OCEAN DRILLING PROGRAM

LEG 136 SCIENTIFIC PROSPECTUS

Ocean Seismographic Network Pilot Hole - Hawaiian Arch

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This Scientific Prospectus is based on pre-cruise site-survey information and JOIDES panel discussions. The operational plans within reflect JOIDES Planning Committee and thematic panel priorities. During the course of the cruise, actual site operations may indicate to the Co-Chief Scientists and the Operations Superintendent that it would be scientifically advantageous to amend the plan detailed in this prospectus. It should be understood that any proposed changes to the plan presented here are contingent upon approval of the Director of the Ocean Drilling Program in consultation with the Planning Committee and the Pollution Prevention and Safety Panel.

ABSTRACT

The primary objective of ODP Leg 136 is to drill a hole for future experiments needed to develop the Ocean Seismographic Network (OSN). The long-term (5-10-year) goal is to establish a global network of 15-20 permanent seismic observatories in the deep ocean. Such a network would revolutionize studies of global earth structure, upper mantle dynamics and lithosphere evolution, earthquake source mechanisms, oceanic crustal structure, tsunami warning and monitoring, and deep ocean noise sources and propagation mechanisms. This hole will provide a site for pilot experiments that include noise measurements, data recording from teleseismic events for comparison with existing nearby island stations, and testing new broad-band sensors and other long term deployment instrumentation.

Coring the sedimentary and basaltic sequences at the OSN site will provide useful geologic data. The sediments and basalts at the site are analogs of the material through which the Hawaiian lavas first erupted. Analysis of the chemistry and physical properties of this material will determine the extent of contamination of Hawaiian magmas and will shed light on the role that these sediments play in the mechanical behavior of Hawaiian volcanoes. The frequency of explosive volcanism of Hawaiian volcanoes will be determined by coring volcanic ash blown downwind from the islands of Hawaii and Maui. Age constraints on these deposits will be determined by paleomagnetic studies. The hole will also be used to test a reentry cone plug designed to seal boreholes for long term temperature monitoring and fluid sampling.

INTRODUCTION AND SCIENTIFIC OBJECTIVES

Ocean Seismographic Network

The need for global distribution of seismograph stations in studies of earthquakes and Earth's structure was recognized as early as the beginning of this century. Major initiatives in deployment of broad-band digital networks are currently under way. These initiatives include, among others, the United States' Global Seismographic Network project sponsored by IRIS, GEOSCOPE in France, and MedNet in Italy. The Federation of Digital Seismographic Networks (FDSN) promotes common instrumentation standards and facilitates data exchange. All member countries of the Ocean Drilling Program are also members of FDSN.

With all this effort, however, distribution of land-based stations would be inadequate to study the Earth with uniform resolution. The potential contribution of ODP in establishing a network of permanent geophysical observatories on the deep-ocean floor was recognized in the COSOD II report (1987). The long-term goal is to establish during the next 5 to 10 years a permanent global network of 15 to 20 seismic observatories in the deep ocean. The objectives of such an effort encompass the most fundamental questions concerning Earth structure and dynamics. Examples of these goals were summarized at a JOI/USSAC-sponsored workshop (Purdy and Dziewonski, 1988) and can be best considered in several broad subject areas:

• Global Earth structure: Some examples of key questions are: Is the inner core heterogeneous or anisotropic? What is the geometry of the core/mantle boundary? Are hot spots correlated with slow regions at the base of the mantle? What is the geometry of the 400-km and 670-km discontinuities?

• Oceanic upper mantle dynamics and lithosphere evolution: Can seismic anisotropy be used to map flow in the upper mantle? What are the degree and spatial variations of lithospheric thinning beneath hot spot swells? What are the spatial variations in the depth extent of anomalous structures beneath ridges? Do oceanic plateaus have roots like continents? What is the form of small-scale convection beneath plates?

• Earthquake source studies: Ocean floor stations are needed to improve source location (particularly depth), focal mechanism, and rupture process determinations. These measurements are critical to studies of the depth of the seismic decoupling zone, the depth extent of outer rise events, and the rheology of the oceanic lithosphere. Near field data, in particular ocean floor recordings, are needed to improve the resolution of the source mechanisms of events not caused by faulting but by slumping or magmatic injection. Such studies have important implications for estimation of long-term seismic hazards.

• In addition, opportunities for study exist in the following areas: oceanic crustal structure, tsunami warning and monitoring, and sources and propagation of seismic noise.

Broad-band, long term ocean floor observatories are needed for these studies. Generally, only seafloor stations can provide uniform global coverage in areas without islands. Seafloor installations are needed for regional studies of individual tectonic features and for sampling wave propagation in "normal" oceanic lithosphere.

At present, island seismic stations are the only places where permanent observatories exist in the oceans. Oceanic islands are, however, located on anomalous structures with thick crust and, in many cases, unusual upper mantle velocities. In addition to the objectives listed above, the following questions may be addressed with ocean floor observatories: How adequate are island based stations? What role should they play in the global seismograph network? Would ocean bottom observatories provide substantial improvements in broad-band signal-to-noise? How does local structure influence seismic signals received on islands compared with an ocean floor site?

Before progress can be made toward the construction of a permanent global ocean floor network, thorough solutions to a number of experimental and technical issues must be found. Current understanding of long period noise sources and noise propagation mechanisms is insufficient to guide emplacement of permanent observatories. Measurements of inertial noise at intermediate frequencies (10-100 mHz) are very limited and at low frequencies (3-10 mHz) do not exist. A key parameter that remains unknown is the depth of sensor burial required (in various tectonic settings) to optimize the signal-to-noise ratio while minimizing required drilling penetration.

In addition, a large number of purely technical problems must be solved. One-Hz geophones are the lowest frequency sensors routinely used on the ocean floor. These geophones have little sensitivity to earth noise below 50 mHz. An urgent priority is to adapt a presently available broad-band sensor for operation on the ocean floor. How would a permanent global ocean floor network be operated in practice? With a data rate between 5 and 50 MBytes per day, the problems of both internal recording (with periodic data retrieval) or real-time telemetry are extremely challenging. Costs associated with use of fiber optic or existing telecommunication cables can be huge, but completely remote packages produce the problem of power source. Completely new (micropower) sensors and data loggers may need to be developed.

Satisfactory solutions to all these questions can be established only by carrying out a series of pilot experiments. These experiments must be carried out at several locations in a variety of tectonic settings. The objective of this leg is to establish the first site at which these experiments, using wireline reentry from a conventional research vessel, can be performed over the next 2-3 years.

The site we have chosen is ~250 km south-southwest of Honolulu (Fig. 1). The experiments will be carried out by a variety of investigators and coordinated by a steering committee, jointly sponsored by JOI and IRIS, as proposed at a workshop held at Woods Hole Oceanographic Institution. Examples of specific objectives of such experiments are:

• To prove the satisfactory and reliable operation of a low-power (and eventually micropower) broad-band ocean floor seismometer.

• To measure and compare noise levels (in the band 3 mHz to 50 Hz) downhole at various burial depths, with adjacent seafloor sensors, and with the island site on Oahu; and to understand the dependencies of the variations in these noise levels upon environmental parameters.

• To establish the satisfactory and reliable operation of the required recording, telemetry and timing systems.

• To develop routine sensor emplacement and data package recovery schemes.

• To obtain a sufficient number of high quality broad-band recordings of teleseismic events to allow quantitative comparisons to be made with the data recorded on Oahu. These data could provide interesting new information on the upper mantle structure beneath the Hawaiian swell.

The benefits of the OSN-1 site for the development of the network will not be realized until the seismic package is deployed at some time in the future. Pilot experiments are needed to address three key issues:

• How "good" will ocean bottom observatories be in comparison with existing island stations? Noise and signals recorded by a broadband downhole sensor must be compared with those recorded on a nearby high quality island station.

• How deep do the drill holes need to be for sensor emplacement? We must measure variations in broadband noise levels on a downhole sensor with depth below the ocean floor.

• Do we need drill holes at all? Comparisons must be made between broadband noise levels on a downhole sensor with identical seafloor and surficially buried broadband sensors.

An example of the components of such a pilot experiment is shown in Figure 2. All of the above questions may be answered by experiments at the OSN-1 site.

Hawaiian Volcanoes

The drilling of the OSN hole presents an excellent opportunity to characterize a poorly known part of the Pacific basin. The Hawaii area is important because it is the type locality for oceanic, intraplate hot spots, and it is centrally located well away from other tectonic and sedimentary influences. The only previous attempt to drill in this region (Deep Sea Drilling Project Site 67, ~150 km north-northwest of Oahu; Winterer et al., 1971) recovered only 3 cores over 60 m of section before drilling stopped due to the presence of porcellanites. The objectives for coring in the Hawaii area are:

• To evaluate the seismic stratigraphy around the drill site and to better understand the relationship of crustal seismic structure to basaltic structure.

• To determine the physical properties of the sediment and basalt for use in modeling the mechanical behavior of Hawaiian volcanoes.

• To determine the chemistry of the sediment and basaltic basement for Hawaiian volcanoes (which could be a contaminant in Hawaiian magmas).

• To determine the amount of ash produced during Hawaiian eruptions.

Reentry Cone Seal

The reentry cone seal or "cork" consists of a mechanism that seals the throat of an ODP reentry cone and the 11-3/4-in. casing suspended below the reentry cone (Fig. 3). The cork latches into the 11-3/4-in. casing hanger and thus will prevent fluid flow into or out of the borehole. The cork will house a removable data logger. Attached to the data logger and suspended in the borehole will be a thermistor string with integral pressure transducers. A hydraulic feed-through will be incorporated into the thermistor string to allow for borehole fluid sampling. The cork has been designed to allow the borehole fluid samples to be retrieved and the data logger to be downloaded and/or removed, without the drill ship, utilizing a remote observation vehicle or manned submarine.

The first deployment of the cork prototype will occur during Leg 136. The cork will be run in the hole, latched into a reentry cone, pressure tested and retrieved as an operational and engineering test. The first deployment of the cork for scientific reasons will occur during Leg 139, Sedimented Ridges (July-August 1991).

REGIONAL SETTING

OSN-1 will be the focus of numerous experiments, carried out using the new U.S. wireline or French submersible reentry capability. Developments at OSN-1 will provide the groundwork for the construction of a global network. We have chosen the site 250 km south-southwest of Honolulu for three simple reasons:

• Clear comparisons can be made between our new data (both signal and noise) and those recorded by a well-established island site (Kipapa tunnel on Oahu);

• The opportunity exists to determine the upper mantle structure beneath the Hawaiian swell.

• Logistics for instrument placement, recovery, and maintenance are excellent.

The seismic experiments require at least a 100-m penetration into basaltic basement, beneath a few hundred meters of sediment cover in ~4000-m water depths at a location sufficiently far from the islands that the noise field is not dominated by island interactions but close enough so that logistics are simple and meaningful comparisons can be made with signals recorded at the joint GEOSCOPE - Global Seismic Network (GSN) site in the Kipapa tunnel on Oahu.

The OSN site is situated ~250 km southwest of the island of Oahu in ~4,500 m of water (Fig. 1). The sites are well clear of the extensive debris slides (Moore et al., 1989) and lava flows (Clague et al., 1989) mapped within the Hawaiian Exclusive Economic Zone by means of the GLORIA sonar imaging system. High-quality multichannel reflection and refraction data (Fig. 4) tightly define the impedance and velocity structure of the sediments and igneous crust (Watts et al., 1985). Expanding Spread Profile data (Fig. 5) indicate two primary sedimentary layers: a 200-m-thick layer of sediment increasing in velocity from 1.5 to 1.6 km/s overlying a thin (40 m), fast layer (4.2-4.3 km/s). The upper layer exhibits a normal gradient for compacting, uncemented seafloor sediments, while the lower layer may well be the same porcellanite encountered at DSDP Site 67 (Winterer et al., 1971).

DRILLING OBJECTIVES AND STRATEGY

Leg 136 will begin with a port call in Honolulu, 28 February - 2 March 1990. *JOIDES Resolution* will sail from Honolulu on 3 March, occupying one site--OSN-1--during the leg. On 20 March the ship will return to Honolulu, ending Leg 136.

The primary objective of Leg 136 is to drill a hole 100 m into basement. Secondary geological and engineering goals will be accomplished through the following scenario:

1. A brief (3-hr) site survey.
2. Hole A: APC and XCB to basement, continuously coring sediments, with ~2 cores in basement.
3. Shift to Hole B. Set reentry cone (cased into basement ~20 m.)
4. Perform 2 days of reentry cone seal testing.
5. RCB at least 100 m into basement. Full coring if time allows.
6. Well logging. Quad-combo string (velocity, density, resistivity, and gamma-ray), digital borehole televiewer. Geochemistry string run through casing depending on time and need to correlate log and core.
7. VSP/Check Shots for traveltime in sedimentary section (run through casing) and in basement if time allows.

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Watts, A. B., ten Brink, U. S., Buhl, P., and Brocher, T. M., 1985. A multichannel seismic study of lithospheric flexure across the Hawaiian-Emperor seamount chain. *Nature,* 315:105-111.

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Table 1. Leg 136 Drilling Schedule.

Leg 136 departs Honolulu on 3 March, 1991.

		Time on Site (days)	Transit Time (days)
Transit from Honolulu to OSN-1.			0.6
Arrive OSN-1	3 March	15.8	
Leave OSN-1	20 March		
Transit from OSN-1 to Honolulu.			0.6
Arrive Honolulu	20 March		
		Total Time	17 days

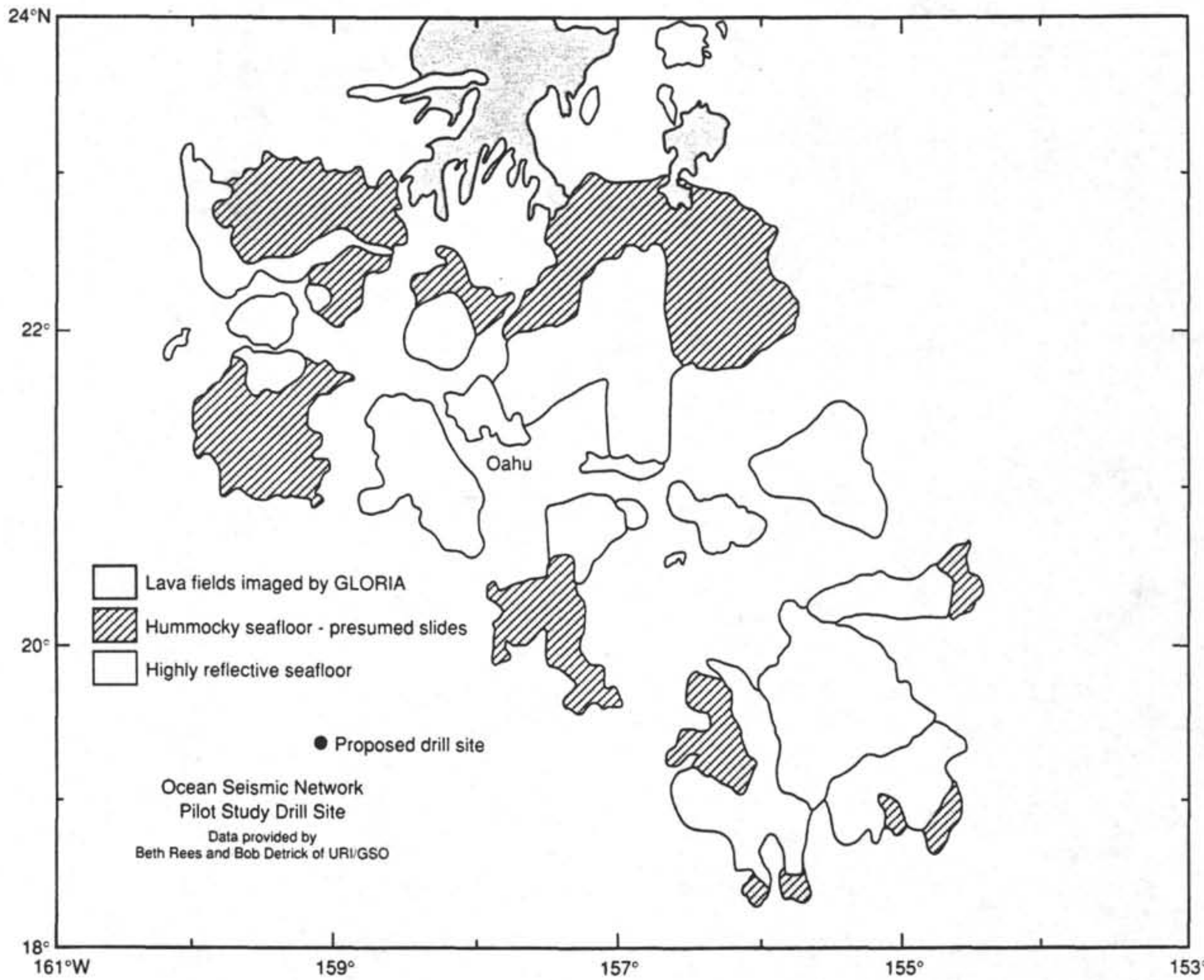


Figure 1. Location of the proposed drill site 250 km south of Oahu. Lava fields and slumps are as mapped by Moore et al. (1989) and Clague et al. (1989). Note that the site is well clear of any of these disturbances.

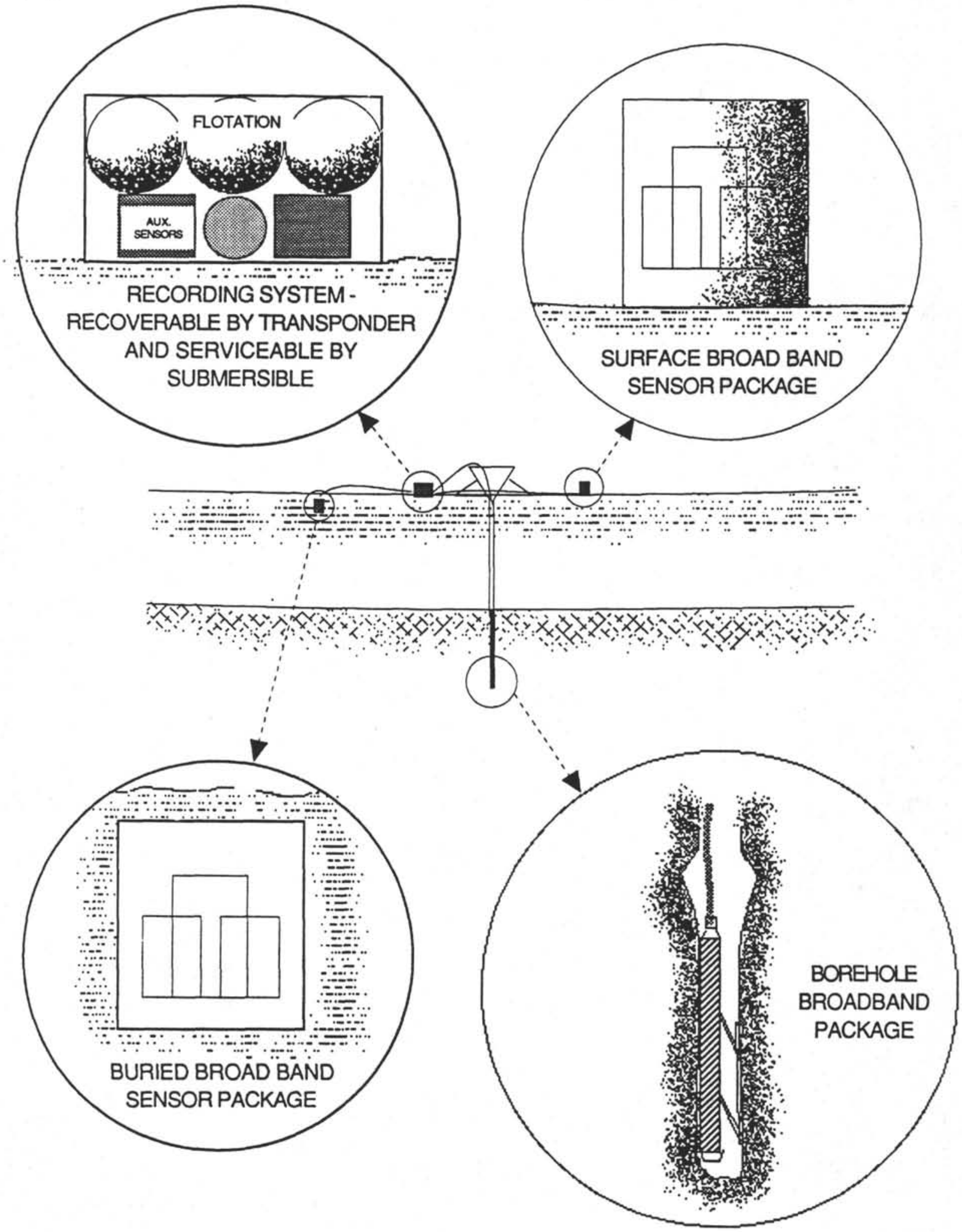


Fig 2. Possible configuration of experiment in which data from borehole, surface, and buried broadband sensor packages are simultaneously recorded by a common data-acquisition system.

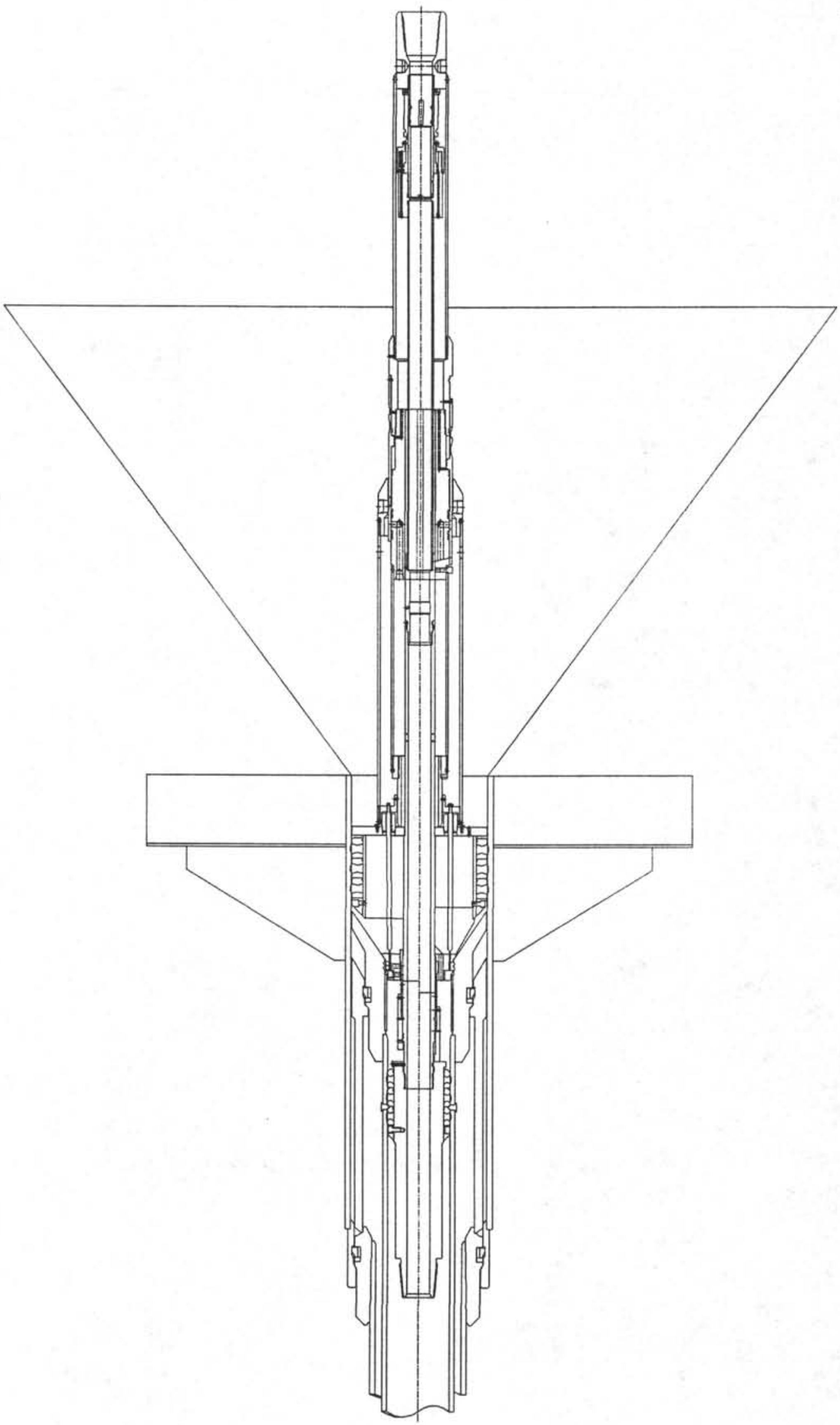


Figure 3. Engineering drawing of ODP reentry cone plug.

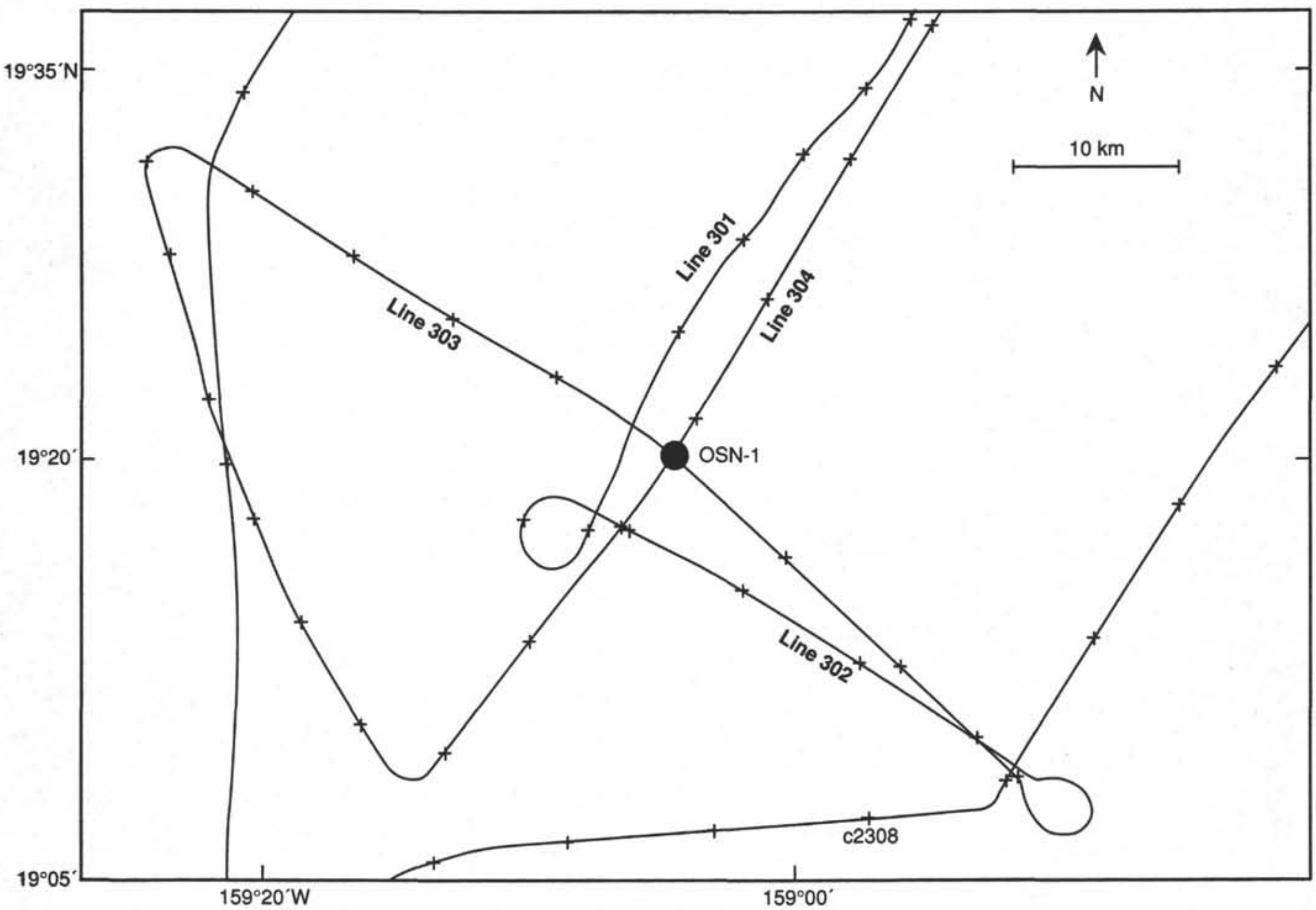


Figure 4. Location of OSN-1 shown on track of *Robert Conrad* Cruise 2308 (From Watts et al., 1985).

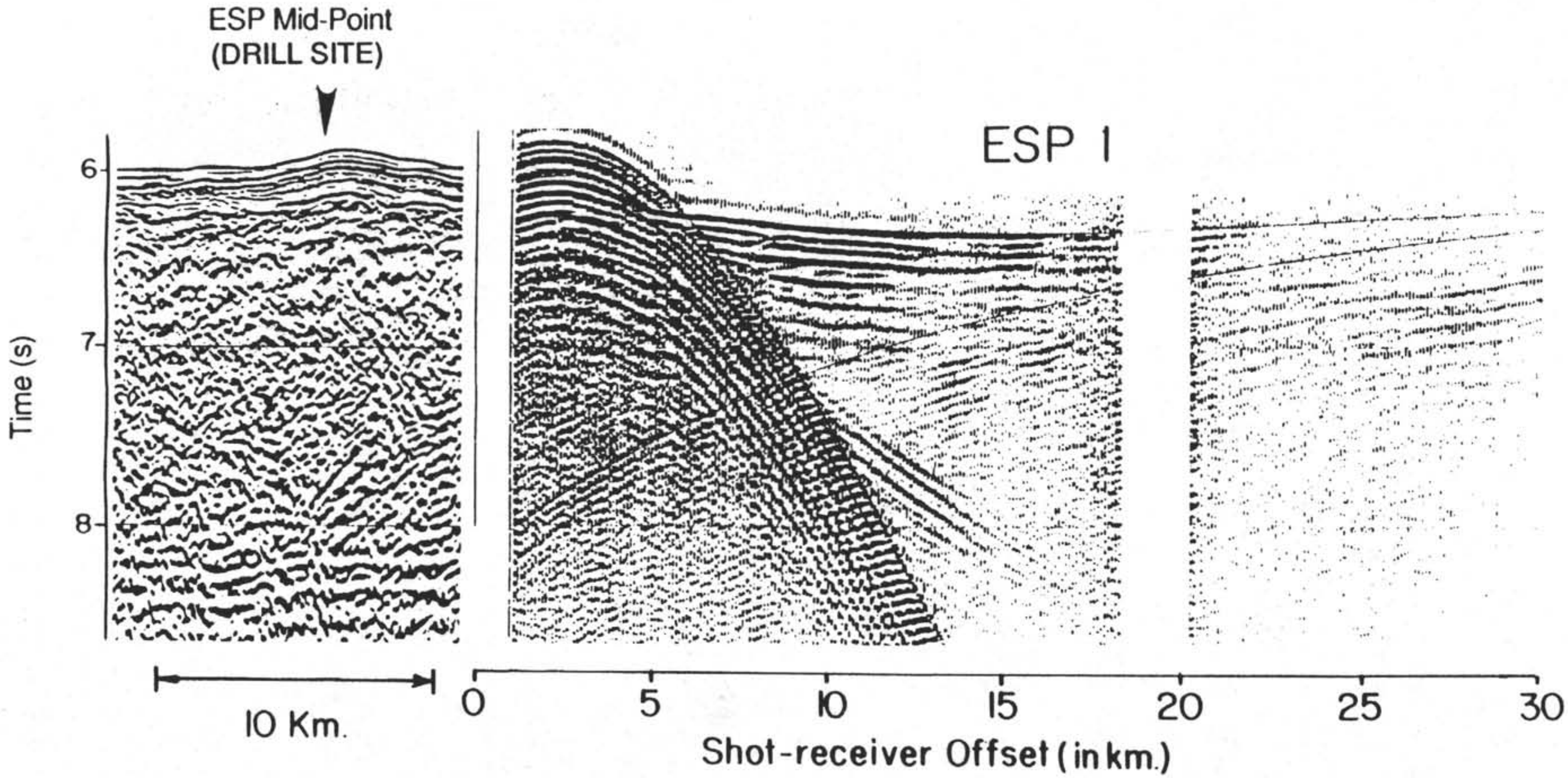


Figure 5. ESP profile, the mid-point of which is our preferred drill site. Note that the shallow crustal refraction can be traced through the bottom reflection thus giving substantial confidence in the validity of the uppermost velocity structures. (From Brocher and ten Brink, 1987.)

Proposed Site: OSN-1

Position: 19°20.6' N, 159°04.8' W

Water Depth: 4500 m Sediment thickness: 240 m

Penetration:	Sediment -	240 m
	Basement -	100 m
	Total -	340 m

Drilling Time (days):	Drilling -	11.8
	Logging -	2.0
	Reentry Seal Test -	2.0
	Total -	15.8

Proposed drilling program:

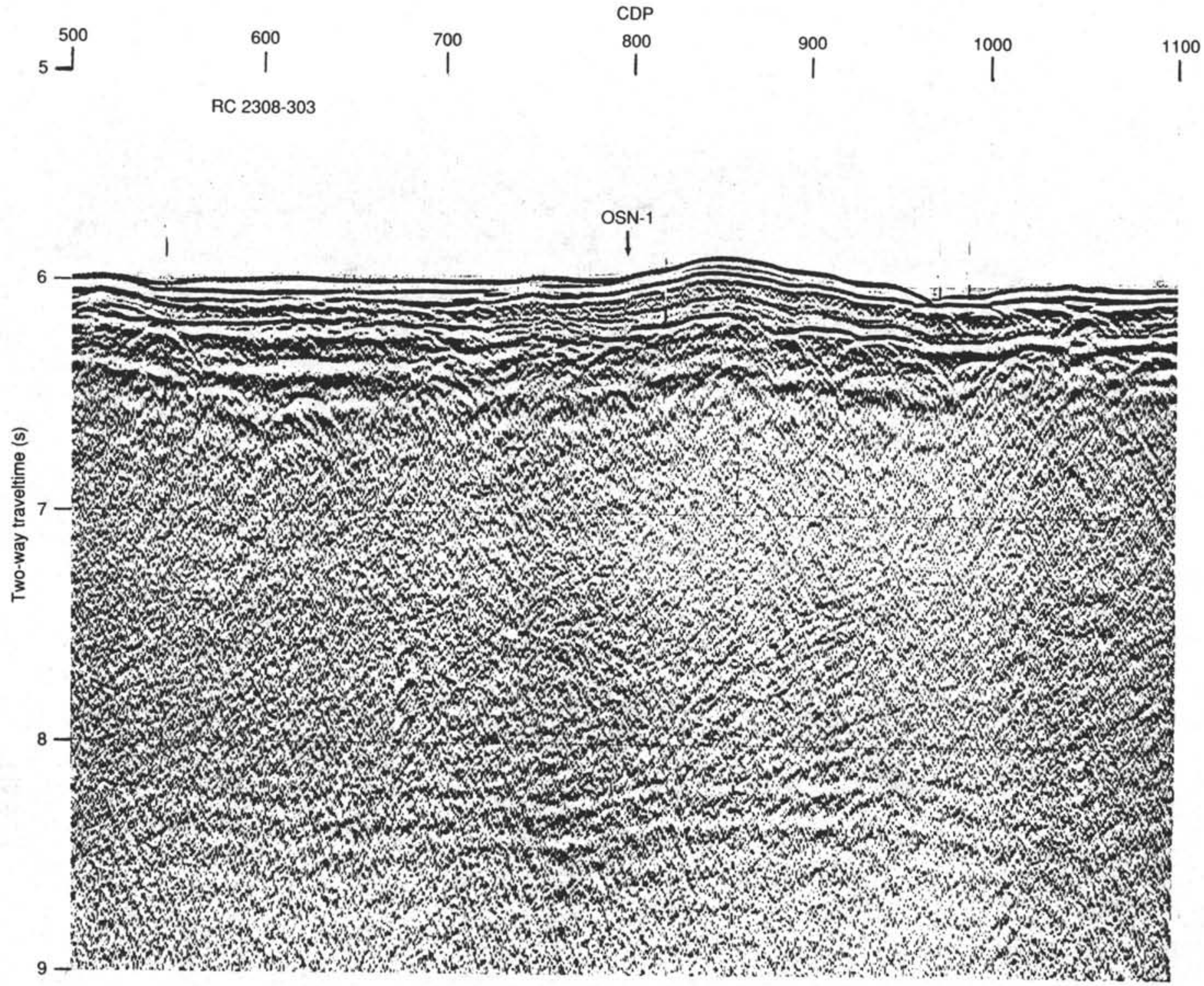
Hole A. APC/XCB sediments, 2 cores into basement.

Hole B. Set casing and reentry cone, test reentry seal, RCB 100 m into basement. Log with Quad combo (geophysical string), digital borehole televiewer, and perhaps the geochemical and vertical seismic profile strings.

Seismic Record: *Robert Conrad* 2308, Line 303, CDP 790
Robert Conrad 2308, Line 304, CDP 840

Objectives: The site was chosen to meet these criteria: (1) The OSN site needs to be in ocean crust about 200 km from the existing installation on Oahu, (2) the site is clear of debris from the Hawaiian Island Chain, and (3) the site is downwind of the Hawaiian Chain, to examine ash stratigraphy.

Nature of sediments/rocks: North Pacific clays, porcellanites; basaltic basement.


CDP
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Two-way traveltime (s)
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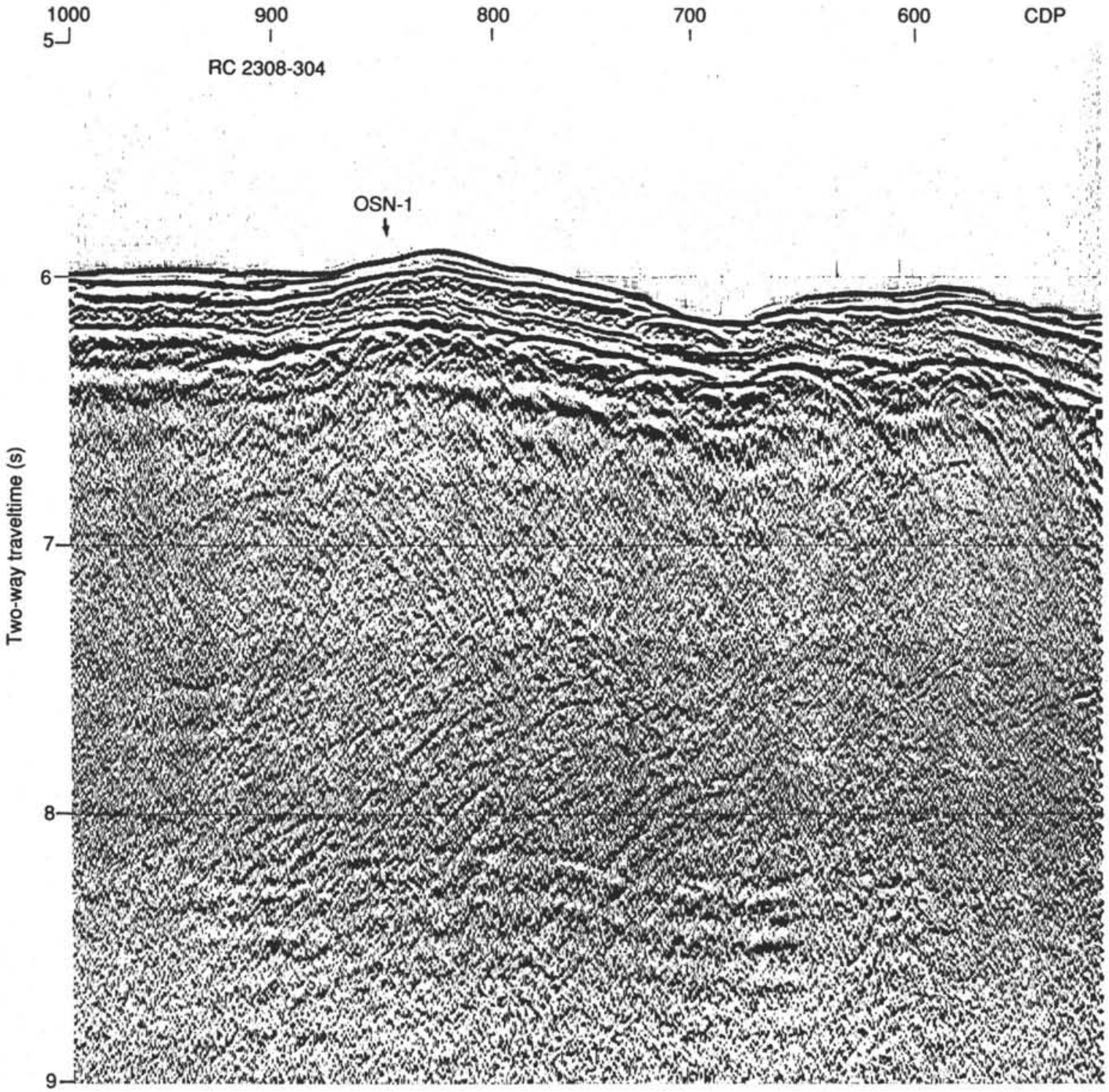
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Two-way traveltime (s)

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