An EM Survey Around the Martha's Vineyard Observatory

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LONG-TERM GOALS

To use the electrical structure of the seafloor to infer critical physical properties such as sediment porosity and permeability and to understand the distribution of these properties in terms of the regional geology.

To examine links between acoustic backscatter properties of seafloor sediments and electrically inferred porosities, using porosity and sediment grain size distributions measured in cores as groundtruth information.

To map variability in the electrical structure that might be due to fresh water discharge across the continental shelf.

OBJECTIVES

To date, we have collected EM data in three ONR funded cruises using a system operated by the Geological Survey of Canada. We aim to complete a fourth survey off Martha's Vineyard Massachusetts in the vicinity of the newly installed seafloor observatory (MVO), using a new system under construction at WHOI.

The proposed survey area has been and will continue to be mapped with a number of tools including sidescan sonar, acoustic backscatter, chirp seismics and coring. Our previous surveys have demonstrated the utility of adding electrical measurements to this suite, both from a structural viewpoint and also in terms of studying variability in surficial sediment. In terms of shallow resolution, the system is able to identify high porosity deposits extending a few tens of centimeters into the seafloor and provides a low-pass filtered version of the shallow porosity structure. Given that the system has reasonable resolution near the seafloor, and that the shallowmost apparent porosity is biased by the shallowmost structure, we have investigated links between apparent porosities and acoustic backscatter. Others have suggested the difficulty of using acoustic backscatter as a sole determinant of sediment type: we suggest that porosity estimates from EM surveys might provide a useful additional constraint allowing more accurate sediment classification over large areas (Evans, in press).

We have also demonstrated the ability of the EM techniques to delineate channel features both in a nearshore and mid-shelf setting (Evans et al., 2000). Paleo-channels, relics of old river systems, and glacial sapping channels (Uchupi and Oldale, 1994) constitute high permeability pathways that might act as pipelines between land and ocean.Field and modeling studies in coastal carbonate (Wallis et al.,

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14. ABSTRACT

To use the electrical structure of the seafloor to infer critical physical properties such as sediment porosity and permeability and to understand the distribution of these properties in terms of the regional geology. To examine links between acoustic backscatter properties of seafloor sediments and electrically inferred porosities, using porosity and sediment grain size distributions measured in cores as groundtruth information.

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1991; Wicks and Herman, 1995) and sand (Ruppel et al., 2000) aquifers indicate that the freshwater-saltwater interface occurs farther landward if a highly permeable zone is in the shallow subsurface near the coast and moves seaward if the zone is deep or far inland. This implies that these features act as conduits for saltwater intrusion rather than for freshwater discharge. Nonetheless, these connected high permeability zones will also enhance contaminant transport toward the coast in the freshwater portion of the aquifer. An important question is how the presence of highly permeable channels and a saltwater boundary at the coast will affect contaminant transport, mixing of groundwater and seawater and groundwater discharge location offshore. While high resolution seismic reflection profiling is able to define the geometry of these channels, the EM technique also constrains the physical properties of the channel infill, and hence provides a clue to the permeability of the channel. Surveys off New Jersey and North Carolina have also shown that there is often a complex relationship between the EM and seismic responses: a channel sequence off New Jersey imaged clearly seismically had no discernible EM response, while channels seen off North Carolina had EM responses that changed with distance from the shoreline. In nearshore settings, the EM method will respond to the presence of fresh water in the channel, as this will make the channel electrically resistive (Hoefel and Evans, 2001).

APPROACH

Our field program will involve towing the new WHOI built towed EM system in a series of lines around the Martha's Vineyard Observatory. The new system is based closely on the design of the Canadian system updated to fully digital receiver technology. The towed EM system is dragged along the seafloor at speeds of 1-2~knots and makes measurements of seafloor resistivity approximately every 10m along track. The raw data collected consist of 3 measurements of magnetic field amplitude and phase on each of three receivers. Data from each receiver are separately converted into apparent porosities by finding the best fitting equivalent half-space resistivity to the data and converting this value to porosity using Archie's law (described above). The three apparent porosity values are essentially averages over different depths of seafloor. The closest receiver is 4m behind the transmitter and averages over about 2m of seafloor. The furthest receiver is 40m behind and provides information to a depth of about 20m.

We will run a series of shore parallel lines extending some distance on either side of the site so that the substructure can be understood in terms of the glacial processes that shaped the seafloor in this region. A particular focus of our survey will be mapping the offshore extension of valleys formed on Martha's Vineyard through sapping induced by the transport of glacial meltwater (Uchupi and Oldale, 1994). While these features have been mapped seismically, we are interested in understanding how physical properties change within the channel as a function of distance. Once locations of the valleys have been mapped, we will run lines along the axis of several of these channels. An additional target of interest will be the buried peat unit found as the MVO was installed. The spatial character of this layer and its relationship to old channels will provide insight into the paleo-drainage and estuarine history of the region during lowstand. The sediments in this area are mostly sands and so towing the system on bottom should be relatively straightforward. We will, however, have to keep a safe distance from the observatory site itself.

WORK COMPLETED

Because of the schedule for assembly and testing of the new WHOI system, and the adverse weather conditions through the winter off Martha’s Vineyard, the survey will be run in late spring or early summer of 2002.

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