Abstract During the 1994 Coastal Benthic Boundary Layer Project research cruise in Eckernförde Bay, multi-channel digital seismic and electrical resistivity data were collected using surface- and bottom-towed arrays. Profiling with a bottom-towed sled yielded shear wave velocity and electrical resistivity data indicative of the structural strength of the sediment and of the properties of the pore space. Shear wave velocities for the gassy mud were, as expected, extremely low, ranging from < 10 m s\(^{-1}\) at the surface to around 16 m s\(^{-1}\) at 2 m. Variations in electrical properties were correlatable with lithological change. It is anticipated that analysis of reflection responses will provide significant additional geotechnical ground-truthing.

Introduction

In late June/early July 1994, the Marine Geophysical Research Group of the University College of North Wales (UCNW) participated in a series of shipboard experiments in Eckernförde and Kiel bays, Germany. The UCNW experiments formed a part of the Office of Naval Research’s Coastal Benthic Boundary Layer (CBBL) Program. For the UCNW team, the major project goals were: (1) to assess the extent to which newly developed UCNW geophysical technologies could be relied upon to provide quantitative information on seabed properties within the area under investigation; (2) to investigate the spatial variability of the measured geophysical quantities: electrical resistivity, shear wave velocity, and seismic reflection attributes (acoustic impedance, compressional velocity, reflection amplitude etc.); and (3) wherever appropriate and with reference to other site data and control information, to further interpret the geophysical data to provide specific information on the geotechnical characteristics of the sea floor materials.

UCNW’s experiments, which were conducted from the German naval research vessel Planet, resulted in a series of interdependent geophysical data sets that are currently being processed and interpreted at the university’s laboratories in Menai Bridge. This paper summarizes the preliminary findings and outlines the scope of the work in the context of the CBBL Program.

Background

The CBBL Program aims to study the physical characteristics of the seabed and model benthic boundary layer processes in relation to their impact on sea-floor properties (Richardson 1994a). Within the CBBL Program geophysical techniques have been identified as being ideally suited to the remote sensing of seabed properties; however it has also been acknowledged that there is a need for additional basic research, both of a theoretical and practical nature, to further quantify the relationships between geotechnical properties and geophysical quantities.

UCNW’s contribution to the CBBL Program arises from research carried out over many years aimed specifically at improving the understanding of geophysical—geotechnical property relationships. The various research approaches have included: (1) laboratory testing—simultaneous measurement of geophysical and geotechnical quantities under controlled conditions; (2) theoretical and empirical modeling—to allow predictions of sediment behavior under varying stress conditions; and (3) development of new marine geophysical survey methodologies—to allow in situ sensing of the physical properties of sea floor sediments.

Within the CBBL Program, the university’s effort is being directed towards in situ measurement, aiming to provide physical property data using underway approaches. Seismic shear wave velocities, which are being
measured with a specially developed bottom-towed geophysical sled (Davis et al. 1989), are known to be indicative of a material's structural strength and will likely be used to make inferences on the sediment's engineering behavior under varying stress conditions; electrical resistivities, obtained simultaneous with the shear wave velocity, are dependent on the properties of the pore space and will be used to supplement the geophysical interpretation. As both quantities are being acquired in a mapping mode, they will also be able to provide information on the spatial variability of the sea-floor sediment properties (Huws et al. 1991). Using a separate underway approach, UCNW is also contributing physical property data through seismic subbottom profiling experiments. High-resolution reflection data are being acquired in digital format ready for advanced signal processing and geotechnical analysis. The final analysis, which effectively converts the seismic section to a physical property section, relies heavily on theoretical and empirical interrelationships (Haynes et al. 1993).

The ability to provide a quantitative description of the seabed sediment properties using underway geophysical techniques will have obvious benefits for the CBBL Program. For instance, it will enable single-point static measurements to be extrapolated to cover a larger area; it will provide a rapid reconnaissance approach to geotechnical site characterization and physical ground-truthing; and it will provide useful input data for geoaoustic model validation exercises. By adopting the UCNW approach, it should be possible to provide important information on meter- and kilometer-sized features and especially on the spatial variability of these features. Through this, it should be possible to provide valuable insights into the effects of biochemical, geological, and hydrodynamic processes on larger-scale sediment structure. In addition to and aside from this, the CBBL Program has provided UCNW with a unique opportunity to ground-truth its own geophysical survey methodologies.

**Eckernförde experiment**

UCNW's experimental program was designed to capitalize on the wealth of information provided by other researchers participating in the CBBL Program. The measurements most directly comparable to UCNW's are those of R. D. Stoll and M. D. Richardson for shear waves, K. B. Briggs and P. D. Jackson for electrical properties, and D. N. Lambert and S. G. Schock for high-resolution reflection profiling. Physical, chemical, and biological property data being provided by a number of researchers, particularly W. B. Bryant and A. J. Silva for physical characterization studies; C. A. Nittrower, F. Abegg, C. T. Friedrichs, and L. D. Wright for data on environmental processes; and the various works on interactive geoaoustic modeling (A. L. Anderson and coworkers) are also seen as being of vital importance to UCNW's ground-truthing experiments. Detail on all the above contributions to the CBBL Program can be found in Richardson (1994b).

**Geophysical sled measurements**

Measurements with the UCNW bottom-towed geophysical sled (the "magic carpet") were carried out on selected trial sites in Eckernförde and Kiel bays (Fig. 1). The main components of the sled are shown in Fig. 2, with further information on the system and on operational procedures contained in Davis et al. (1989, 1991) and Huws et al. (1991). During three separate deployments of the magic carpet in three different sedimentary environments, a total of 302 shear wave records were collected and 200 electrical resistivity readings made. Measurements were made either with the ship drifting in the wind, or with the vessel underway making approximately 0.5–1 knot over the ground. The distance between geophysical sampling points was typically 20–25 m. Figure 1 shows the location of survey tracks and provides information on sea-floor sediment distribution. Each seismic record, which comprises a series of signal traces resulting from a single shot with the shear wave source (see Fig. 3 for an example record), is inverted to provide information on the velocity structure (using a standard refraction analysis—see Figs. 4 and 5 below) at the measurement location. Measurements of the sediment electrical resistivity were taken simultaneous with shear wave travel times, and the values converted to an equivalent formation factor through input of a seawater resistance reading.

**Subbottom profiling**

Seismic subbottom reflection profiling was carried out independent of the shear wave/electrical resistivity survey, along lines that had previously been surveyed using a Chirp sonar system and the NRL Acoustic Sediment Classification System (ASCS) (see Fig. 1 for location of UCNW survey tracks). During part of the survey, the ASCS was run in parallel with the UCNW profiling system to provide simultaneous output for a rapid visual comparison of data during recording and for subsequent systems evaluation. An EG&G Uniboom seismic source was used to generate seismoacoustic energy. The Uniboom was chosen for its high repeatability of signal generation and the broadband nature of the pulse (typically 400 Hz to 10 kHz). High-resolution single and multichannel digital seismic reflection data were recorded with either a single element hydrophone or a newly developed multichannel streamer coupled to a multichannel digital seismic acquisition system. The multichannel streamer, comprising 12 single-element transducers at 1-m spacings, was designed and constructed in the university's laboratories. The acquisition system, the Marine Geophysical Systems' MDAS, enabled the seismic waveform to be sampled rapidly with a minimum sampling rate of 30 kHz (typically 40 kHz), this level