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Seismic Experiment Paves Way for Long-term Seafloor Observatories

Debra S. Stakes, Barbara Romanowicz, Jean-Paul Montagner, Pascal Tarits, Jean-Francois Karczewski, Steve Etchemendy, Craig Dawe, Doug Neuhauser, Paul McGill, Jean Claude Koenig, Jean Savary, Mike Begnaud, and Mike Pasyanos

The Monterey Bay Ocean Bottom International Seismic Experiment (MOISE) has successfully deployed a suite of geophysical and oceanographic instrument packages on the ocean floor using the Monterey Bay Aquarium Research Institute's (MBARI) Ventana, a tethered Remotely Operated Vehicle (ROV). The goal of this international cooperative experiment is to advance the global Seafloor Observatory effort by developing a prototype suite of instruments and installing them on the western side of the San Andreas fault system offshore of central California. The centerpiece of the instrument suite was a digital broadband seismometer package partially buried within the sediment-covered floor of Monterey Bay, 40 km offshore and 10 km west of the San Gregorio fault at a depth of 1015 m (Figure 1).

The initial seismic data suggest that, with careful deployment of the broadband sensor package completely below the sediment-water interface, background noise can be reduced to levels comparable to those at the Berkeley Digital Seismic Network (BDSN) station on the adjacent Farallon Island, which allows the collection of useful data from teleseismic events.

Need for Long-Term Seafloor Observatories

Due to the limited distribution of continents and islands around the world, it has long been recognized that the coverage provided by land-based seismic and other geophysical observatories is inadequate to address many important scientific issues related to plate tectonics and the deep structure and dynamics of the Earth [e.g., *COSOD*, 1987]. MOISE is one among several planned or ongoing pilot experiments designed to define the technology and optimal deployment procedures appropriate for the installation of long-term/permanent ocean bottom geophysical observatories in the spirit advocated by the International Ocean Network (ION) program [*Suyehiro et. al.*, 1995] as well as the U.S. Ocean Seismic Network (OSN) program [*Purdy*, 1995]. MOISE is also the centerpiece of a series of proof-of-concept experiments that were conducted in Monterey Bay in the summer of 1997 to test and refine the ROV methodology required to support such installations. Although the instrumentation was deployed for only 3 months, most of the manipulations are identical to those required for a permanent deployment.

Two basic scientific objectives require long-term seismic observatories on the ocean floor: global investigations of the structure and dynamics of the deep Earth and regional investigations of active processes concerning the seismicity, tectonics, and hydrothermal-volcanic activity of the Earth's crust [e.g., *Purdy*, 1995]. There are large gaps in the global distribution of seismic stations in the eastern Pacific and the southern oceans that cannot be filled by installation of instruments on islands. These long-term stations should be as low-noise and broadband as possible with deployment periods of at least 5 years [e.g., *Romanowicz and Dziewonski*, 1986].

Many major regional-scale scientific problems related to the deep structure of ridges, subduction zones, ocean basins, and hotspots require the deployment of arrays of both short- and long-period ocean bottom seismometers. In northern California, for example, existing broadband stations necessarily bias coverage toward the eastern side of the North America/Pacific plate boundary, and the seismic activity on the offshore fault system related to this plate boundary is poorly documented.

As a result, the location, mechanism, and size of moderate to large events is biased by the uneven distribution of observations, and events of magnitude smaller than 4 are very imprecisely described, if at all. The geometry of this active plate boundary thus calls for an expansion of the existing broadband monitoring network to include at least five offshore stations. This would allow not only better characterization of the offshore seismicity, but also improve our knowledge of three-dimensional

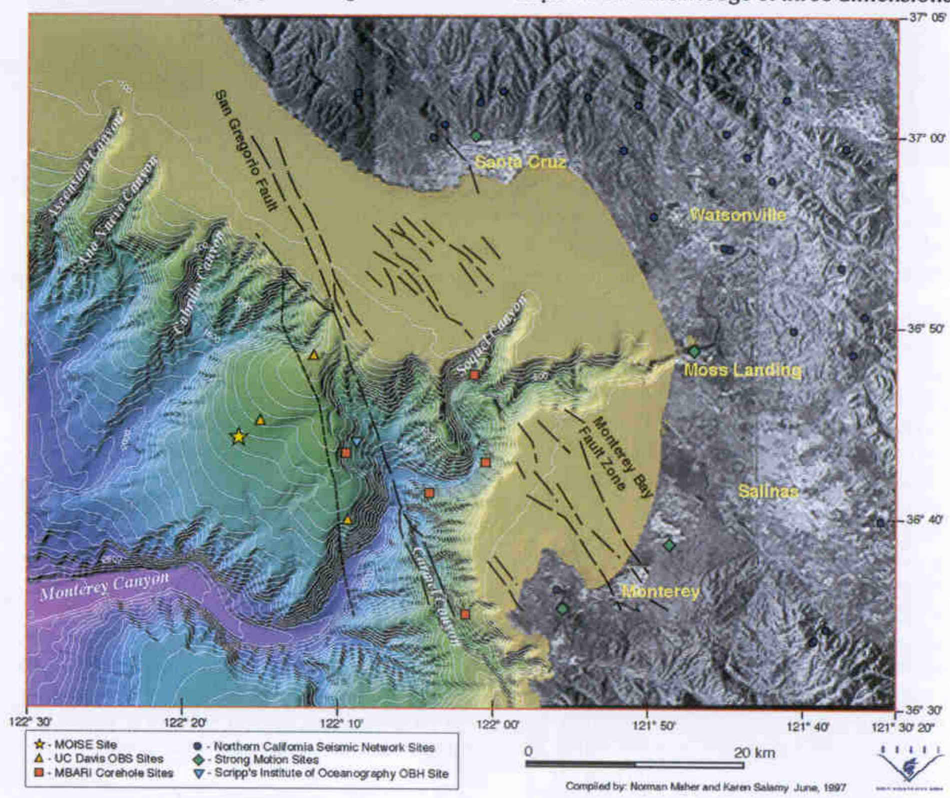

Fig. 1. Bathymetric map of the Monterey Bay area showing the locations of instruments deployed during MOISE. The broadband seismometer, EM sensor package, and current meter/pressure gauge were deployed at a depth of 1015 m at the site indicated by the star.

For more information, contact Debra S. Stakes, MBARI, PO Box 628, Moss Landing CA 95039-0628 USA

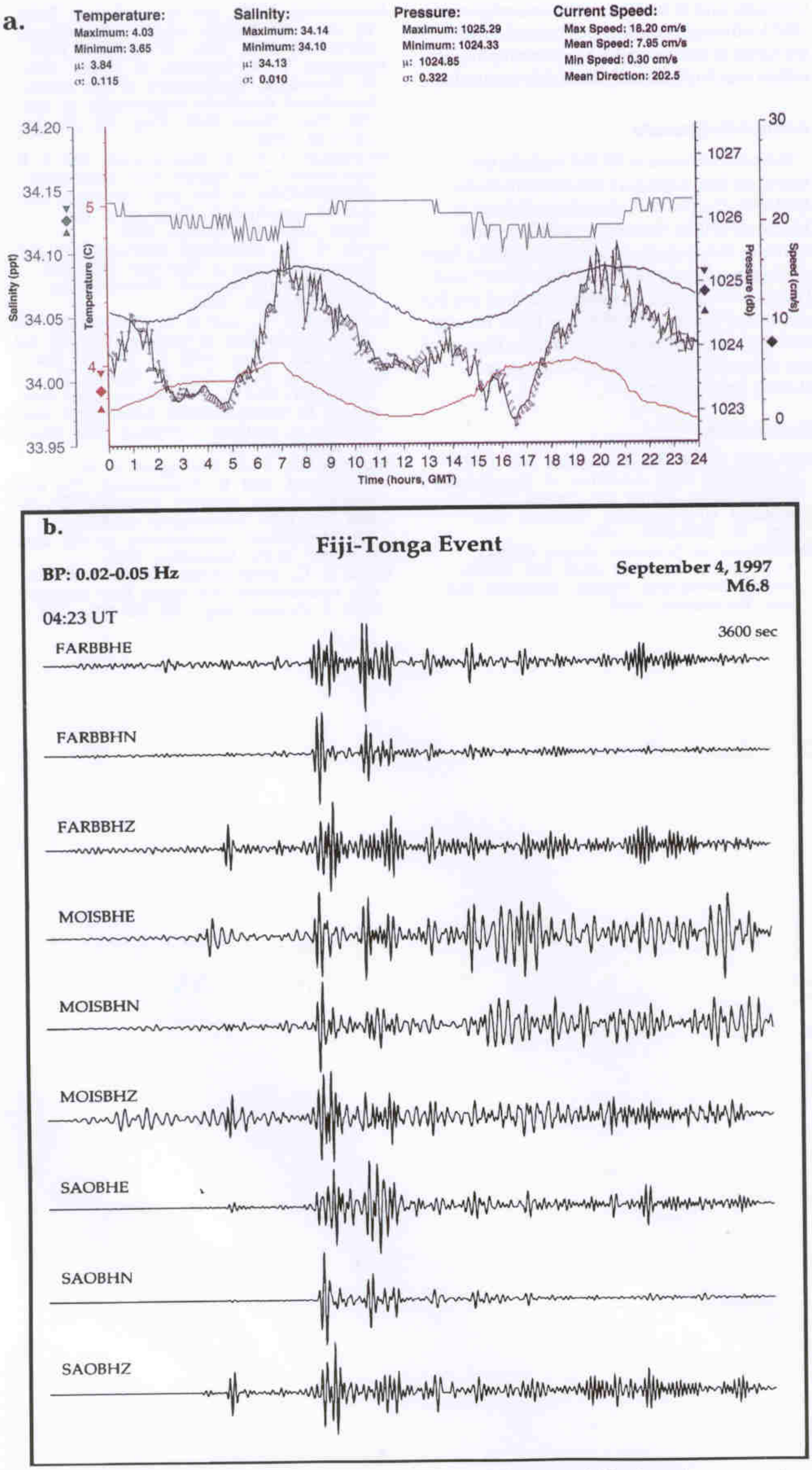

Fig. 3. a) Data from CTD (salinity is green), pressure gauge (pressure is blue), and current meter (black with vectors showing direction) for September 4, 1997. Temperature is in red. Note that 0430 is a window of extremely low bottom currents. b) Comparative seismograms for Fiji-Tonga event at 0423 GMT on September 4. FARB is the BDSN site on the Farallon Islands, MOIS is the Moise instrument, and SAO is the BDSN site south of Monterey Bay.

of strong bottom currents at the site induced large seismic and electric noise, which will facilitate a correlation between currents, electric field, and seismic signal.

To address the question of bottom current and tidal effects, a conductivity-temperature-depth (CTD) instrument for salinity measurement with an onboard pressure gauge was deployed. This was mounted into a tripod support frame with an S4 current meter mounted at the apex. The bottom currents were anticipated to be the most profound marine noise present in the seismic record due to the shear coupling at the sediment water interface [*Duennebier and Sutton*, 1995; *Webb*, 1988].

A variety of conventional and well-coupled short-period seismometers and hydrophones were also deployed as stand-alone, contemporaneous instruments to provide more comparative data for regional studies. These instruments included conventional, surface-ship deployed, short-period seismometers with either 4.5 Hz or 1 Hz sensors and a single channel hydrophone. In addition, ROV-deployed "corehole seismometers" were installed in small diameter boreholes in the granite walls of the Canyon for most of the experiment.

Initial Results

The MOISE site at 1015 m depth was well within the SOFAR channel as well as within a marine mammal sanctuary. This location was the deepest site easily accessible to the MBARI ROV Ventana, which operates daily from Moss Landing. As a result, many marine mammal calls and T-phase arrivals (water-carried acoustic signal) were recorded in the seismometer's data records. On the well-coupled, short-period seismometers, these events are clear enough to permit characterization of the mammal species. The deployment of the broadband sensor package was successful, though less than perfect. Although the sensors and gimbals were completely buried in the sediment and stabilized by the glass beads, the upper third of the housing and the support for the connector were exposed to highly variable bottom currents. The support provided by the caisson, however, limited the tilting of the sensor package so that it remained within the acceptable dynamic range between ROV visits. This eliminated the need for frequent releveling cycles during the early deployment period as was required in a previous experiment on the Mid-Atlantic Ridge [*Montagner et al.*, 1994], which was a great improvement.

Despite the less-than-optimal installation, we were able to identify all large teleseisms (M>6.0), as well as many regional M>4 earthquakes in the continuous data recorded by the instrument. Samples of background noise were recovered twice during the deployment period. As expected the background was highest in the microseismic band 5 s, with a quiet window in the band 10-50 s. The background noise in this band decreased during the first month of deployment, after which it was mostly controlled by the strength of bottom currents (Figure 3a). An event that occurred in