Deep Ocean Sensor Implantation System

J. J. Kollé
HydroPulse L.L.C., Seattle, Washington, USA

L. D. Bibee
Naval Research Laboratory, Stennis Space Center, Mississippi, USA

ABSTRACT

Seismometers deployed on the deep ocean floor are subject to significant noise from interfacial seismic waves, currents, surface waves, ships and marine life. This paper describes an autonomous, battery-powered drilling system designed to deploy a seismometer deep into sediments to reduce noise and provide better coupling to seismic signals. The Deep Ocean Sensor Implantation System (DOSIS) is designed to deploy a 75-mm-diameter penetrator to a depth of 100 m in pelagic clays. An integral geophone sensor package is incorporated into the penetrator. When drilling is complete, the drilling module ascends to the surface leaving behind a data acquisition module.

INTRODUCTION

The world’s oceans cover 70% of the planet’s surface, but almost all geophysical observatories are located on land. Placement of instrumentation within the seafloor provides valuable opportunities for broadband seismic observations, heat-flow measurements, and observations of fluid circulation (Langseth and Spiess, 1987; Purdy and Dziewonski, 1988).

Seismic stations in the oceans were first deployed in 1937 (Ewing and Vine, 1938), and development continued sporadically until the early 1960s when nuclear monitoring (Project VELA UNIFORM) became important.

A new generation of seafloor seismometers resulted from this program (Ewing and Ewing, 1961; Bradner and Dodds, 1964; Schneider et al., 1984). Development continued through the 1970s when at least 11 different institutions routinely operated ocean-bottom seismometer (OBS) systems. Sutton et al. (1980) summarize the design of most of these systems, which in general consist of a pressure housing containing seismometers, electronics and tape recorders; flotation; and a heavy anchor that can be detached on acoustic command or by timers. These instruments are designed to free-fall to the seafloor. The seismometer is integral to the OBS package, which sits above the seafloor and is subject to noise related to currents and interface waves at the boundary between the water and near-surface sediments, as well as local biological activity.

In the early 1980s, the package coupling to the seafloor was generally acknowledged to be a significant problem (Sutton et al., 1981), and techniques to mitigate (but not solve) this problem by proper sensor mechanical design and detachable sensor packages were developed (Sutton and Duennebier, 1988; Byrne et al., 1983).

The first few meters of pelagic sediment typically have a very low shear strength and stiffness (Moore, 1964; Richards and Hamilton, 1967; Hamilton, 1974), which leads to poor coupling with seismometers that lie on the surface or are buried shallow. The density and shear strength of pelagic sediments increase significantly within a few meters of the surface, so deep burial of seismometers should improve seismic coupling to the sediment and increase the fidelity of signals. At the same time, this approach reduces the influence of noise generated by currents interacting with the deployment frame or other sources of noise in the water column. A variety of techniques have been proposed for burying instrumentation in ocean sediments. The Ocean Drilling Program (ODP) and its predecessor, the Deep Sea Drilling Program (DSDP), have successfully placed seismometers in the seafloor either through the drill string (Stephen et al., 1980; Duennebier et al., 1987) or with wire-line techniques from the drill ship (Adair et al., 1987). In addition, hundreds of holes have been drilled in the deep ocean, and over 30 holes with re-entry cones and surface casings have been left. Seismometers and heat-flow instrumentation can be deployed in open holes from a drill ship using wireline re-entry techniques. Drill-ship costs are quite high, so wireline techniques are also being developed to re-enter ODP holes using conventional oceanographic research vessels (Langseth and Spiess, 1987). Legrante et al. (1989) and Stephen et al. (1994) describe the re-entry of holes using remotely operated vehicles (ROVs).

Another approach involves the development of a capability for drilling holes in the seafloor from a conventional research vessel. Johnson (1991) describes a remotely operated rock-drilling system designed to return core samples up to 6 m deep from water depths of up to 5000 m. Kollé (1994) describes a system designed to sample gases in the upper 500 m of sediment in water depths of up to 1000 m. Both systems include wireline re-entry capability for small-bore instrumentation. A free-fall penetrator system capable of deploying a geophone package to a depth of 8 m in soft sediments of the deep ocean is described by Bibee and Kollé (1993). Trevorrow et al. (1989) describe a hydraulic jetting system for 1-m burial of seismometers in shallow water.

This paper describes the development and testing of a Deep Ocean Sensor Implantation System (DOSIS) designed to allow deep burial (to 100 m) of seismometers or other instrumentation in the sediments of the deep ocean. The system was designed for autonomous operation in soft pelagic clays common to the deep