data, and so the choice of misfit criteria can quickly become arbitrary. How should we choose between smooth models that have slightly different misfits but which have significantly different structure? Is a single misfit criteria good enough as a discriminator between models?

An additional issue arises over the choice of model norm to be minimised. The Occam method (Constable et al., 1987) allows minimisation of the 1st and 2nd derivative of the L2 norm of the model. There has been debate in the community over the ability of these kind of smooth models to represent real earth structures. While these models were introduced as a means of avoiding over-interpretation of the more traditional blocky, layered models, recent optimisation schemes have sought to produce L1 norm minimised models consisting of the least number of layers required to satisfy the data.

In order to invert data for resistivity depth profiles, we combine data from adjacent stations so that we have 9 adjacent measurements of amplitude and phase. The core profiles against which we have compared our inversion results extend no deeper than about 5m, and so we have chosen to invert only those amplitudes and phases that have sensitivity over a similar interval. This means that we have inverted data at all three frequencies recorded by the 4m receiver, as well as the two highest frequencies recorded on the 13m receiver, giving a total of 10 independent data values.

We then invert these values for layered earth structures that are regularised in that we seek model norms that are minimised in some way. There are several approaches adopted for minimizing model norm. The conventional approach minimises the L2 norm of either the first or second derivative of the model. This approach, often referred to as an Occam inversion (Constable et al., 1987), returns either the flattest (1st derivative smooth) or least oscillatory (2nd derivative smooth) model which satisfies the data (i.e., fits to a desired tolerance). Errors in the measurements are obtained during the calibration run and are based on the variance in repeat measurements at each receiver. Such errors will not account for other distortions in the data that may arise from two- or three-dimensionality in the seafloor structure (e.g., large lateral gradients in properties) nor from other sources of instrumental noise such as the source or receiver leaving the bottom.

ACCOMPLISHMENTS AND RESULTS

(1) Inversion Results: The nature of the Occam search through model space allows us to seek optimally smooth models over a decreasing range of target misfit values. By so doing, we can examine the changes in models as the fit between the model response and the data is improved as well as the changes in agreement between the core profiles and the model returned.

We have inverted data located close to 10 cores. We systematically decreased the target misfit in the Occam algorithm and show the returned 1st and 2nd derivative smooth models. The first point of note is that for Gaussian errors, we should expect an RMS misfit of 1.0. In none of the cases we have examined is a misfit of 1.0 achievable with any reasonable model, indicating that our error estimates are certainly not ideal.

The second qualitative observation is that as the misfit is decreased, the agreement between the returned model and the core profile generally improves near the seafloor, but worsens towards the base of the model. In order to understand this phenomena we need to closely examine the misfits and residuals between sub-groups of the data.

Despite these issues, the agreement between core porosity profiles and the EM data is strong and suggests that the EM data provide a reliable measure of subsurface porosity.

(2) Cause of Anomalously High Resistivities: In our manuscript describing the preliminary results of the 1996 Eel Shelf cruise (Evans et al., in press), we speculated that the cause of high resistivities seen in one region of the inner shelf might be due to either gas, fresh water or authigenic carbonates deposited by gas seepage. Recent seismic data collected by Neal Driscoll show a major anticline system beneath the zone of high resistivities only a few meters below the seafloor. Since these data are new, we do not yet know the exact spatial correlation or inter-relationships between the two phenomena (i.e. anticline and high resistivities) but will examine this over the next few months.

(3) Structure of the Eel River Subaqueous Delta: An observation from previous studies is that the Eel River subaqueous delta is characterised by a low amplitude acoustic backscatter: the opposite of what is expected of a coarse grained deposit. Furthermore, the delta is underlain by a more or less uniform buried resistive layer about 5-10m thick and buried at a depth of about 5m below the seafloor. As with the highly resistive zone, new seismic reflection data will allow us to place further constraints on this region. Core profiles suggest the presence of gas within this region. We are developing a model that can explain all of these observations.

IMPACT/APPLICATIONS

The ability to invert field data where there are numerous ground-truth profiles against which to test results provides a powerful means of assessing the validity of many assumptions that are often taken for granted. It also gives us strong evidence of the reliability of the non-invasive EM technique as a means of mapping porosity. The results of our inversion study should prove useful not only in as far as they help us understand the Eel shelf structure, but will also have ramifications for a larger circle of geophysical studies.

PUBLICATIONS

Evans, R.L., L.K. Law, B. St. Louis, S. Cheesman and K. Sananikone, The shallow porosity structure of the Eel shelf, northern California: results of a towed electromagnetic survey. Marine Geology, 154, (in press).