2.14 SEAFLOOR SEISMIC MEASUREMENTS IN THE SOUTHERN BERING

by

James P. Hickerson 1/

ABSTRACT

The purpose of this paper is to discuss the plans being made to monitor the earthquake response of seafloor sediments in and near southwestern Alaskan offshore leasing areas. These sites possess high seismicity for which limited data exist. The Sandia Seafloor Earthquake Measurement System (SEMS) would be deployed to collect the necessary data over an eight-year time span. A proposal for a joint industry-government project to accomplish this goal has been circulated.

INTRODUCTION

This past summer, five oil companies initiated wildcat drilling operations in the St. George Basin of the southern Bering Sea, site of Outer Continental Shelf Sale 70 (Williams 1984). Thus began an active campaign to explore potential petroleum reserves in a large area that encompasses not only Sale 70, but also future sales north and south of the Aleutian Islands and western Alaska Peninsula. Already under consideration by major oil companies and supporting consulting firms are the designs for necessary drilling and production structures, should recoverable amounts of oil be found. The candidates for these facilities range from concrete gravity platforms developed for the North Sea, to pile-founded jacket structures modified to deal with intermittent encounters with first year ice floes.

The design criteria for offshore structures are well established and sound, provided that adequate information about the engineering environment is available. Climatic and oceanographic knowledge for the southern Bering and Aleutians is extensive. This is the product of many decades of manned activities, exploratory, military, commercial, and private. These have yielded a solid foundation on which to base structural design to meet the threats of storm winds and waves and ice floes. There is, however, an additional environment that is considerably less documented, but also as important for properly configuring certain structural features. This is the dynamic behavior of sediments created by strong, frequent local earthquakes originating from some of the most active and energetic sources in the world.

1/ Sandia National Laboratories, Division 6252, PO Box 5800, Albuquerque, NM 87185.

The lack of extensive data on Alaskan earthquakes is a well recognized fact (Woodward-Clyde Consultants 1978, ERTEC Western 1983, Jacob and Hauksson 1983, and Beaven and Jacob 1984). This deficiency is readily explained. Quantitative seismology is a relatively recent scientific pursuit whose initial efforts have been most often directed towards populous regions of the world where the benefits are obvious. It is also true that earthquake data are not convenient byproducts of other activities, as wind, wave, ice, and climate data so often are. Quantitative earthquake data are only obtained when a concerted and sustained effort is mounted to do so.

The array of seismic stations in the Shumagin Islands, established by Lamont-Doherty Geological Observatory in the early 1970's, is currently the best effort aimed at defining the local earthquake environment (Jacob and Hauksson 1983). A logical extension of that work is a seafloor-based array that would collect strong motion data from actual sediments. Such data would be valuable, not only in characterizing the Alaskan earthquake environment, but also in providing definitive measurements of the actual response of saturated seafloor sediments that support a substantial water column overhead. This paper discusses plans being made to deploy a seafloor array of remote seismic stations to accomplish this. The instruments themselves are termed Seafloor Earthquake Measurement Systems (SEMS) (Ryerson 1981) and have been developed at Sandia National Laboratories under the sponsorship of the Departments of Energy, Interior, and Commerce. A proposal is currently being circulated to industry to solicit its support of the project (Geotechnical Engineering Division 1984). The substance of that proposal will be covered later in this paper.

TECTONIC SETTING AND EARTHQUAKE HAZARDS

Figure 1 presents a map of the region

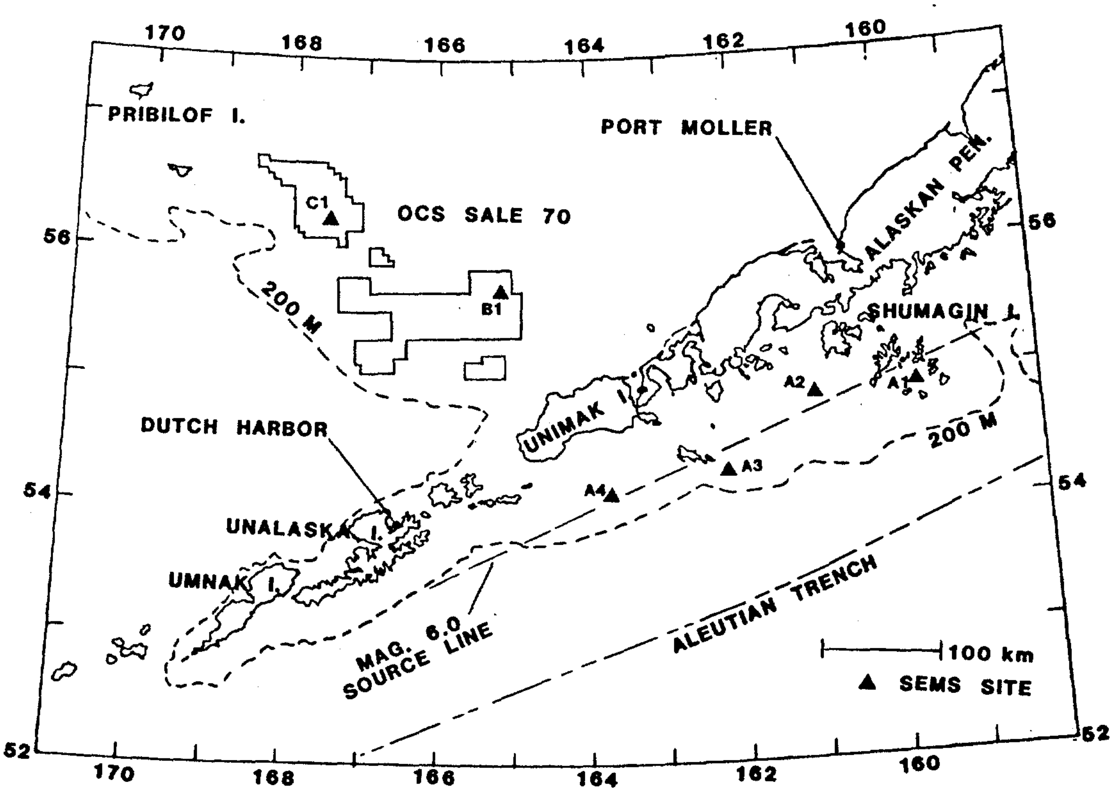

Figure 1. Southern Bering and Aleutian Region.

of interest. Sale 70 appears north of the Aleutians, soon to be followed by three more sales covering the same general area and extending eastward to Port Moller. Later the Shumagin sale may take place near the islands of the same name.

Extending downward beneath the peninsula and island arc is the dipping lithosphere of the Pacific Plate (Figure 2). This massive feature, moving northward at 7-9 cm/yr (Davies et al. 1981), is being subducted by the North American crustal plate. In the process, geologic structures now considered classical are being created:

- a deforming and descending segment of cold lithosphere that is being heated as it sinks lower,
- an island arc, volcanic in origin,
- a deep, fore-arc ocean trench,
- extensive local faulting.

Accompanying the creation of each of these structures are seismic events, of which the strongest and most frequent result from the subduction of the lithosphere (Woodward-Clyde Consultants 1978, and ERTEC Western 1983). Here the major activity occurs in the first 60 km of depth

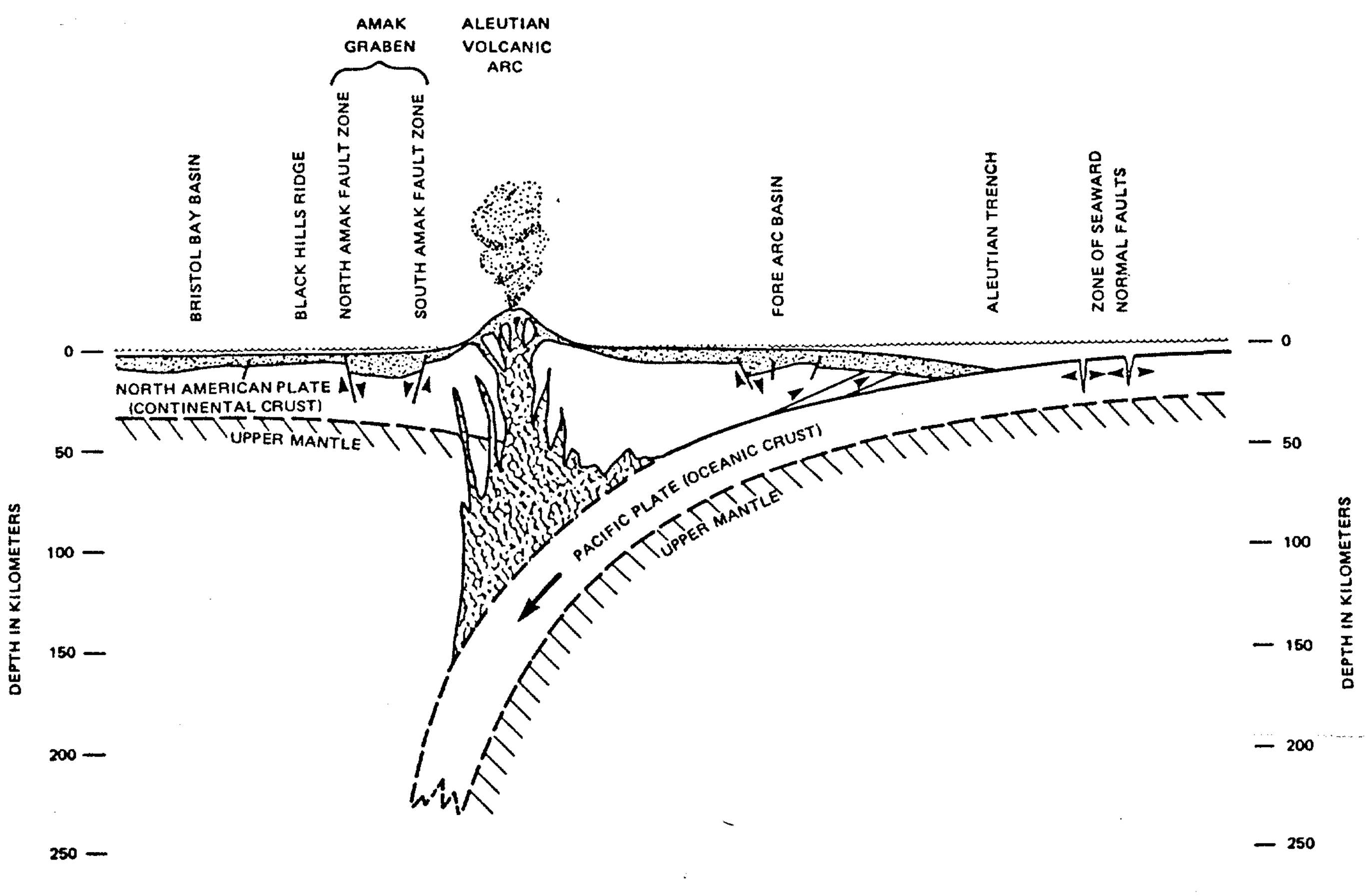

Figure 2. Geologic Cross Section Running N-S Through the Eastern Aleutians (ERTEC Western 1983).

due to the movements and deformations associated with this zone. Consequently, the majority of earthquake epicenters, and particularly the strongest ones, tend to scatter about a line identified in Figure 1 as the magnitude 6.0 source line. Within the area of approximately 40,000 km^2 monitored by the SEMS stations A1 through A4, the return period of a magnitude 6.0 or greater earthquake is approximately 3-5 years. Seafloor acclerations accompanying those events will be in excess of 0.1 gravity units (g) for structures within 80 km of the epicenter (Woodward-Clyde Consultants 1978). Further to the north, local sources are far less active, with recurrence intervals for strong earthquakes in excess of 30 years.

In addition to producing numerous small-to-moderate earthquakes, the Alaskan subduction zone is also responsible for great earthquakes in excess of magnitude 7.8. The Shumagin Islands occupy a site that typically experiences such an event every 50 to 90 years (Davies et al., 1981). Based on an analysis of recurrence data, Jacob predicts such an occurrence with near certainty during the next 20 years (Jacob 1984). This event will not only be stressful to local structures, but will also create strong low frequency waves that can be potentially damaging to offshore structures located hundreds of kilometers away.

TECHNICAL OBJECTIVES FOR SEMS

The principal reason for deploying a SEMS array is to collect and analyze strong motion data that can be useful to the design of offshore structures. The specific goals making up this broad statement of purpose are:

- selection of an active site that will allow the recording of earthquake accelerations in excess of 0.1 g during the five-year life span of SEMS.
- recording accelerations in all three spatial axes for the complete duration of a magnitude 6.0+ event.
- characterization of the actual acceleration, velocity, and displacement response versus frequency for free field sediments excited by a nearby magnitude 6.0+ event.
- measurement of sediment response at locations in the southern Bering distant from the source for comparison with earthquake model predictions.
- comparison of sediment response with similar data from a nearby land station.

The array shown in Figure 1 is intended to maximize the possibility of achieving these objectives.

DESCRIPTION OF SEMS

The Sandia Seafloor Earthquake Measurement System (SEMS) is a self-contained, remote, seismic station (Ryerson 1981). It is capable of measuring and recording strong sediment motions with a three-axes probe (Figure 3) buried six feet into the underlying soil. Recorded measurements are retrieved at regular 3-4 month intervals by acoustically interrogating the SEMS with a portable shipboard command unit that can also reset or adjust operating parameters for the SEMS control system.

The SEMS Seafloor Platform is shown in Figure 4, and consists of two pressure vessels housing batteries and electronics, an acoustic telemetry system, and a recovery float and line. All are supported by a smooth frame that protects them

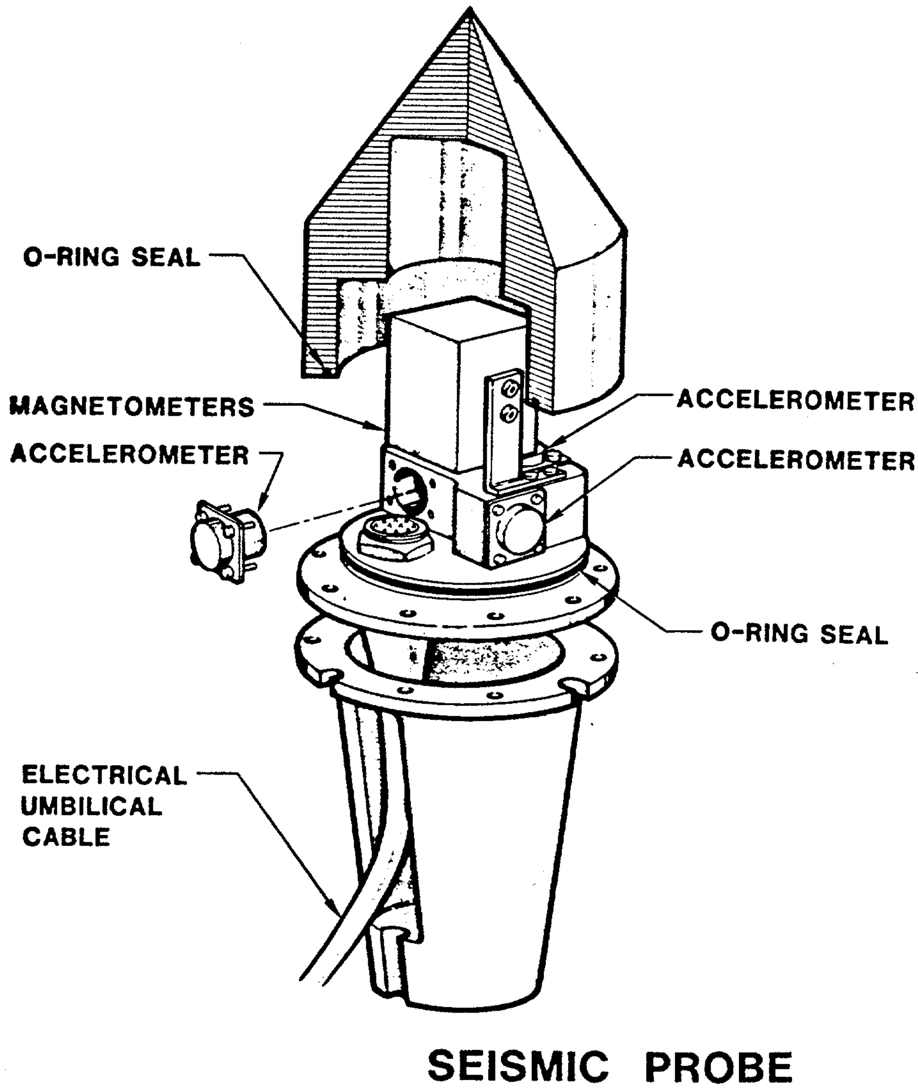

Figure 3. SEMS Seismic Probe

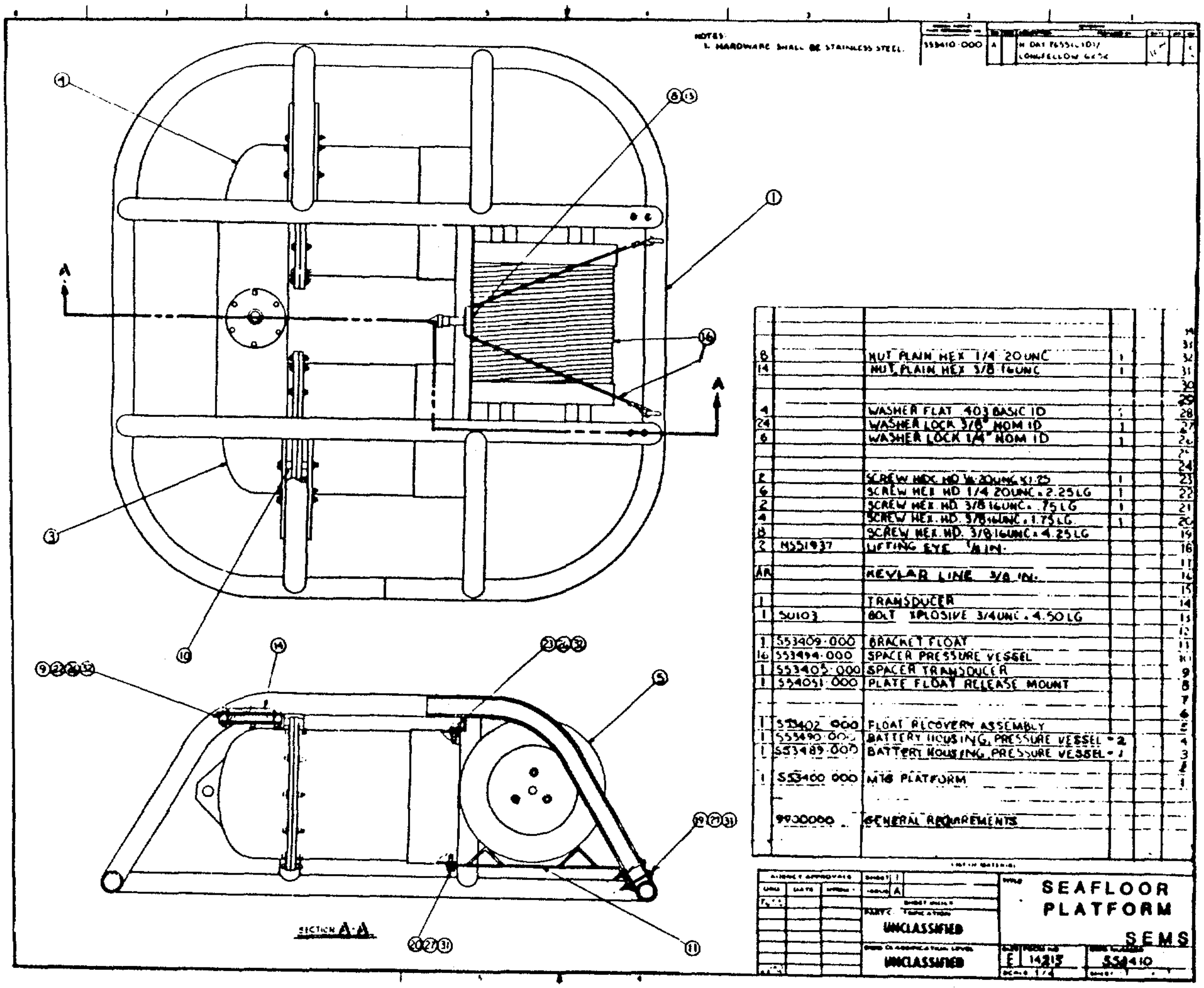

Figure 4. SEMS Seafloor Platform.

from nets and cables that are dragged across the seafloor by commercial fishermen. The Seafloor Platform communicates with the seismic probe, which is emplaced in a drilled hole six feet below the platform, via an electrical cable. The probe also contains a precision magnetometer so that its orientation can be established after installation.

General specifications for SEMS appear in Table 1. In operation, a microprocessor controller monitors a three-axis accelerometer package in the probe. When incoming signals exceed 1.5 times the background level for two seconds, an event is declared and buffer recording begins. At the same time a magnetic bubble memory is activated and searched. Should the incoming event be stronger in magnitude than any other earthquake(s) in memory, it will replace the weakest event(s). When the incoming signals have decayed to 1.2 times the earlier background level, the controller declares the event over and shuts down the non-volatile memory to conserve power.

The controller also operates the acoustic telemetry system. Upon command from the surface, SEMS will respond with its data and information on its operating

TABLE 1. SEMS: PHYSICAL DESCRIPTION AND OPERATING SPECIFICATIONS

COMPONENT OR CHARACTERISTIC	DESCRIPTION OR VALUE
1. COST:	
HARDWARE	$ 68,000
ASSEMBLY	$ 35,000
DEPLOYMENT	$ 7,000
TOTAL COST DEPLOYED	$ 110,000
2. SYSTEM LIFE	BATTERIES AND PRESSURE RATED SEALS DESIGNED FOR 5 YEARS OPERATION. STATED LIFE: 4 YEARS.
3. CONTROLLER	RCA 1802 MICROPROCESSOR MONITORS PROBE AT A SAMPLING RATE OF 100/SEC PER ACCELEROMETER AND CONTROLS MEMORY AND TELEMETRY FUNCTIONS.
4. MEMORY	1520 SEC OF MAGNETIC BUBBLE MEMORY ARRANGED IN ADDRESSABLE 23.8 SEC BLOCKS.
5. TELEMETRY:	
SLANT RANGE	1000 METERS
ANTENNA PATTERN	140 DEGREE CONICAL BEAM
TRANSMISSION RATE	1200-2400 BITS PER SECOND
6. PROBE MAGNETOMETER	2-AXIS. 1.5 DEGREE ORIENTATION MEASUREMENT ACCURACY
7. PROBE ACCELEROMETERS:	
MODEL	ENDEVCO 7751-500 SOLID STATE
DYNAMIC RANGE	10,000 OVER 0.0001 TO 10.0 G
FREQUENCY RESPONSE	0.2-1500 HZ (±5%) 0.1-1500 (±10% CALIBRATED)
FREQUENCY RANGE	5-1500 HZ PHASE SHIFT <2 DEGREES 0.1-20 HZ PHASE SHIFT CALIBRATED
NATURAL FREQUENCY	7000 HZ
8. TIME ACCURACY	(±) 100 MILLISEC RELATIVE TO WWV TIME

condition. Memory blocks can be remotely cleared, the internal clock rezeroed to WWV time, the orientation of the probe read, battery status measured, and certain operational instructions modified, if necessary.

The SEMS just described has evolved over the past eight years under an ongoing program, managed by the Department of Energy and partially funded by the petroleum industry and the Departments of Commerce and Interior. During 1979-1981 five SEMS were deployed, four in the Santa Barbara Channel offshore of California. All operated successfully and recorded numerous earthquakes, although none were strong enough to create accelerations in excess of 0.03 g. Since that time SEMS has been given design upgrades as electronic, battery, and telemetry technology have progressed. It is now 1/4-1/3 its original cost in terms of hardware required to provide a given monitoring time on the seafloor, and far more capable. The latest version (Fig. 4) is being prepared with joint funding from Shell Development Company and will be installed in the offshore California Beta Field in early 1985.

STATUS OF THE ALASKAN SEMS PROPOSAL

In December, 1984, at the request of industry, a proposal was submitted to major oil companies soliciting their participation in this project. If accepted by at least six participants, an array similar to that shown in Fig. 1 will be deployed. Monitoring could begin as early as the summer of 1985, and is scheduled to continue until 1992.

REFERENCES

Beaven, J., and Jacob, K. H., 1984, "Processed Strong-Motion Data from Subduction Zones: Alaska," Lamont-Doherty Geological Observatory, Palisades, NY, October.

Davies, J., Sykes, L., House, L., Jacob, K., 1981, "Shumagin Seismic Gap, Alaska Peninsula: History of Great Earthquakes, Tectonic Setting, and Evidence for High Seismic Potential," J. of Geophysical Research, Vol 86, p 3821, May 10.

ERTEC Western, Inc., 1983, "Seafloor Geologic Hazards on the Northern Aleutian Shelf," prepared for the National Oceanic and Atmospheric Administration, Contract NA80-RAC-00167, June.

Geotechnical Engineering Division, 1984, "A Proposal for Seafloor Earthquake Measurement in the Southern Bering Sea and Aleutian Shelf," Proposal No. 6241126, Sandia National Laboratories, November 26.

Jacob, K., 1984, "Estimates of Long-Term Probabilities for Future Great Earthquakes in the Aleutians," Geophysical Research Letters, Vol. 11, No. 4, p 295.

Jacob, K., and Hauksson, E., 1983, "Final Report: A Seismotectonic Analysis of the Seismic and Volcanic Hazards in the Pribilof Islands--Eastern Aleutian Region of the Bering Sea," Lamont-Doherty Geological Observatory, NOAA Contract of 03-5-022-70.

Ryerson, D. E., 1981, "Seafloor Earthquake Measurement System," Sandia National Laboratories, SAND81-1810/1,2,3.

Williams, B., 1984, "First Wildcats in Bering Sea Pave Way for Busy Season off Alaska," Oil and Gas Journal, p. 25, July 16.

Woodward-Clyde Consultants, 1978, "Offshore Alaska Seismic Exposure Study," prepared for the Alaska Subarctic Operators Committee.