# OCEAN DRILLING PROGRAM

# LEG 146 SCIENTIFIC PROSPECTUS

# CASCADIA MARGIN


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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 relationship between fluid flow and tectonics in the accretionary wedge formed at the Cascadia convergent plate boundary is the issue that ODP Leg 146 will investigate. Near Vancouver Island, drilling at three sites will examine the progressive changes in porosity of sediments that are accreted and deformed and the associated fluid flow. Near Oregon, the channeling of fluid outflow along faults will be the focus of investigations at the three sites there. The seabed of the Cascadia margin is extensively underlain by a bottom-simulating reflector (BSR) associated with the base of a zone permeated by methane hydrate. This will be penetrated at two sites to determine its nature and whether free gas is present beneath it. At all drill sites, measurements will be made of in-situ physical and chemical conditions to relate fluid chemistry, the composition and state of deformation of the sediments, and measured or inferred rates of fluid flow. These measurements will employ Geoprops Probe, Lateral Stress Tools (I and II), packer/flowmeter, and Pressure Core Sampler along with more conventional tools. The ODP borehole seal (CORK) will be installed at two sites to make long-term measurements of temperature gradients downhole, fluid pressure, and fluid chemistry.

## Introduction and Objectives

Sediments on the ocean crust of the subducting Juan de Fuca plate, and the pore water and organic and inorganic compounds that are contained within them are placed under increased pressure and temperature as they are subducted beneath or incorporated into the thickening accretionary wedge at the Cascadia margin (Fig. 1). Compaction under increased load drives pore water out of the sediments. The resulting outflow can be widespread and diffuse, but it is also channeled along zones of high permeability, such as faults, which produce vents at the seafloor. Increased temperature and bacterial activity produce methane and other hydrocarbons from the organic material in the sediments. The presence of methane in this region is demonstrated by the widespread occurrence of bottom-simulating seismic reflectors that represent the base of sediment containing methane hydrate, by the dissolved methane in water escaping from vents, and by the occurrence of pavements of diagenetic carbonate generated by the oxidation of methane in fluids seeping out of the seafloor. Other diagenetic reactions produce changes in the fluid chemistry, and can generate additional water, such as in the transition from smectite to illite. Production of volatiles can contribute additional pressure to drive fluids through the system.

Leg 146 will investigate fluid flow from and sediment deformation within the accretionary wedge that forms the continental margins off Oregon and Vancouver Island. The scientific program is dedicated to advancing our knowledge of the budget, sources, pathways, and ultimate fate of sediment, water, and dissolved chemicals in the wedge, and the relationships between accretion tectonics and the fluid regime. Our objective is to gather information on the fluid chemistry and pressure, the physical properties of the sediments, and the nature and history of diagenetic events associated with accretion and fluid discharge. In light of the occurrence of extensive venting of fluids on the Cascadia margin established by submersible observation, direct measurement, geochemical analyses, and inference from sidescan sonar images, Leg 146 promises to be the first ODP cruise to determine the relationships between active fluid venting and subsurface physical and chemical conditions.

## Regional Geology and Tectonics

The Cascadia margin has been a zone of convergent plate motion since the Eocene as the Kula/ Farallon and, most recently, the Juan de Fuca plates subducted obliquely beneath the North American plate. The process accreted several terranes, most notably the Crescent and Pacific Rim terranes to the north (Vancouver Island and Olympic Peninsula) and the Klamath Terrane to the south.

Modern accretion on the northern Cascadia margin (Vancouver Island) is characterized by thrust faulting which extends to oceanic basement. As a result, in contrast to accretion farther south, the entire sedimentary section is being transferred to the North American plate, and little if any of this sediment is being subducted.

The forearc Tofino Basin, where more than 3000 m of Eocene to modern sediments are deposited, covers most of the continental shelf off Vancouver Island. It has formed by deposition of Eocene to Holocene marine clastic sediments over the Pacific Rim and Crescent terranes and the modern accreting sedimentary wedge.

The Crescent Terrane appears to consist of Eocene oceanic crustal rocks trapped on the margin by a westward jump of the subduction zone. The Pacific Rim Terrane consists of Mesozoic sedimentary rocks wedged between the older continent and the ophiolitic Crescent rocks. The two terranes are assumed to have been emplaced in the same tectonic event. Beneath and against the Crescent Terrane, the modern accretionary complex has formed by scraping off the incoming sediments on the subducting Juan de Fuca plate (Fig. 2a). The subduction since the Eocene has been relatively simple, the continuous record of accretion having shown no evidence for the arrival of allochthonous terranes.

Off central Oregon, Quaternary underthrusting of 9-m.y.-old oceanic crust blanketed with nearly 4 km of sediment produces a series of well-defined folds and thrust faults which make up the lower continental slope. The depositional system is characterized by rapid clastic influx associated with large submarine fans. The currently forming accretionary wedge is the youngest part of the larger subduction complex that encompasses Paleogene and Neogene portions exposed on land (Fig. 2b). West of the Coast Range, four distinct geologic terranes are recognizable: (1) deep forearc basin on the inner shelf, (2) mid-shelf tectonic high, (3) mid- to outer-shelf Eocene-Miocene accretionary melange wedge, and (4) folds and thrust faults of the Pliocene-Pleistocene accretionary complex that makes up most of the continental slope. Eocene to Miocene sedimentation in the forearc (shelf) basin resulted in accumulation of more than 7000 m of sedimentary and volcanic rocks. Convergent episodes in the late Eocene and middle Miocene formed thick accreted sequences of melange and broken formation that underlie the present outer shelf and upper continental slope. Modern subduction began in the late Miocene, and produced progressive westward migration of the continental slope as abyssal plain (Cascadia Basin)/deep-sea fan deposits were accreted to the margin. It is these Pliocene-Pleistocene deposits to which the drilling program is directed.

## Heat Flow and Geothermal Gradient

Heat flow has been measured extensively on the continental margin in the vicinity of Vancouver Island. Along the Oregon coast, heat-flow data are less abundant, but the ninety or so measurements adequately define similar trends in heat-flow variation to those in the vicinity of Vancouver Island. Heat flow from the ocean basin is high, about 140 mW/m$^2$, because of the young age of the oceanic lithosphere (8 Ma, Oregon, and 6 Ma, Vancouver). Heat flow decreases landward across the continental margin to about 60 mW/m$^2$, because of the deepening of the oceanic lithosphere as it is subducted. The initial decrease is accentuated by the tectonic thickening of the accretionary wedge, which stretches the isotherms and reduces the thermal gradient. Local increases and decreases in heat flow over the margin are produced by the effects of thrusting, erosion, localized deposition at high sedimentation rates, and the outflow of warm pore fluid. For example, a heat-flow high of 182 $mW/m^2$ measured on the Oregon margin in a ponded basin between the major thrust sheets is attributed to the advective movement of pore fluids through the accretionary complex. The broad distribution of temperature within the Vancouver Island margin has been modeled, taking into account the age of the oceanic lithosphere, the history of sedimentation, and the accretion of sediment at the margin. Beneath the ocean-basin floor, a temperature of 100°C is reached at a depth of 1.3 km, whereas 20 km landward of the toe of the accretionary wedge, this temperature is reached at a depth of 1.9 km. The pattern of isotherms near Oregon is similar.

## Drilling Strategy

Leg 146 will drill a series of relatively shallow (≤600 m) holes (see Tables 1 and 2), in contrast to some previous accretionary-prism programs which sought deep penetration to sample the sediments of the décollement. These holes will be of two kinds:

1. Non-reentry holes will be cored with APC/XCB tools in the upper part of the section; RCB-coring will be used in indurated sediments deeper in the hole. Extensive downhole logging and special sampling (PCS, GEOPROPS, LAST 1 and 2, and WSTP) are to be carried out in these holes.

2. Two reentry holes will be cased to depth and fitted with ODP borehole seals (CORKs) for long-term monitoring of temperature and pressure, and subsequent fluid sampling and hydrogeologic tests. In addition to the logging and special sampling procedures planned for the non-reentry holes, packer-flowmeter tests will be run in the cased portions of these holes.

Because it has been postulated that fluid flux is dispersed off Vancouver Island, and focused along fault zones near Oregon, two transects will be drilled. The Vancouver Island sites (Fig. 3) will document the loss in porosity from Cascadia Basin onto the continental slope, and determine the relation between fluid flux and methane clathrates, which are manifested as a strong BSR. Sites on the Oregon margin (Fig. 4) were selected to penetrate fault zones suspected or known to be active aquifers, which focus the fluid discharge.

## Description of Subareas and Scientific Basis for Drilling

### *Vancouver Island Margin*

The accretionary sedimentary wedge has formed by off-scraping of the sediment section overlying the incoming Juan de Fuca plate (Fig. 5). This section is 2 to 3 km thick near the Vancouver Island margin, and consists of Pleistocene turbidites overlying a thinner, acoustically transparent (hemipelagic/fine-grained turbidites?) layer. Both the extension of seismically imaged thrust faults very close to the downgoing crust, and mass balance calculations (i.e., total sediment brought in compared to that in the wedge), indicate that most if not all of the sediment has been scraped from the incoming oceanic crust over the past 42 m.y., forming the 70-km-wide prism. The detachment surface or décollement zone at present, and probably since the Eocene, is thus close to the top of the oceanic crust. The incoming sediments fail first along widely spaced listric faults, although only 10-20 km behind the frontal fault, deformation must become more cataclastic, as regionally coherent reflectors are no longer observed (Fig. 5).

Two types of data delineate the regional fluid expulsion and porosity reduction across the deformation front on the Vancouver Island margin: porosities from multichannel seismic velocity data and vertical fluid flow from the effect on the thermal regime. One of the drilling objectives of Leg 146 is to test the resulting model of dispersed fluid expulsion associated with compaction.

Porosity-depth profiles derived from multichannel seismic velocities for the Vancouver Island margin at positions seaward of the deformation front, just behind the front, and about 10 km farther landward all show a porosity decrease of about 10% in the upper 1 to 2 km over a distance of 20 km. Using the convergence and sediment-accretion rates, the estimated fluid expulsion rate at the surface required to give this rate of porosity change is approximately $1 \times 10^{-10}$ m/sec (3 cm/yr).

A complementary estimate of fluid flow is obtained from thermal data. Surface heat flow has been constrained by 110 probe measurements and estimated from the depth to the bottom simulating reflector that represents the base of the stability field for methane hydrate (Figs. 6 and 7). The values of heat flow derived from the depth of the BSR are systematically lower than for probe measurements at almost identical locations, with the difference tending to decrease landward.

It is postulated that vertical-advective fluid flow is responsible for the difference. The effect is illustrated in Figure 8 for a point about 10 km inland of the deformation front. The temperature at the depth of the BSR obtained by extrapolating the surface temperature gradient downward is substantially higher than the temperature derived from the hydrate stability field. A simple vertical-advective fluid-flow model resolves the disparity if the near-surface rate is about $1 \times 10^{-9}$ m/sec. This flow rate is about an order of magnitude greater than that estimated from porosity loss, and so it is crucial to calibrate the temperature and pressure at which the BSR forms.

Bottom-simulating seismic reflectors commonly occur several hundred meters beneath the seafloor in continental-slope sediments, particularly in subduction-zone accretionary prisms. That these reflectors mark the base of the region for hydrate stability is inferred from a number of observations, notably that the pressure and temperature conditions estimated for the BSRs agree with the maximum temperature and pressure at which hydrate is stable from laboratory data, and that interstitial and massive hydrates have been recovered in Deep Sea Drilling Project cores from sections above BSRs.

Numerous studies have focused on the problem of the configuration of hydrate and possible free gas required to generate BSRs. The main results are the following: (1) The reflection polarity is usually reversed. This indicates that for a simple interface contrast there is a lower impedance (velocity $\times$ density) below the boundary. (2) The BSR reflection coefficients are large, commonly 50% of that of the seafloor. (3) The multichannel and other seismic velocity data indicate that the average velocity increases only slightly in the sediment section from the BSR to the seafloor, indicating that the hydrate is concentrated at the base of the stability field, (i.e., no more than several tens of meters thick). (4) The zone containing hydrate must be at least a quarter wavelength thick (5 to 10 m minimum) and there must be an abrupt contrast at the base of the layer. The lack of a reflection from the upper boundary of the hydrate layer indicates that the upper boundary is a gradual transition.

A model for formation of methane hydrate BSRs has been proposed (Hyndman and Davis, in press), which is to be tested on the northern Cascadia accretionary wedge. In this model, hydrate is formed primarily from dissolved methane removed from upward-advecting pore fluids as they pass into the hydrate stability field, rather than being formed from locally derived methane. Methane-saturated pore fluids containing free gas are not believed to be required. The very low percentage of organic carbon in the accreted sediments makes the production of free gas in-situ unlikely. The model provides explanations for why the hydrate is concentrated in a layer at the base of the stability field, for the source of the large amount of methane required, and for BSRs being restricted to special environments. In normal sediment depositional regimes, there is no upward fluid advection into the hydrate stability field, so no hydrate BSR is formed. Upward fluid advection does occur through tectonic thickening and consolidation in subduction accretionary wedges and in areas where rapid deposition results in initial under-consolidation, and in these areas hydrate BSRs are commonly observed. Thus, BSRs may be an important indicator of fluid flow. The model predicts that the hydrate concentration is greatest near the base of the stability field and decreases upward. It also predicts that methane and perhaps $CO_2$ concentrations are higher below the BSR than above, but also predicts that the BSR is permeable. A simple velocity/density/depth model, based on the distribution of hydrate from the theoretical model, has been formulated. The synthetic seismogram of this model is in good agreement in amplitude and form with the reflection data; no low-velocity layer containing free gas is required below the BSR. A typical BSR reflector can be modeled with about half of the sediment pore space filled by hydrate just above the BSR; i.e., sediment is approximately 25% hydrate and 25% water. Such a layer would be a strong seismic reflector, but permeable to advecting fluids.

Given the specific expectations for hydrate composition, concentration, and distribution derived from this hypothesis, drilling on Leg 146 will evaluate this model against alternative mechanisms of formation. In relation to this and the expulsion of methane-rich waters that form diagenetic carbonate and sustain the biota around vents, the microbiological control of methane cycling will be investigated. This will involve the measurement of the activity rates of bacterially mediated methanogenesis, methane oxidation, and sulphate reduction.

Site VI-5 and its alternatives (B,C) have as their primary purpose the investigation of the mechanism of formation of gas hydrate that produces a bottom-simulating reflector seen on seismic reflection sections. The criteria adopted for the selection of the sites so that they would fulfill this purpose were that:

i. The bottom-simulating reflector (BSR) should be as well developed and as continuous as possible;

ii. The BSR should lie well within the deformed sediment of the accretionary wedge, not the slope cover;

iii. The BSR should be at a shallow depth below sea level, and be only gently dipping to optimize the comparison of the results from drilling with those obtained from surface seismic data;

iv. The BSR should not lie beneath dipping sea bed or at the foot of a slope to avoid disturbance of the thermal gradient by erosion from mass wasting or by deposition of slumps.

### *Central Oregon Margin*

MCS data from the Oregon margin (Fig. 4) indicate that subduction-related deformation begins on the abyssal plain about 5 km seaward of the frontal thrust, with development of incipient faults. Frontal thrust faults beneath the toe of the continental slope are moderately to shallowly rooted in the south, where they verge seaward (Fig. 9a), and are deeply rooted (≈4 km sub-bottom) in the northern subarea, where vergence is landward (Fig. 9b). Additionally, the seismic data show a variety of active backthrusts and out-of-sequence thrusts landward of the deformation front, where seaward vergence dominates. Direct submersible observations and sidescan imagery (SeaMARC-1A and GLORIA) demonstrate that many of these fractures represent active fluid conduits. As a result, this structural context affords the opportunity to tap fluid sources from various depths in the incoming sedimentary section.

A bottom-simulating reflector is commonly resolved about 10 km landward of the frontal thrust (Fig. 9a). As off Vancouver island, the BSR is not observed closely adjacent to the frontal thrust, but does occur locally beneath the first anticlinal ridge.

ALVIN dives on the central Oregon accretionary prism provide information on the locations and character of active, focused fluid vents. More than ten fluid venting sites have been discovered along the initial deformation front (i.e., on the marginal ridge in the southern area and on an incipient fold on the abyssal plain in the northern area). Many of the vent sites are characterized by unique animal communities, by expulsion of methane alone or with hydrogen sulfide, and by diagenetic carbonate deposits. The highly $^{13}C$-depleted carbon of this assemblage of biota, carbonates, and methane suggests that expulsion of biogenic gas-bearing fluids and subsequent oxidation of reduced gasses is a major geochemical mechanism in accretionary prisms.

The magnitude of methane concentrations measured above vents in the two Oregon subareas varies by a factor of at least 300, suggesting equivalent variability in flow rates. The methane in the fluids is highly depleted in carbon-13 (-66 to -73‰, referred to the "Pee Dee Belemnite" standard), indicating its microbial origin and probable derivation from shallow levels (<1 km) of the accretionary complex. A shallow and probably variable source depth of fluids is also evident from the presence of both hydrogen sulfide and methane in water venting from one location on the marginal ridge, and the absence of hydrogen sulfide at a second location of methane-venting on the ridge.

Helium concentrations and helium isotopes from waters collected in-situ from the vents suggest that fluids from the southern subarea have a strong radiogenic component and hence were generated entirely from within the accretionary sediment pile ($\delta^3He < 22‰$). Conversely, preliminary evidence suggests that those fluids venting from a deeply rooted fault-fold intersection in the northern subarea have some primordial component ($\delta^3He > 22‰$) that suggests some contact with oceanic basement.

Rates of fluid flow from local vent sites on the marginal ridge in the southern subarea have been estimated from dissolved methane transfer and directly measured by flowmeters. The results imply a subsurface advective flow rate of about 100 m/yr. These discharge rates are several orders of magnitude higher than rates calculated for steady-state expulsion due to accretion-related consolidation, indicating that flow through vents is regionally focused and probably episodic. Similarly, the enormous variation in methane-expulsion rates (see above) attests to a nonhomogeneous distribution of flow paths. For comparison, heat-flow-based rates of dispersed intergranular flow through the slope sedimentary blanket off Vancouver are estimated to be about 3 cm/yr and are thought to account fully for the dewatering of the accretionary prism.

Flow is almost certainly focused by inhomogeneities in permeability. Figure 10 depicts measured porosity and permeability of surface samples collected in the submarine canyon north of OM-3A. Mean permeability is approximately $10^{-1}$ md, with no obvious control by grain size. Porosity of the accreted slope sediments is also low, averaging 46% for surface samples and declining to about 12% at 2.2 km, the depth of the décollement .

That fluid expulsion is not evenly distributed across the lower margin is confirmed by sidescan sonar, which responds to diagenetic carbonate deposits precipitated by oxidation of methane-bearing pore waters. Analysis of GLORIA imagery indicates that carbonates are concentrated along fault traces. The most widespread cementation occurs on the second ridge (OM-7), with less extensive deposits on the marginal ridge and in the proto-deformation zone in Cascadia Basin.

## Logging and Downhole Measurements

Leg 146 will rely heavily on logging and other downhole measurements to meet the highest priority objectives of the scientific program. Important measurements include sub-bottom temperatures, pore pressures, fluid flux, sonic velocity, porosity, and resistivity.

To accommodate the heavy program of downhole measurements within the time available for the six proposed sites at which drilling is expected, it will be necessary to omit deployment of the "geochemical" logging suite at sites VI-1, VI-2, OM-3, and OM-2A. This will mean the absence of records from the aluminum clay tool and gamma-ray spectrometry, but these do not contribute significantly to the objectives of the leg. Without these tools, logging will comprise:

Sonic (waveform)
Gamma ray (spectral)
Resistivity
Density
Neutron porosity
Caliper-temperature
Formation microscanner
General purpose inclinometer

In addition, the formation microscanner will have to be omitted from Site VI-1, which is in undeformed sediments, because of time constraints.

Sonic and density logs, and vertical seismic profiles (VSPs), are crucial to the calibration of lateral variation in porosity-depth functions determined from surface seismic reflection data. Due to time contstraints, most of the VSPs will be run as closely spaced checkshot surveys rather than as true VSPs, with a typical geophone spacing of 20 or 30 m. At site OM-3, a full-scale VSP and oblique seismic experiment are planned in conjunction with RV *New Horizon* over a period of 36 hr.

Measurements of temperature will be made extensively with the ADARA and WSTP tools (about 10 measurements per site).

The Pressure Core Sampler will be used, on average, four to five times at each site to retrieve core samples at in-situ pressures. The greatest intensity of use will be on critical intervals, such as those containing gas hydrate BSR at sites VI-5, OM-3, and OM-7.

In-situ measurements of pore-fluid pressure and stress will be made with LAST 1, LAST 2, and the Geoprops Probe. The Geoprops Probe will receive its first full operational test on this leg, and the extent to which it is utilized will clearly be dependent upon its effectiveness. Two days of the leg will be devoted to the LAST tools and Geoprops.

The Becker-Morin packer/flowmeter combination will be used at sites VI-5 and OM-3, where it will be deployed in the cased sections of the holes. Rather than injecting seawater, we will rely on natural flow up the pipe to drive the flowmeter. If flow rates are below the detection limits of the flowmeter, the packer will be set in the casing and a slug test performed to determine the integrated permeability of the lower, open section of the hole.

The long-term monitoring of the temperature, pressure, and fluid chemistry will be undertaken at two sites, VI-5 and OM-3, through the deployment of sealed borehole systems (CORKs), which have pressure transducers, a fluid sampling tube, and a thermistor string. An incorporated data logger will record P-T data for 2 years. The seals will be accessed subsequently by submersible to retrieve fluid samples and data, and to conduct hydrogeologic tests on the boreholes.

## Special Operations

Because fluid sampling, physical properties, and downhole logging and experiments are fundamental to the success of the scientific objectives, some nonstandard procedures are required on Leg 146.

Whole-round samples will be needed for shore-based determinations of permeability and deformation behavior and for extraction of interstitial water for geochemical and bacterial studies. As drilling time is extremely limited (see Table 1), whole-round sampling will be necessary without the constraint of triple coring.

Hole instability in accretionary prisms has been a problem since the inception of the Ocean Drilling Program. While we are optimistic that carbonate cementation, elevated levels of mud in the Cascadia sands, and relatively shallow holes will minimize spalling and hole degradation, we need to anticipate hole instabilities induced by formation overpressures, particularly during our extensive logging and downhole experimental programs. The JOIDES Downhole Measurements Panel, in 1990, recommended treating the holes with heavy mud prior to logging. Sufficient drilling mud to accommodate the proposed logging program should be available on Leg 146.

## Re-Instrumentation of Borehole Seal; Hole 857D

During the transit between the two margin areas of Leg 146, 1.1 days have been reserved for the replacement of the thermistor string suspended below the instrumented CORK at Hole 857D. The hole was drilled to a total depth of 936 mbsf, cased to a depth of 568 mbsf, and the CORK was installed during ODP Leg 139 in September 1991. The instrumented CORK currently supports a 300 m-long, ten-thermistor temperature-sensor string as well as the data logger and plumbing for fluid sampling. This assembly will be removed, total depth will be re-measured (a water sample will be attempted at this time), and a 900 m-long thermistor string will be installed. This string will be shortened as necessary prior to installation based on the current hole depth.

**Santa Barbara Basin Operations**

The sediments in the Santa Barbara Basin are ideally suited for ultra-high resolution studies of marine records with regard to climate change and the global carbon cycle. They are being deposited in a semi-enclosed basin behind a sill at a depth within the oxygen minimum zone. Thus, little oxygen enters the basin. The high productivity in overlying waters, due to seasonal upwelling, leads to a high supply of organic matter and corresponding depletion of oxygen in the bottom water. As a consequence, dysaerobic/anaerobic conditions develop near the seafloor, preventing benthic microfauna from disrupting the sediment. A bacterial mat develops which acts as a sediment trap. Seasonal variations in the quantity and quality of sediment supply provide for annual varves. The existence of both a terrigenous-clastic and marine-biogenic signal allows for detailed reconstruction of climatic fluctuations. Due to the high organic carbon content of the sediment, the carbon isotopic record of carbonate can be directly compared to the carbon isotopic composition of individual biological markers on a lamina basis.

In addition, these sediments will enhance our knowledge about the history of coastal upwelling at interglacial-glacial time scales. This information is necessary to better understand changes in the carbon dioxide content of the atmosphere as observed in ice cores. Better understanding of the role of Quaternary sea-level changes on basinal sedimentation should also assist in paleoenvironmental interpretations of the middle to late Miocene Monterey Formation and Pliocene Sisquoc Formation, both of which exhibit distinct sedimentary cycles.

One day has been allocated to operations (which includes transit time), in the Santa Barbara Basin. The sedimentation rate (0.5 to 1 m/1000 yr.) is such that double APC coring to about 200 mbsf should retrieve a substantial portion of the Quaternary record (last 0.5 m.y.). Triple APC coring will be carried out if time permits to ensure continuous recovery of the stratigraphy. Cores recovered from this basin will be cut into section lengths and receive standard geochemical monitoring. Additional shipboard analyses will be limited to continuous-core measurements such as the GRAPE. The cores will then be stored for further shore-based analysis.

## Table 1 - Primary Site Time Estimates

| Site | Location Latitude | Location Longitude | Water depth (m) | Penetration (m) | Drill (days) | Log (days) | Downhole Experiments[1] | Total (days) | Transit (days) |
|---|---|---|---|---|---|---|---|---|---|
| Victoria | 48°30'N | 123°20'W | | | | | | | |
| | | | | | | | | | 0.6 |
| VI-5 | 48°41.84'N | 126°52.30'W | 1290 | 400 | 9.6 | 1.7 | WVC | 11.3 | |
| | | | | | | | | | 0.1 |
| VI-2 | 48°15.13'N | 126°30.00'W | 2125 | 600 | 4.7 | 1.4 | WV | 6.1 | |
| | | | | | | | | | 0.1 |
| VI-1 | 48°09.97'N | 126°39.87'W | 2550 | 600 | 5.3 | 0.8 | WV | 6.1 | |
| | | | | | | | | | 0.3 |
| Hole 857D | 48°26.52'N | 128°42.65'W | 2431 | | | | | 1.1 | |
| | | | | | | | | | 1.1 |
| OM-3 | 44°38.59'N | 125°19.57'W | 2655 | 540 | 10.5 | 3.2 | WOC | 13.7 | |
| | | | | | | | | | 0.1 |
| OM-7 | 44°40.45'N | 125°07.23'W | 668 | 300 | 2.2 | 1.0 | W | 3.2 | |
| | | | | | | | | | 0.1 |
| OM-2a | 44°40.42'N | 125°21.53'W | 2865 | 500 | 5.1 | 1.2 | W | 6.3 | |
| | | | | | | | | | 2.7 |
| [2]Santa Barbara | 34°16'N | 120°04'W | 500 | | | | | 1.0 | |
| | | | | | | | | | 0.7 |
| San Diego | 32°45'N | 117°10'W | | | | | | | |
| | Subtotals = | | 2940 | | 37.4 | 9.3 | | 50.8[3] | 5.8 |
| | Grand total = | | **56.6 days at sea** | | | | | | |

[1] Downhole experiments to be conducted include WSTP and PCS (W), VSP (V), oblique VSP (O), and packer/flowmeter and instrumented borehole seal or CORK (C). Estimated time required for these experiments has been included in estimated drilling time.
[2] Drilling at this site is subject to Pollution Prevention and Safety Panel approval.
[3] Included in this value is time alloted for Geoprops and LAST work (unallocated).
Note: Transit times are calculated for a speed of 10.5 kts.

**Table 2 - Alternate Site Time Estimates**

| Site | Location Latitude | Location Longitude | Water depth (m) | Penetration (m) | Drill (days) | Downhole Experiments[1] | Log (days) | Total (days) |
|---|---|---|---|---|---|---|---|---|
| VI-2a | 48°16.58'N | 126°27.38'W | 2060 | 600 | 4.8 | WV | 1.3 | 6.1 |
| VI-3[2] | 48°18.31'N | 126°23.96'W | 1625 | 600 | 4.8 | WV | 1.6 | 6.4 |
| VI-3a | 48°21.77'N | 126°17.32'W | 1200 | 600 | 4.8 | WV | 1.6 | 6.4 |
| VI-5b | 48°42.27'N | 126°54.36'W | 1290 | 400 | 9.3 | WVC | 2.0 | 11.3 |
| VI-5c | 48°39.82'N | 126°56.55'W | 1437 | 400 | 8.1 | WVC | 2.0 | 10.1 |
| OM-2b | 44°41.10'N | 125°22.00'W | 2860 | 500 | 5.0 | W | 1.3 | 6.3 |
| OM-3a | 44°40.46'N | 125°19.57'W | 2625 | 585 | 12.4 | WOC | 1.3 | 13.7 |
| OM-4 | 44°40.44'N | 125°17.63'W | 2025 | 600 | 4.8 | WV | 1.3 | 6.1 |
| OM-7b | 44°41.11'N | 125°07.80'W | 760 | 300 | 2.1 | W | 1.1 | 3.2 |
| OM-8[2] | 44°59.54'N | 125°22.22'W | 2400 | 660 | 5.2 | W | 1.9 | 7.1 |
| OM-8a | 45°02.66'N | 125°23.33'W | 2440 | 500 | 4.5 | W | 1.6 | 6.1 |
| OM-10 | 45°11.00'N | 125°32.10'W | 2620 | 500 | 4.8 | W | 1.6 | 6.4 |

[1] Downhole experiments to be conducted include WSTP and PCS (W), VSP (V), oblique VSP (O), and packer/flowmeter and instrumented borehole seal or CORK (C). Estimated time required for these experiments has been included in estimated drilling time.

[2] Site approval subject to further seismic processing.

## References

Hyndman, R.D. et. al., 1990. The northern Cascadia subduction zone at Vancouver Island: Seismic structure and tectonic history, Canadian Journal of Earth Science, 27, 313-329.

Hyndman, R.D. and Davis, E.E., in press. A mechanism for the formation of methane hydrate and sea floor bottom simulating reflectors by vertical fluid expulsion, *J. Geophys. Res.*

Snavely, P.D., Wagner, H.C., and Lander, D.L., 1980. Geological cross section of the central Oregon continental margin, GSA Map and Chart Series MC-28J, Scale 1:250,000.

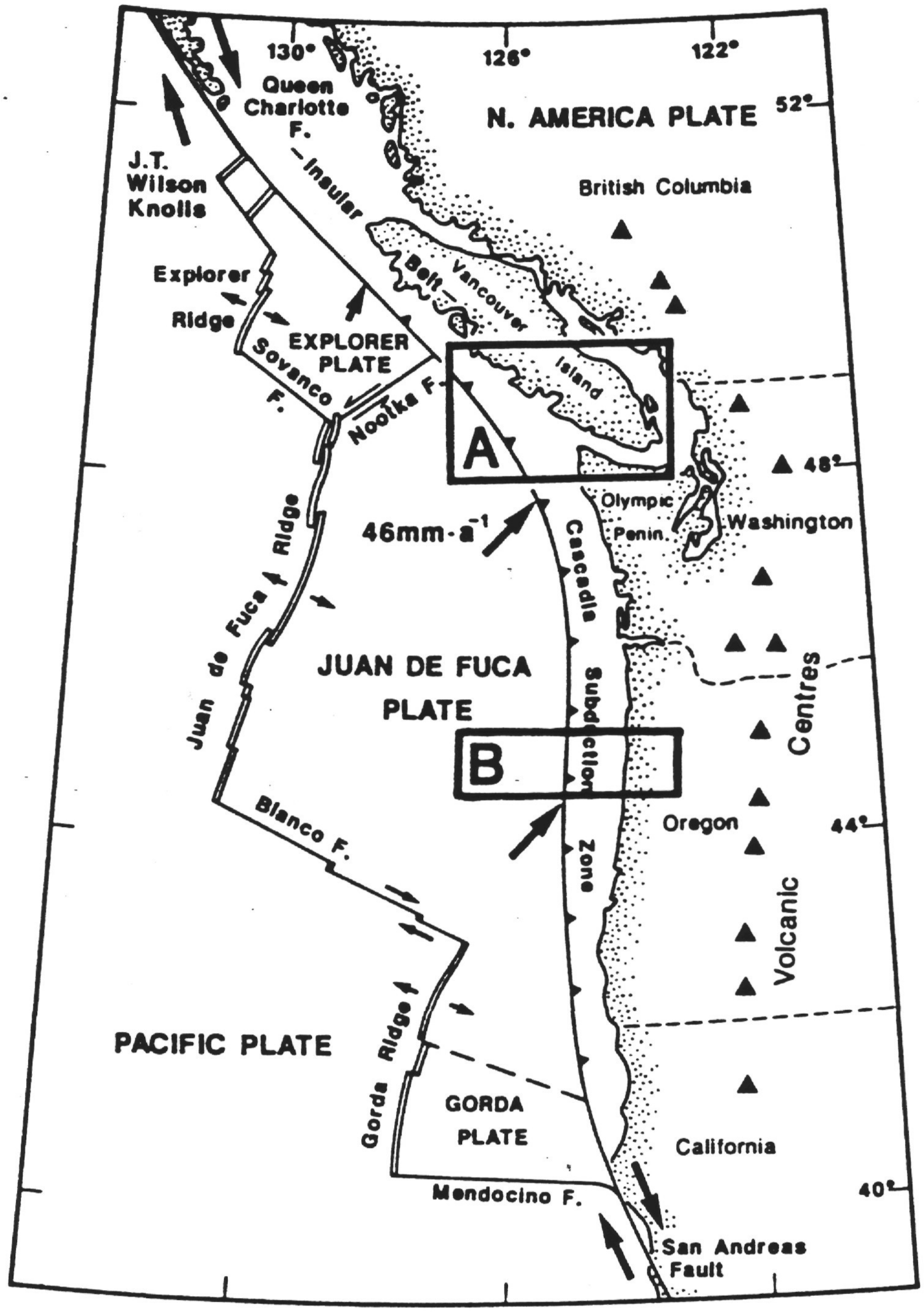


Figure 1. Map of Cascadia margin, showing the two areas of proposed drilling activity near Vancouver Island (A) and Oregon (B).

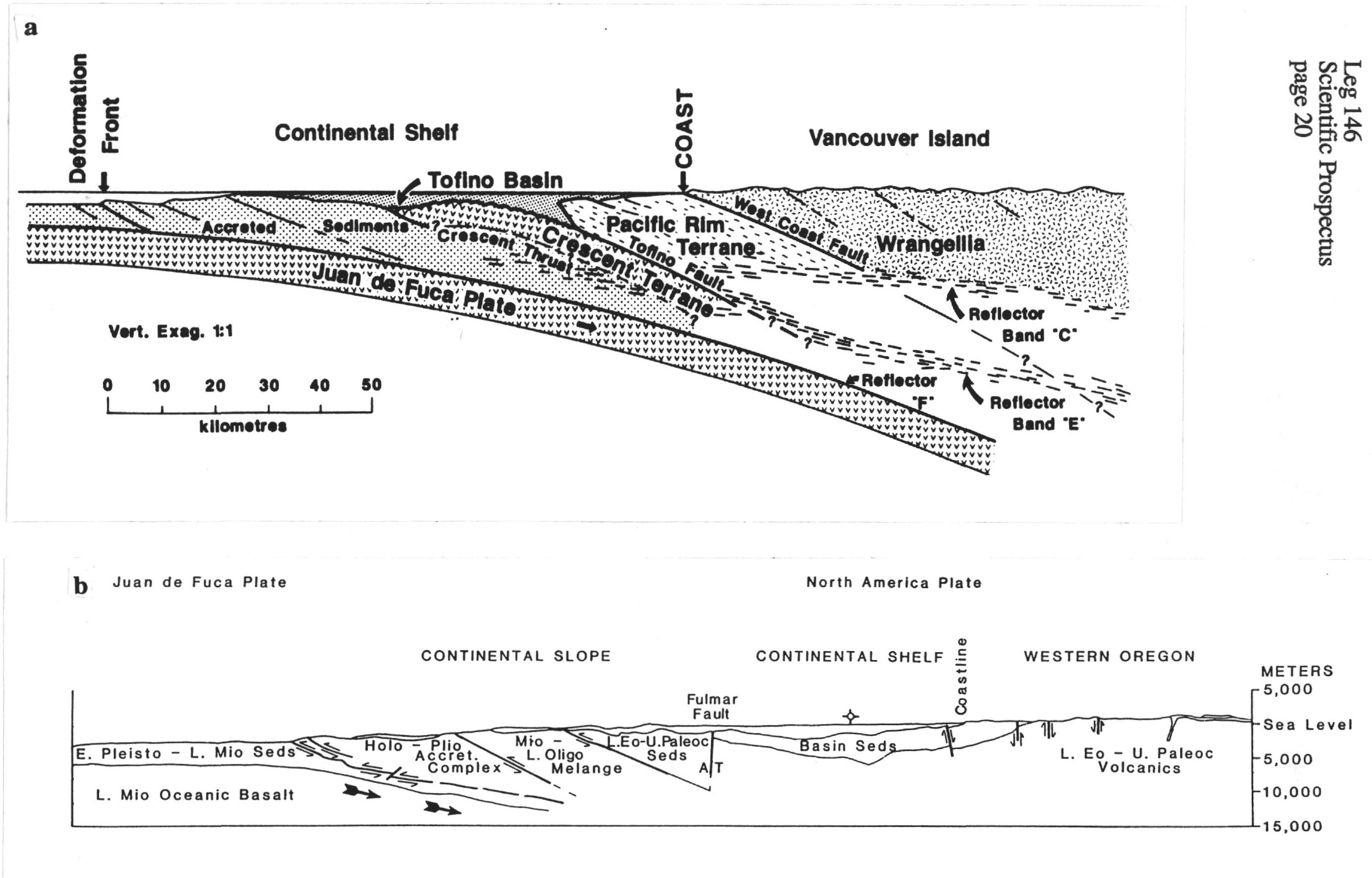


Figure 2. (a) Schematic crosssection of the Vancouver Island margin. (Hyndman et. al., 1990.)
(b) Schematic crosssection of the Oregon margin at 44°52'N. (Snavely, Wagner, and Lander, 1980.)
Section is located about 20 km north of the proposed drilling sites on MCS Line OR-9.

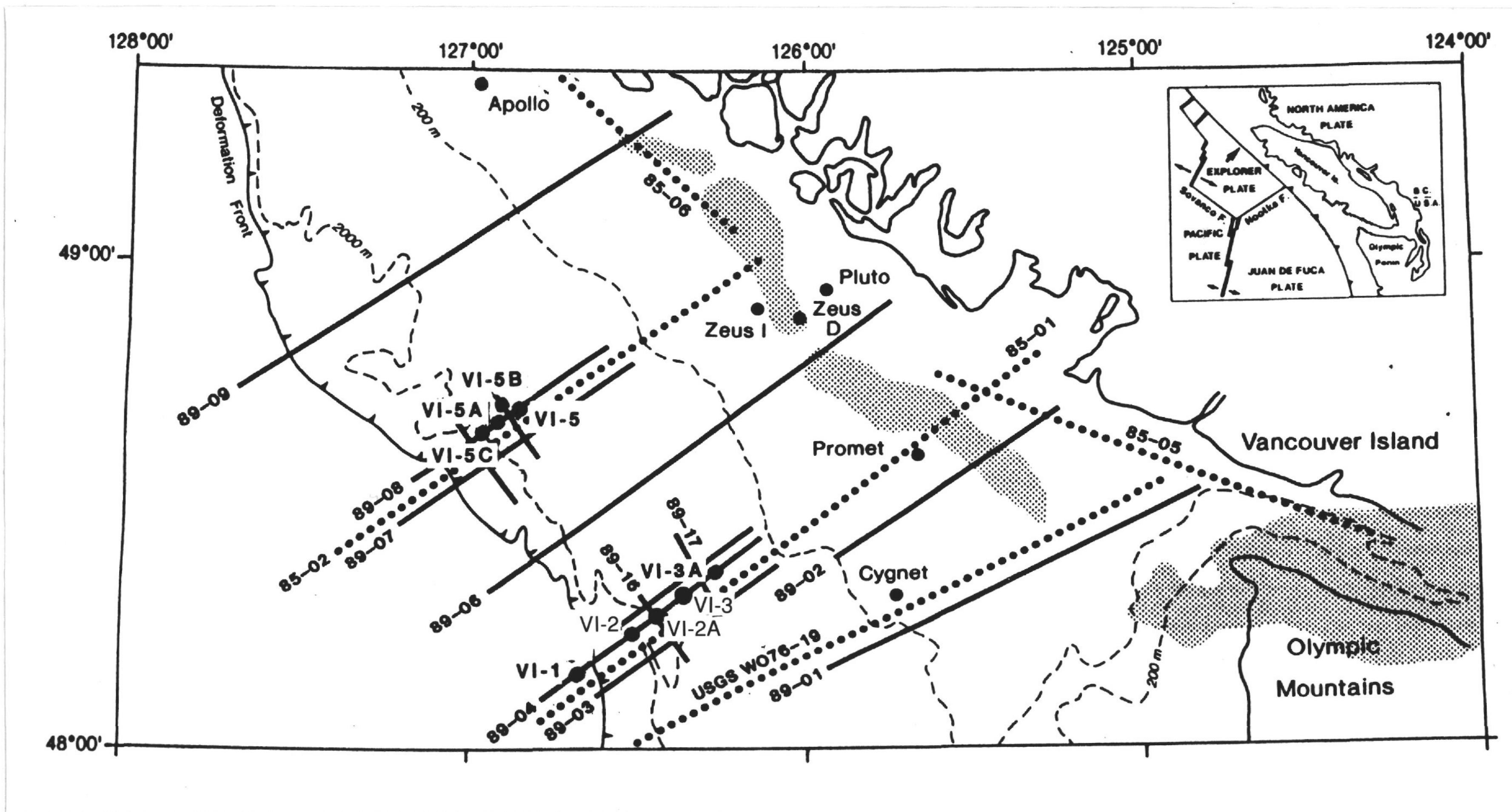


Figure 3. Proposed drill sites and multichannel seismic reflection tracklines near Vancouver Island. Solid circles on shelf indicate positions of exploration wells.

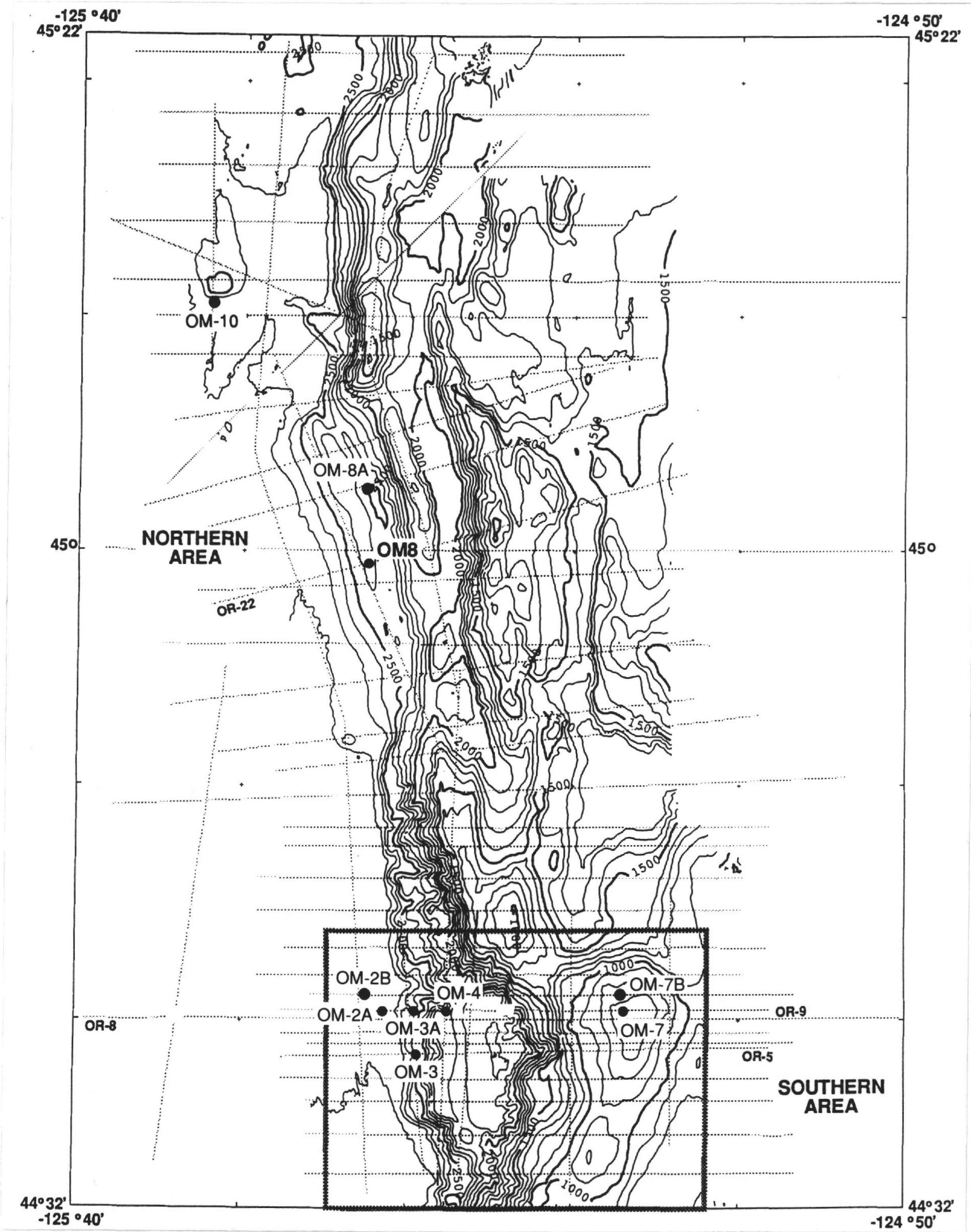


Figure 4. SeaBeam bathymetry and multichannel reflection tracklines near Oregon.
Locations of proposed drill sites are indicated by solid circles.

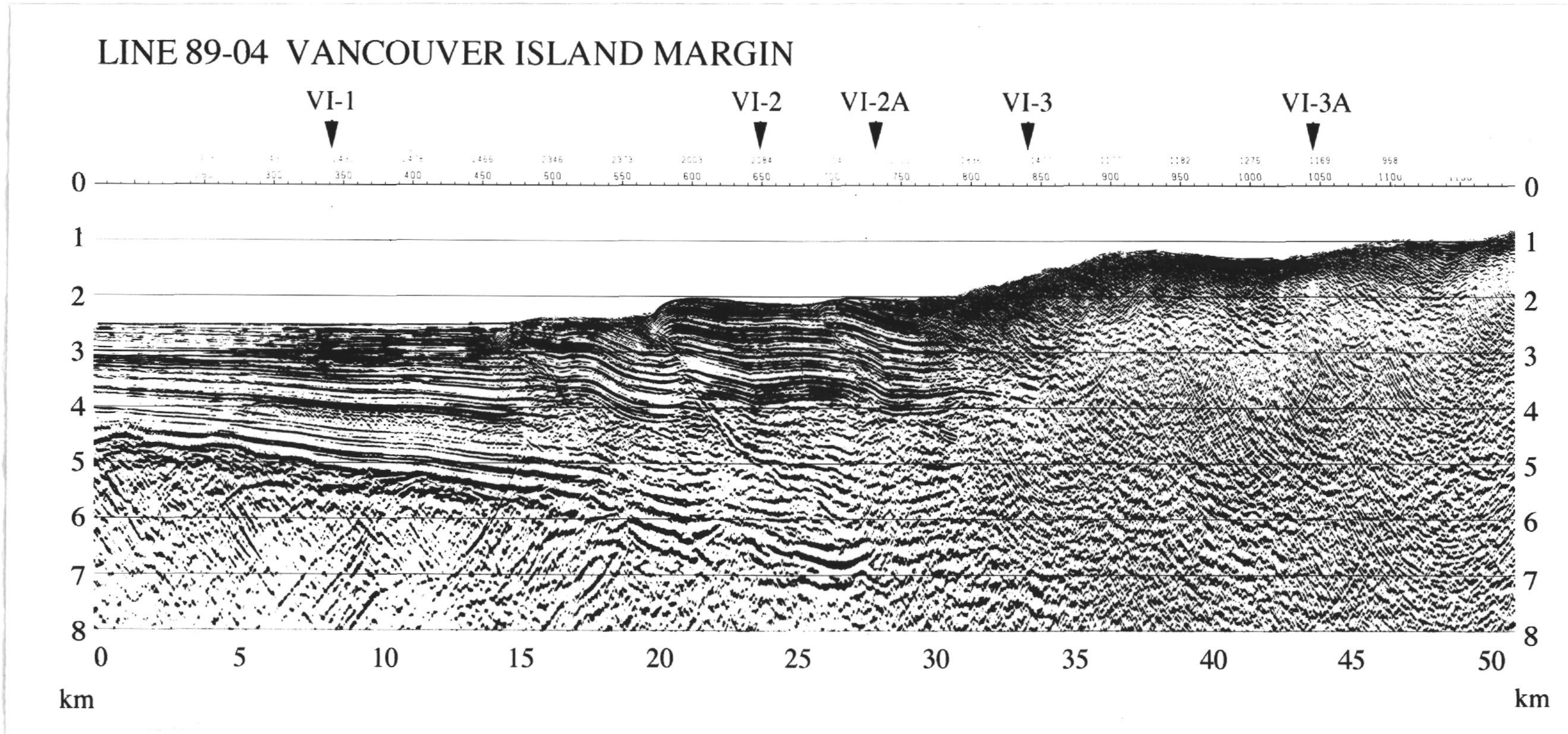


Figure 5. Depth-converted migrated seismic reflection section 89-04, showing proposed drill sites VI-1, -2, -2A, -3, and -3A, extending from Cascadia Basin across the deformation front and coherent and incoherent deformation zones. Position of profile is given in Fig. 3.

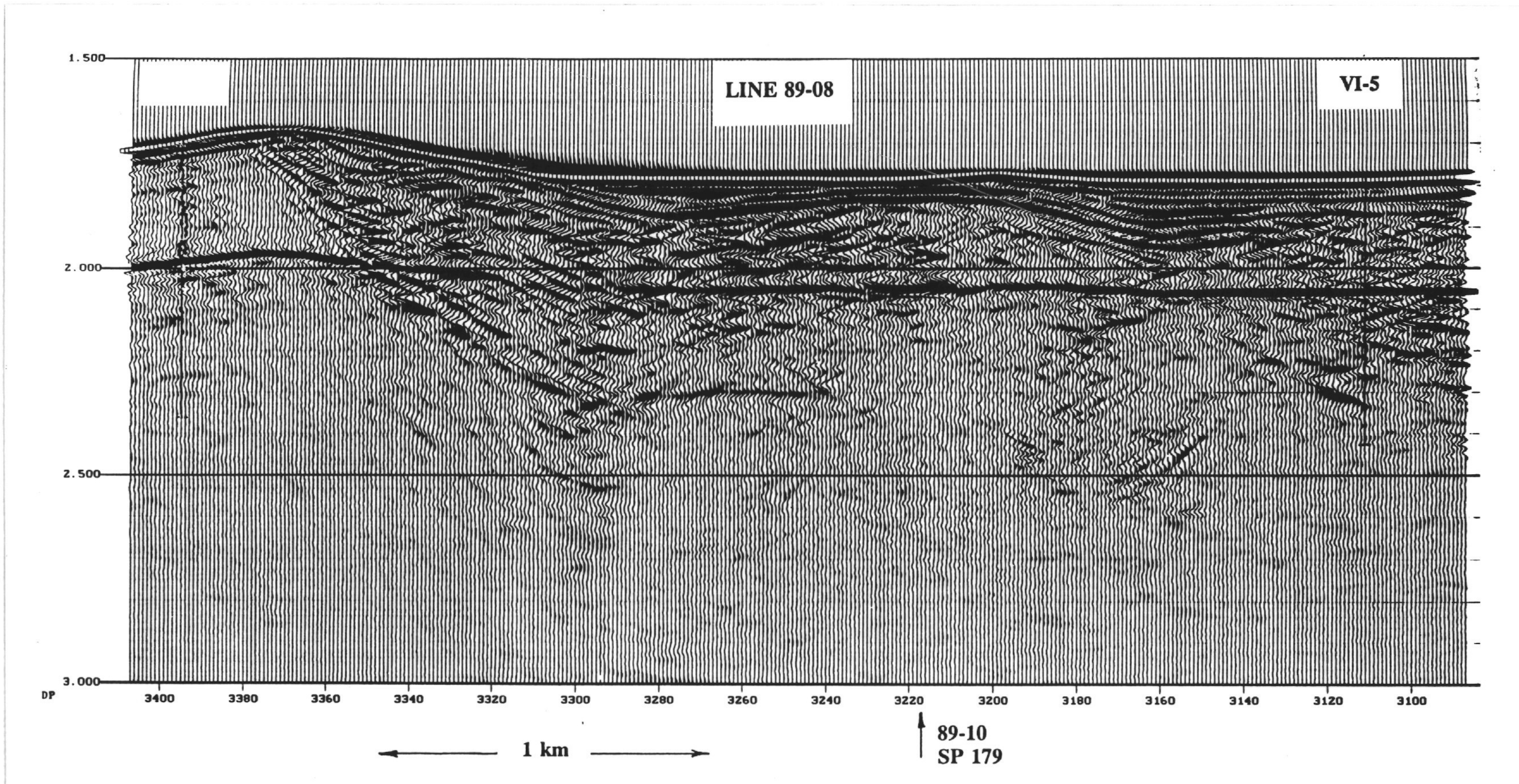


Figure 6. Multichannel seismic line 89-08, showing position of proposed site VI-5.

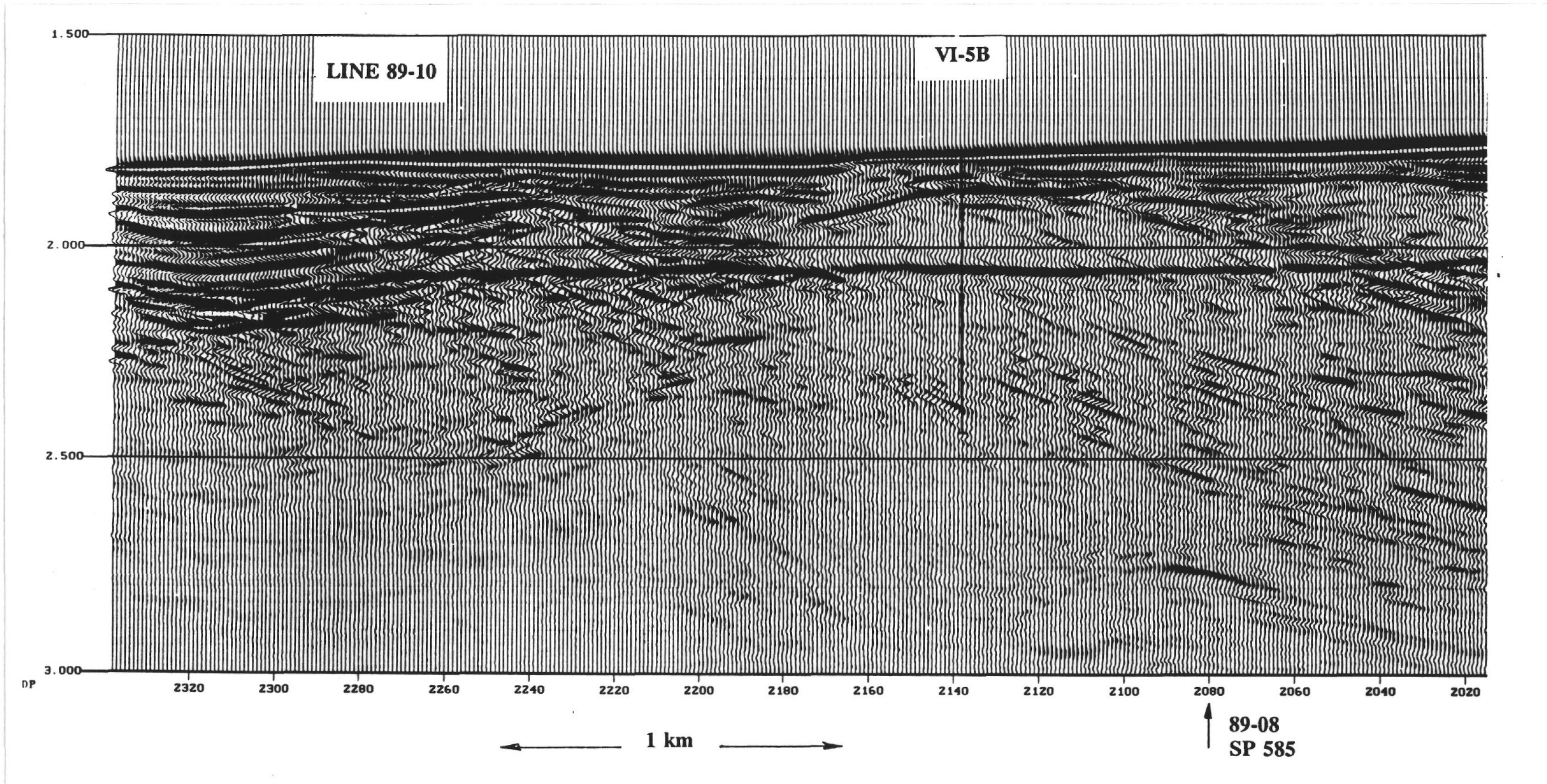


Figure 7. Multichannel seismic line 89-10, showing position of proposed site VI-5B.

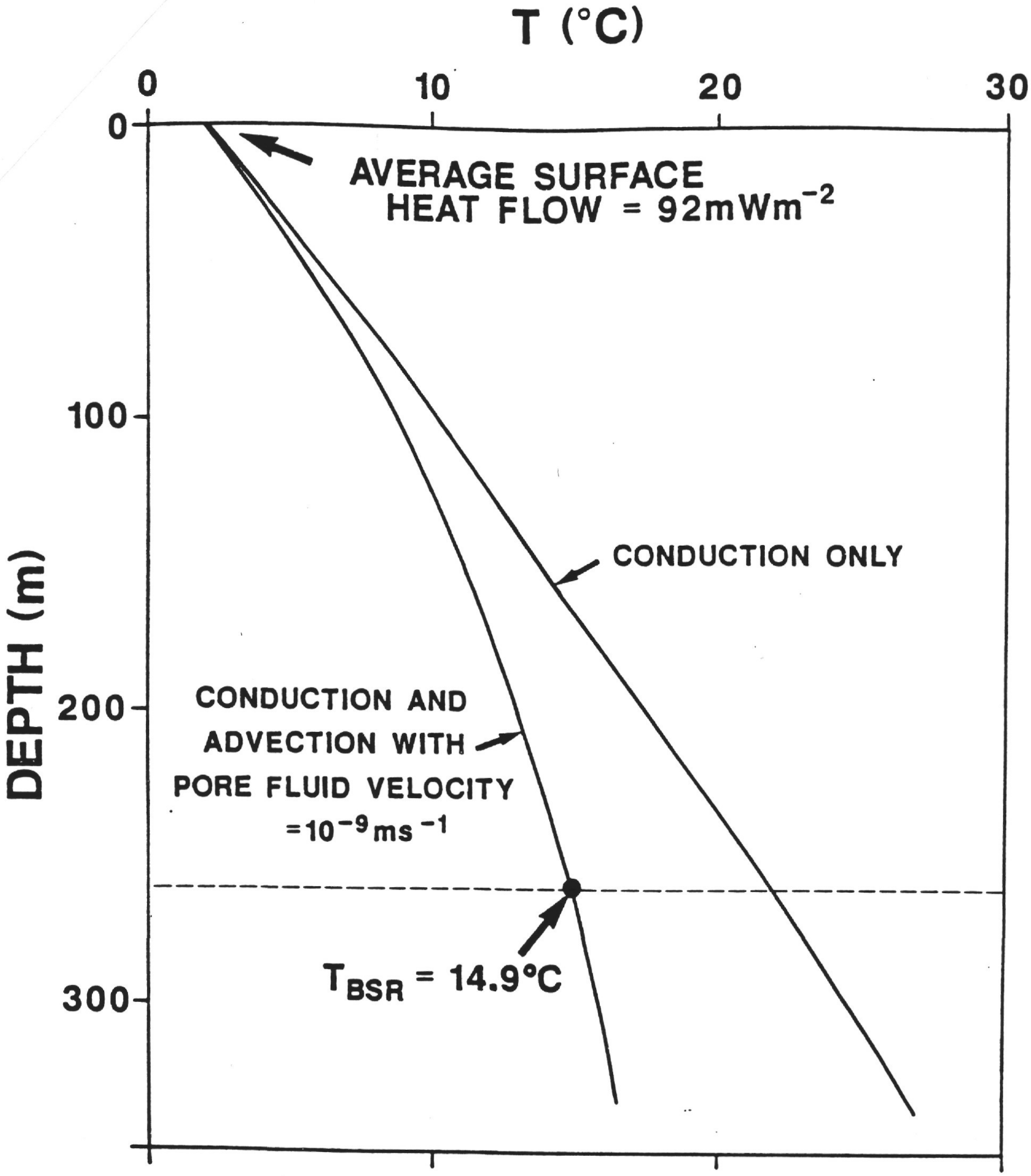


Figure 8.The rate of vertical fluid expulsion estimated from comparison of the conductive geothermal profile predicted from heat flow measured at the surface with that predicted from the depth of the BSR, assuming that it was causedby a methane hydrate formed with pure methane and pure water at hydrostatic pressure.

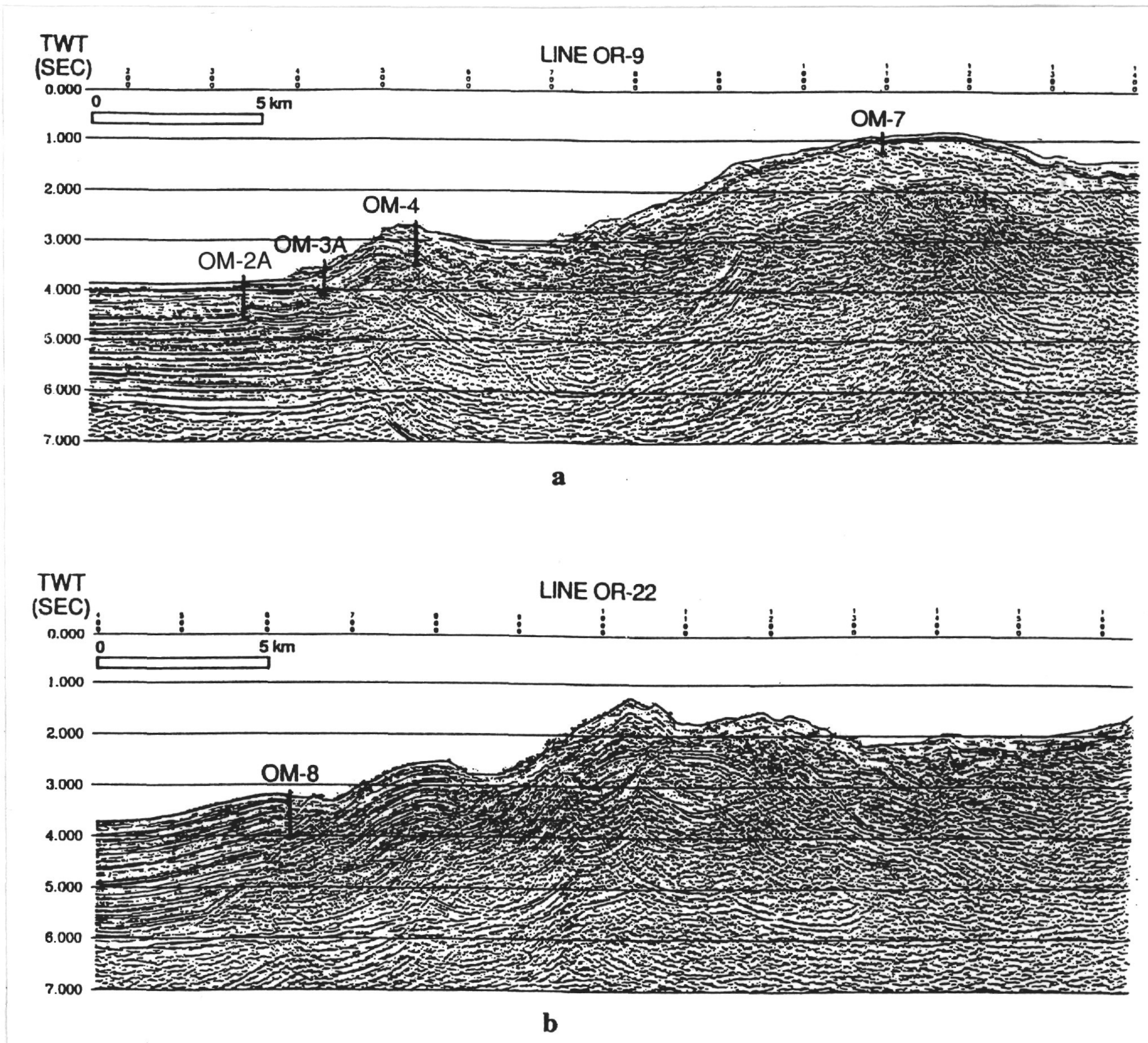


Figure 9. (a) Multichannel seismic line OR-9, showing proposed drill sites OM-2A, -3A, -4, and -7 extending from the proto-deformation zone in Cascadia Basin across the marginal ridge and onto the second ridge of the lower continental slope. (b) Multichannel seismic line OR-22, showing proposed drill site OM-8. Note the landward vergence of the accreted section seaward of shot point 1100, and the deeply rooted frontal thrust.

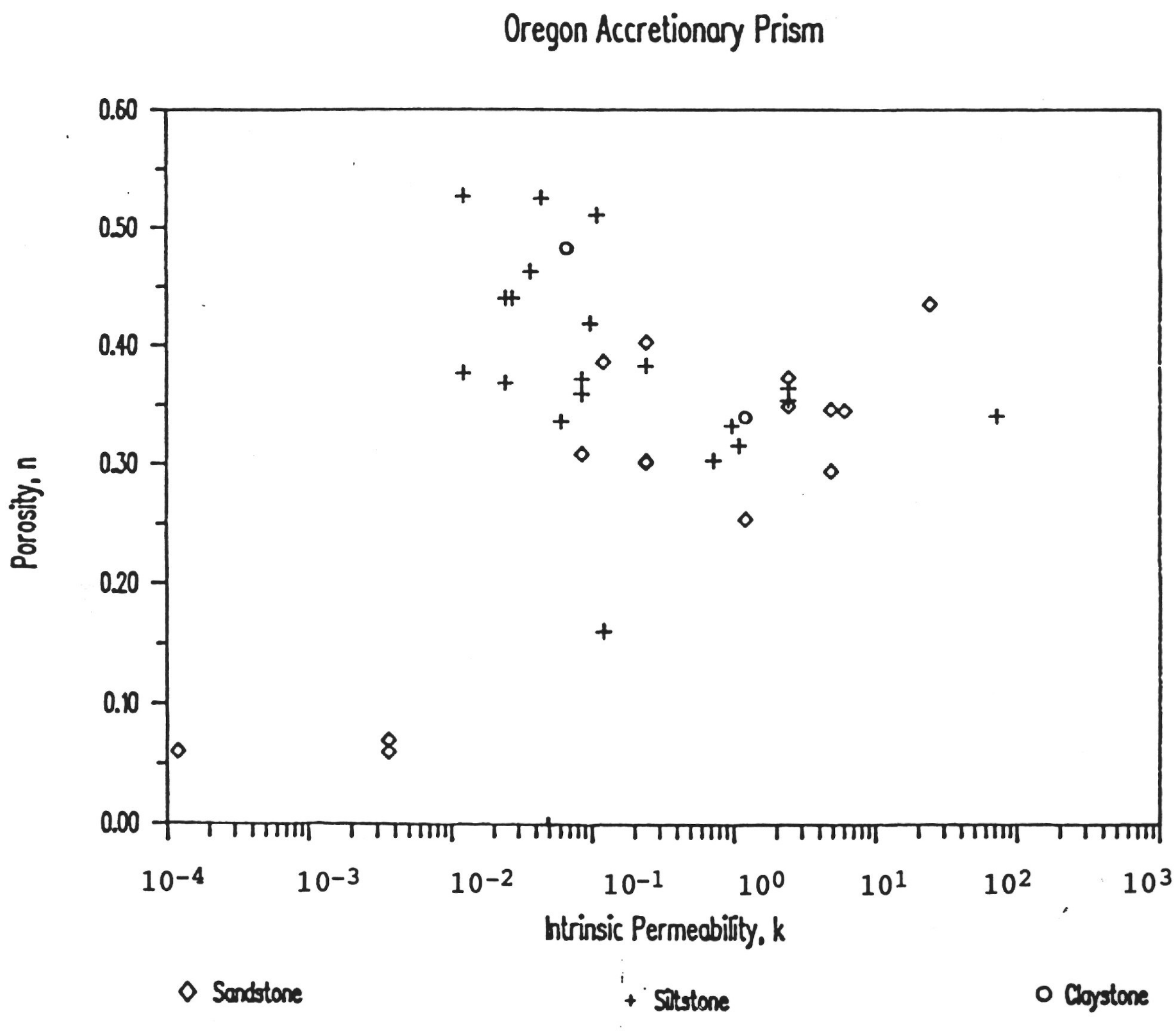


Figure 10. Porosity and permeability of 45 surface samples collected from the lowermost continental slope just north of proposed site OM-3A. Permeability is given in millidarcies.

PROPOSED DRILL SITES

SITE: **VI-5** PRIORITY: **1**

---

POSITION: 48°41.84'N, 126°52.30'W

WATER DEPTH: 1290 m

NATURE OF SEDIMENT: Pleistocene to late Pliocene; medium to very fine turbidite sand with interbedded muds.

SEDIMENT THICKNESS: 4000 m

SEISMIC RECORD: MCS Line 89-08, shot point 615 (see Fig. 6).

---

OBJECTIVES:

To delineate mechanisms of gas hydrate formation, to sample and analyze fluids and associated clathrates, and to determine the fluid flow and thermal regime in a region characterized by dispersed fluid discharge.

PROPOSED DRILLING PROGRAM:

Hole A: APC/XCB to 400 mbsf.

Hole B: Offset minimum of 200 m from Hole A, drill reentry hole for ODP borehole seal (CORK); cement 11-3/4-in. surface casing; drill an RCB 9-7/8-in. hole to 400 mbsf; emplace small-diameter, perforated casing below BSR; deploy ODP borehole seal.

Hole C: Offset minimum of 200 m from Hole B, XCB 220 - 320 mbsf.

LOGGING AND DOWNHOLE OPERATIONS:

Numerous runs with WSTP and PCS tools; check shot VSP; logs to consist of seismic-stratigraphic combination, geochemical combination, and formation microscanner in Hole A; packer/flowmeter experiment within casing and borehole seal deployment in Hole B. GEOPROPS and LAST tools may be deployed.

---

SITE: **VI-2** PRIORITY: **1**

---

POSITION: 48°15.13'N, 126°30.00'W

WATER DEPTH: 2125 m

NATURE OF SEDIMENT: Pleistocene to late Pliocene; medium to very fine turbidite sand with interbedded muds.

SEDIMENT THICKNESS: 4000 m

SEISMIC RECORD: MCS Line 89-04, shot point 650.

---

OBJECTIVES:

To characterize the chemical, thermal, physical, and hydrologic regime within a gently deformed sequence of accreted sediments, that are equivalent to those investigated at VI-1.

PROPOSED DRILLING PROGRAM:

APC/XCB to 600 mbsf.

LOGGING:

Numerous runs with WSTP and PCS tools; check shot VSP; logs to consist of seismic-stratigraphic combination and formation microscanner. GEOPROPS and LAST tools may be deployed.

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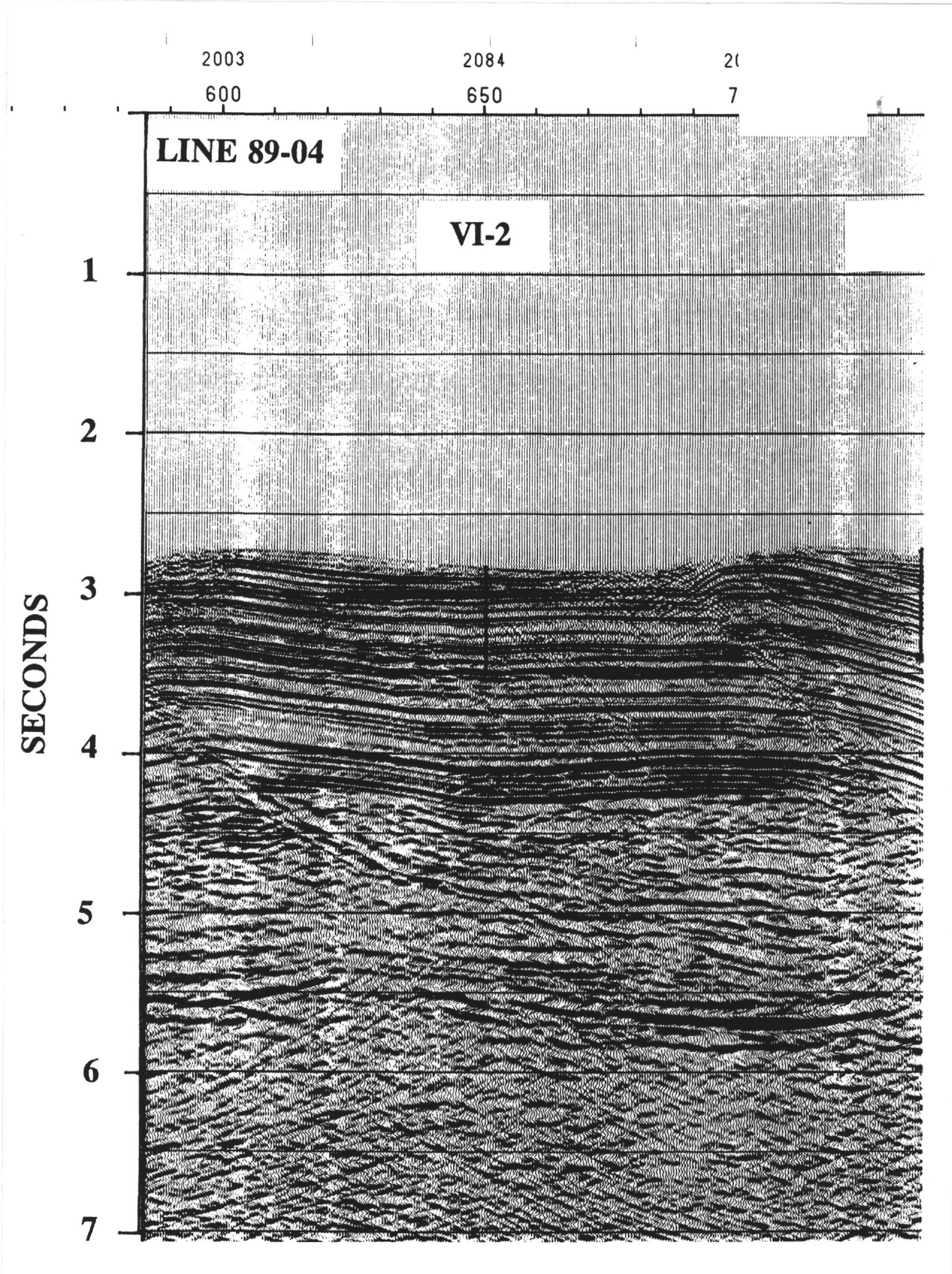
2003
2084
2(
600
650
7
LINE 89-04
VI-2
1
2
3
4
5
6
7
SECONDS

SITE: **VI-1** PRIORITY: **1**

---

POSITION: 48°09.97'N, 126°39.87'W

WATER DEPTH: 2550 m

NATURE OF SEDIMENT: Pleistocene to late Pliocene; medium to very fine turbidite sand with interbedded muds.

SEDIMENT THICKNESS: 2500 m

SEISMIC RECORD: MCS Line 89-04, shot point 340.

---

OBJECTIVES:

To provide a reference section within Cascadia Basin against which holes in the accretionary prism can be compared. To delineate the chemical, thermal, physical, and hydrologic characteristics of the sedimentary section.

PROPOSED DRILLING PROGRAM:

APC/XCB to 600 mbsf.

LOGGING AND DOWNHOLE EXPERIMENTS:

Numerous runs with WSTP and PCS tools; check shot VSP; logs to consist of seismic-stratigraphic combination. GEOPROPS and LAST tools may be deployed.

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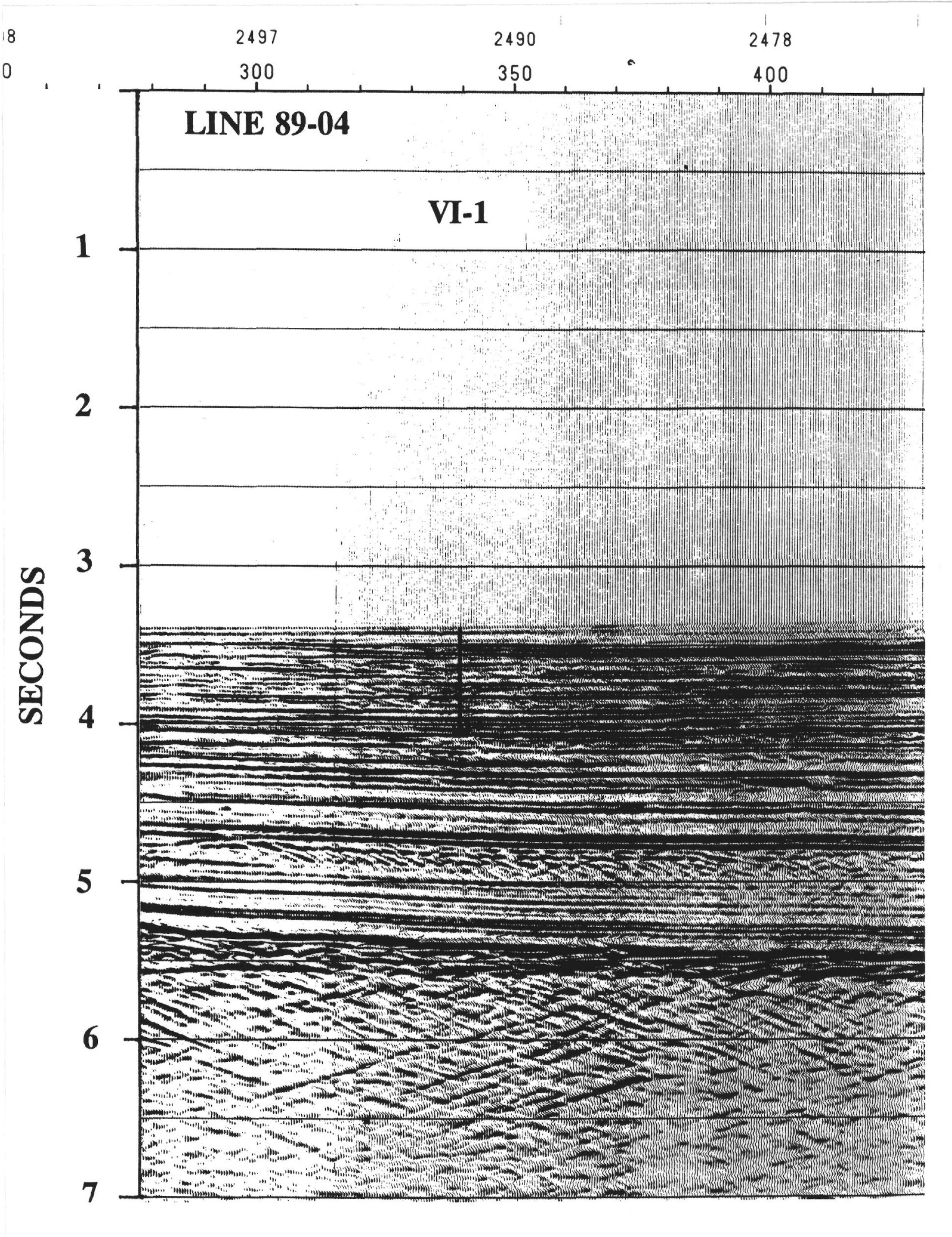
2497
2490
2478
300
350
400
LINE 89-04
VI-1
SECONDS
1
2
3
4
5
6
7

SITE: **OM-3** PRIORITY: **1**

---

POSITION: 44°38.59'N, 125°19.57'W

WATER DEPTH: 2655 m

NATURE OF SEDIMENT: Pleistocene to late Pliocene; medium to very fine turbidite sand and silt with interbedded hemi-pelagic muds.

SEDIMENT THICKNESS: 3500 m

SEISMIC RECORD: MCS Line OR-5, shot point 440; crossline MCS Line OR-41, shot point 461.

---

OBJECTIVES:

To determine the hydrogeologic regime associated with the frontal thrust penetrated at this site, to characterize the chemistry and hydrology of the advecting fluids, and to determine the effects of deformation on physical properties and diagenesis of the Late Pleistocene sediment sequence.

PROPOSED DRILLING PROGRAM:

Hole A: APC/XCB to 540 mbsf or bit destruction.

Hole B: Offset not less than 200 m from Hole A, drill reentry hole for ODP borehole seal (CORK); cement 11-3/4-in. surface casing; RCB 9-7/8-in. hole to 540 mbsf; emplace small-diameter, perforated casing at level of frontal thrust fault; deploy ODP borehole seal.

LOGGING AND DOWNHOLE MEASUREMENTS:

Numerous runs with WSTP and PCS tools; oblique VSP experiment; logs to consist of seismic-stratigraphic combination and formation microscanner in Hole A hole; packer/flowmeter experiment within casing and borehole seal deployment in Hole B. GEOPROPS and LAST tools may be deployed.

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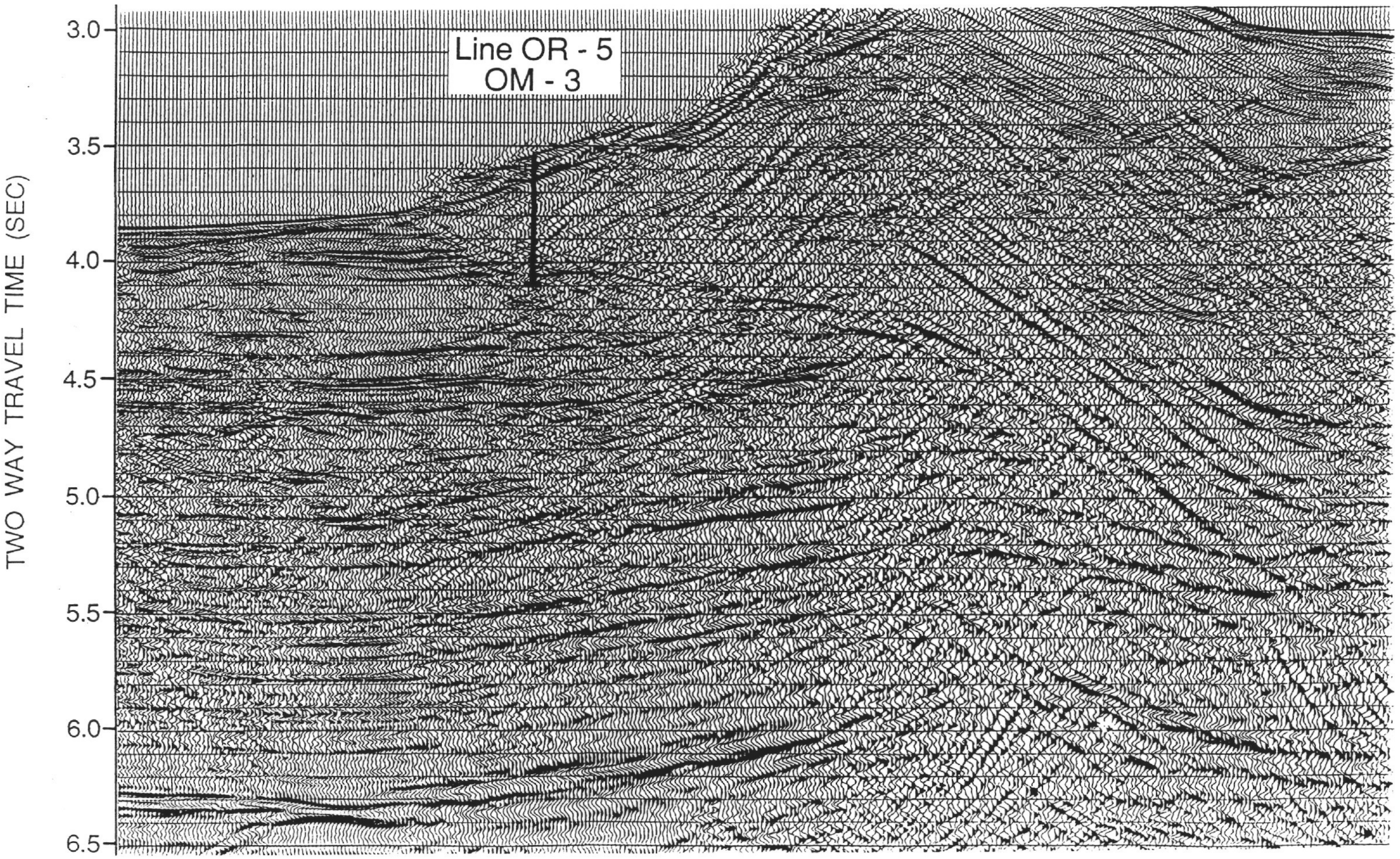
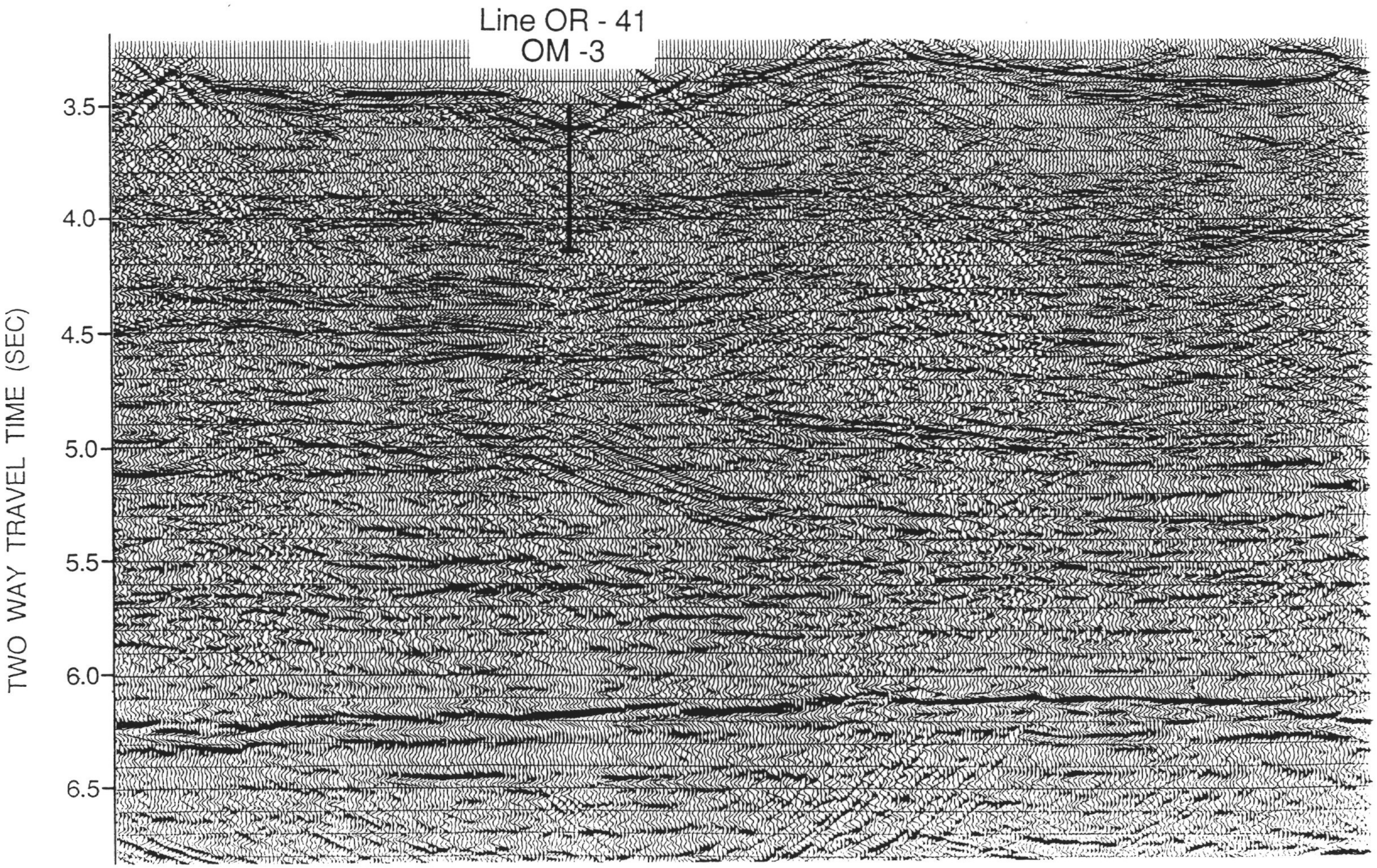

Line OR - 5
OM - 3
TWO WAY TRAVEL TIME (SEC)
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5


Line OR - 41
OM -3
3.5
4.0
4.5
5.0
5.5
6.0
6.5
TWO WAY TRAVEL TIME (SEC)

SITE: **OM-7** PRIORITY: **1**

---

POSITION: 44°40.45'N, 125°07.23'W

WATER DEPTH: 668 m

NATURE OF SEDIMENT: Pliocene to Pleistocene; mudstone micaceous and argillaceous sandstone.

SEDIMENT THICKNESS: 5000 m

SEISMIC RECORD: MCS Line OR-9, shot point 1092.

---

OBJECTIVES:

To determine the hydrogeology and fluid chemistry of the Pliocene portion of the accretionary prism; to assess the role of an out-of-sequence thrust fault as an aquifer; and to delineate the effect of focused fluid advection and thermal regime on the BSR.

PROPOSED DRILLING PROGRAM:

APC/XCB to 300 mbsf.

LOGGING AND DOWNHOLE EXPERIMENTS:

Numerous runs with the WSTP and PCS tools; logs to consist of seismic-stratigraphic combination, geochemical combination, and formation microscanner. GEOPROPS and LAST tools may be deployed.

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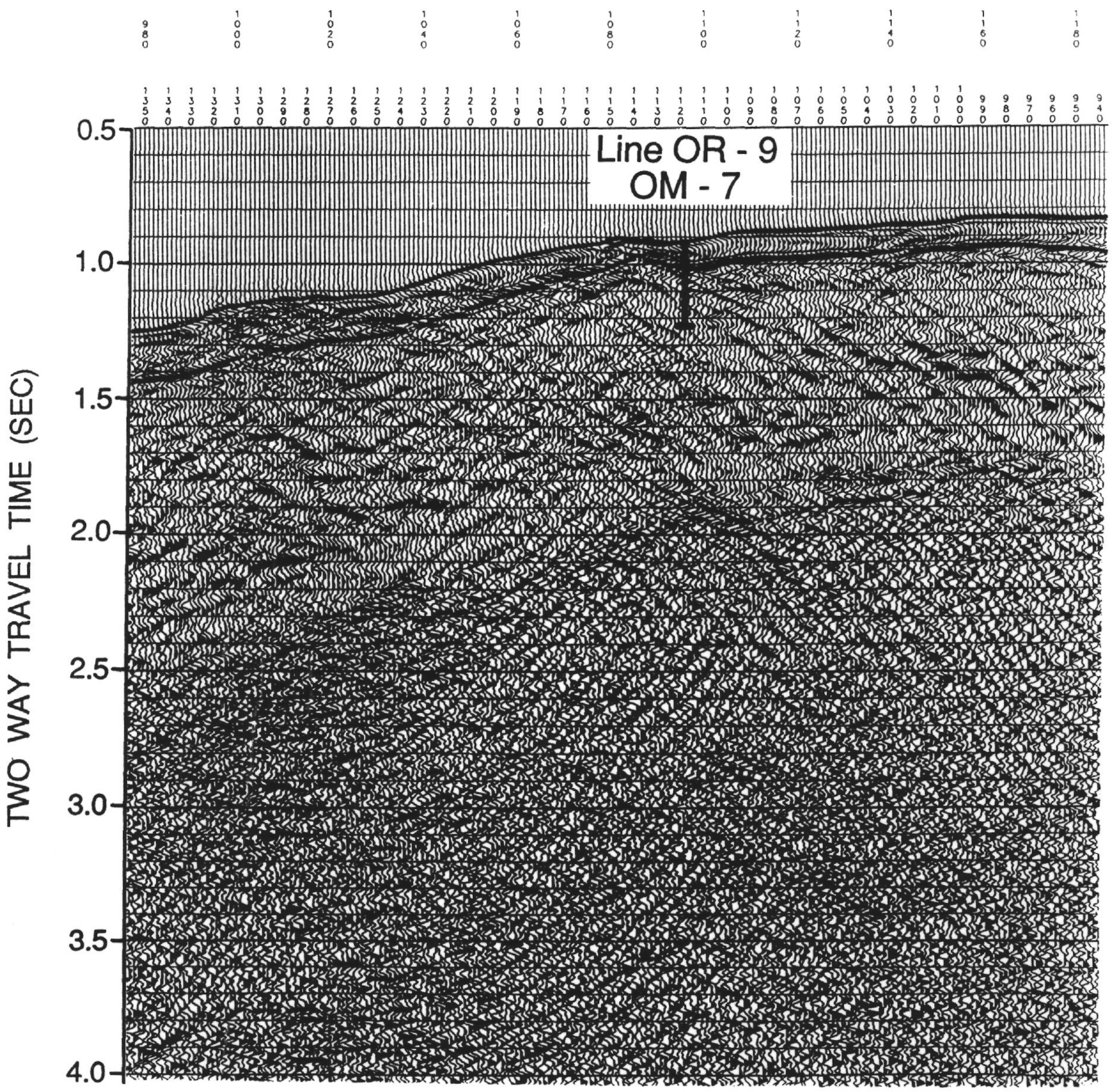
Line OR - 9
OM - 7
TWO WAY TRAVEL TIME (SEC)
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0

SITE: **OM-2a** PRIORITY: **1**

---

POSITION: 44°40.42'N, 125°21.53'W

WATER DEPTH: 2865 m

NATURE OF SEDIMENT: Pleistocene to late Pliocene; medium to very fine turbidite sand and silt with interbedded hemi-pelagic muds.

SEDIMENT THICKNESS: 3000 m

SEISMIC RECORD: MCS Line OR-9, shot point 322.

---

OBJECTIVES:

To determine the hydrologic role of incipient thrust faults within the proto-deformation zone, seaward of the toe of the accretionary prism. To examine fluid chemistry, diagenetic products, and evidence for compaction-related dewatering.

PROPOSED DRILLING PROGRAM:

APC/XCB to 500 mbsf (approved to 700 mbsf).

LOGGING AND DOWNHOLE EXPERIMENTS:

Numerous runs with the WSTP and PCS tools; logs to consist of seismic-stratigraphic combination and formation microscanner. GEOPROPS and LAST tools may be deployed.

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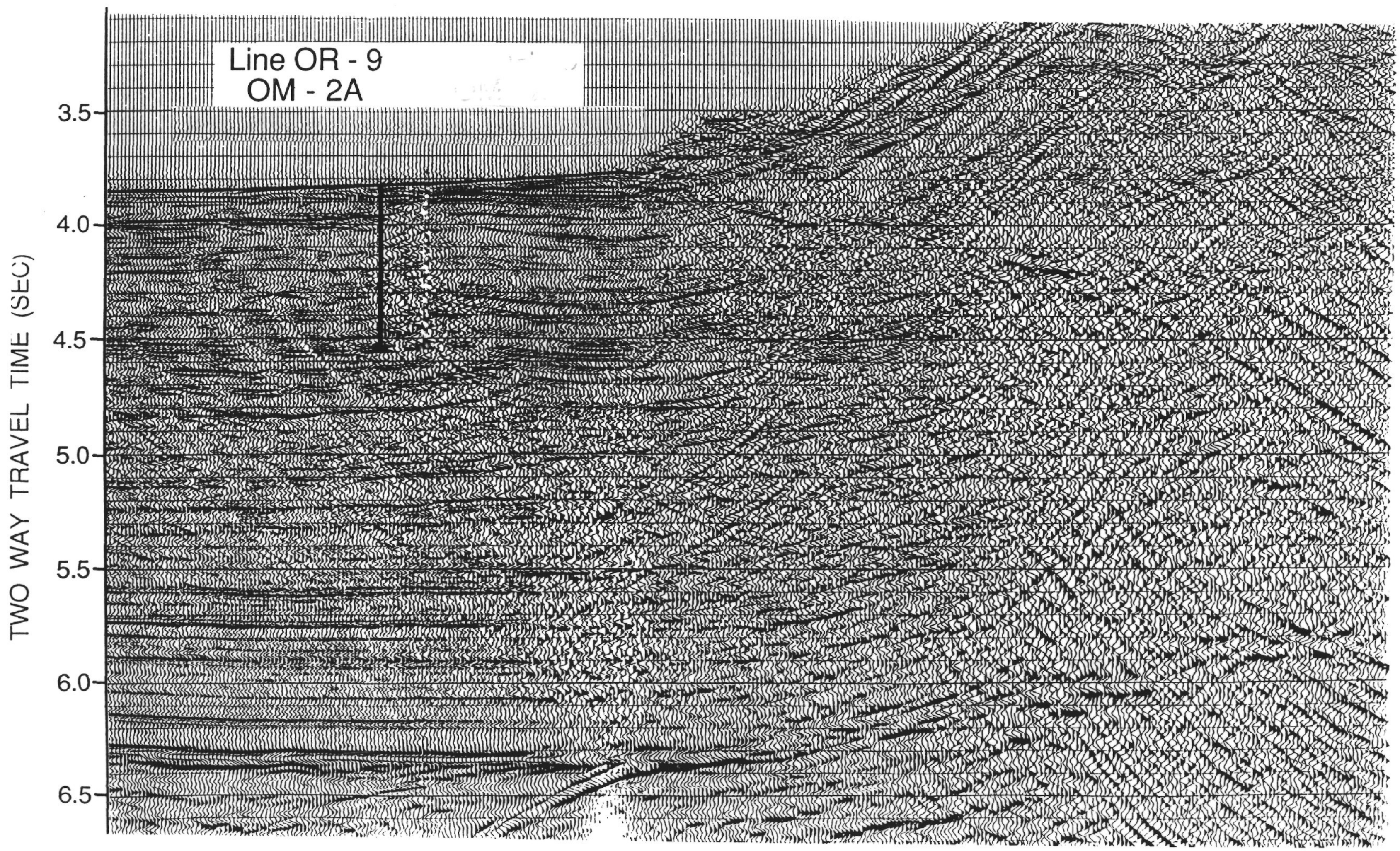
Line OR - 9
OM - 2A
TWO WAY TRAVEL TIME (SEC)
3.5
4.0
4.5
5.0
5.5
6.0
6.5

SITE: **Santa Barbara Basin** PRIORITY: **1**

---

POSITION: approximately 34°16'N, 120°04'W

WATER DEPTH: 500 m

NATURE OF SEDIMENT: Middle to late Neogene upper bathyal terrigenous/biogenic mud. Highly laminated in sections with occasional thin turbidite sands.

SEDIMENT THICKNESS: upper 200 m of interest

SEISMIC RECORD: Line courtesy of Halliburton Geophysical Service, Inc. Trackline proprietary information; not approved for publication or distribution.

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OBJECTIVES:

Stable isotopic, geochemical, and micropaleontological studies will be used to provide critical information within the context of global climate change and the role of the ocean in the global carbon cycle.

PROPOSED DRILLING PROGRAM:

APC/XCB to 200 mbsf.

LOGGING AND DOWNHOLE EXPERIMENTS:

None

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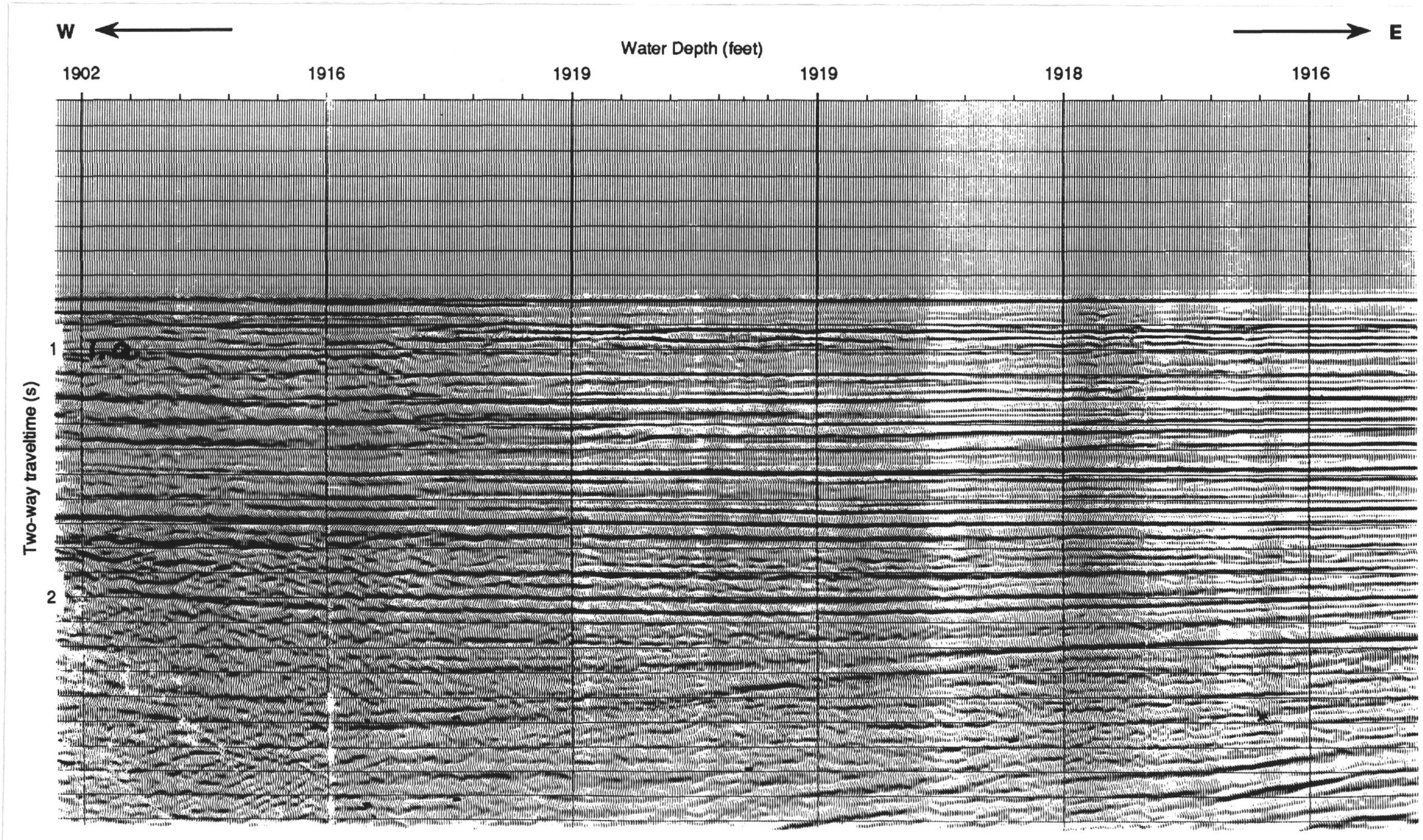
W
E
Water Depth (feet)
1902
1916
1919
1919
1918
1916
Two-way traveltime (s)
1
2

SITE: **VI-2a** (Alternative to Site VI-2) PRIORITY: **2**

---

POSITION: 48°16.58'N, 126°27.38'W

WATER DEPTH: 2060 m

NATURE OF SEDIMENT: Pleistocene to late Pliocene; medium to very fine turbidite sand with interbedded muds.

SEDIMENT THICKNESS: 4500 m

SEISMIC RECORD: MCS Line 89-04, shot point 735; crossline MCS Line 89-16, shot point 205.

---

OBJECTIVES:

To chartacterize the chemical, thermal, physical, and hydrologic regime within a gently deformed sequence of accreted sediments that are equivalent to those investigated at VI-1.

PROPOSED DRILLING PROGRAM:

APC/XCB to 600 mbsf.

LOGGING AND DOWNHOLE EXPERIMENTS:

Numerous runs with WSTP and PCS tools; check shot VSP; logs to consist of seismic-stratigraphic combination and formation microscanner. GEOPROPS and LAST tools may be deployed.

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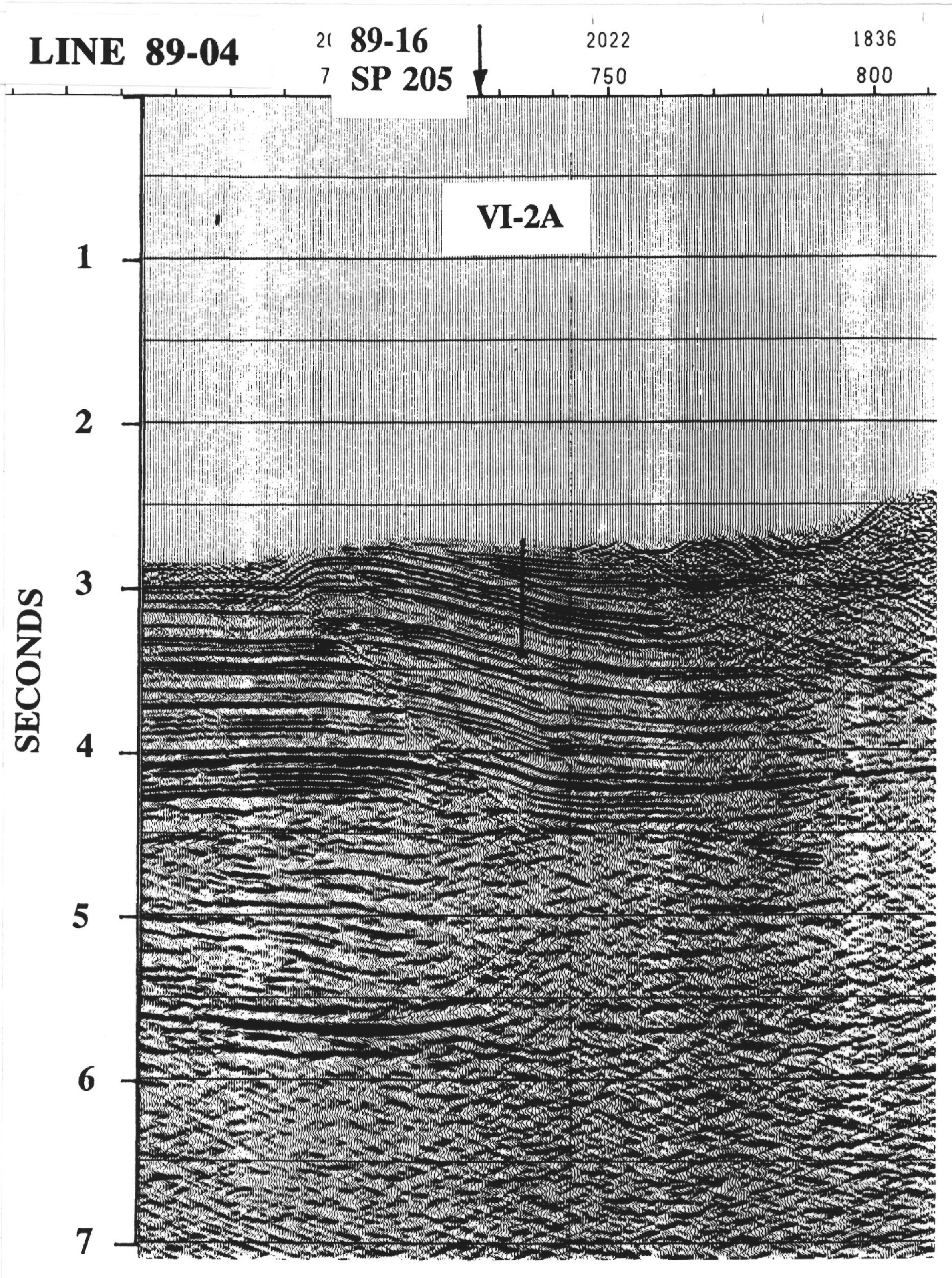
LINE 89-04
89-16
SP 205
2022
750
1836
800
VI-2A
SECONDS
1
2
3
4
5
6
7

SITE: **VI-3** PRIORITY: **2**

---

POSITION: 48°18.31'N, 126°23.96'W

WATER DEPTH: 1625 m

NATURE OF SEDIMENT: Pleistocene to late Pliocene; medium to very fine turbidite sand with interbedded muds.

SEDIMENT THICKNESS: 5000 m

SEISMIC RECORD: MCS Line 89-04, shot point 843.

---

OBJECTIVES:

To assess the effects of progressive deformation at a site characterized by incoherent seismic reflectors and a BSR. To characterize the physical properties and diagenetic deposits associated with deformation, to determine the fluid chemistry and pressure, and to delineate mechanism of gas hydrate formation and the thermal regime in which it occurs.

PROPOSED DRILLING PROGRAM:

APC/XCB to 600 mbsf.

LOGGING AND DOWNHOLE EXPERIMENTS:

Numerous runs with WSTP and PCS tools; check shot VSP; logs to consist of seismic-stratigraphic combination, geochemical combination, and formation microscanner. GEOPROPS and LAST tools may be deployed.

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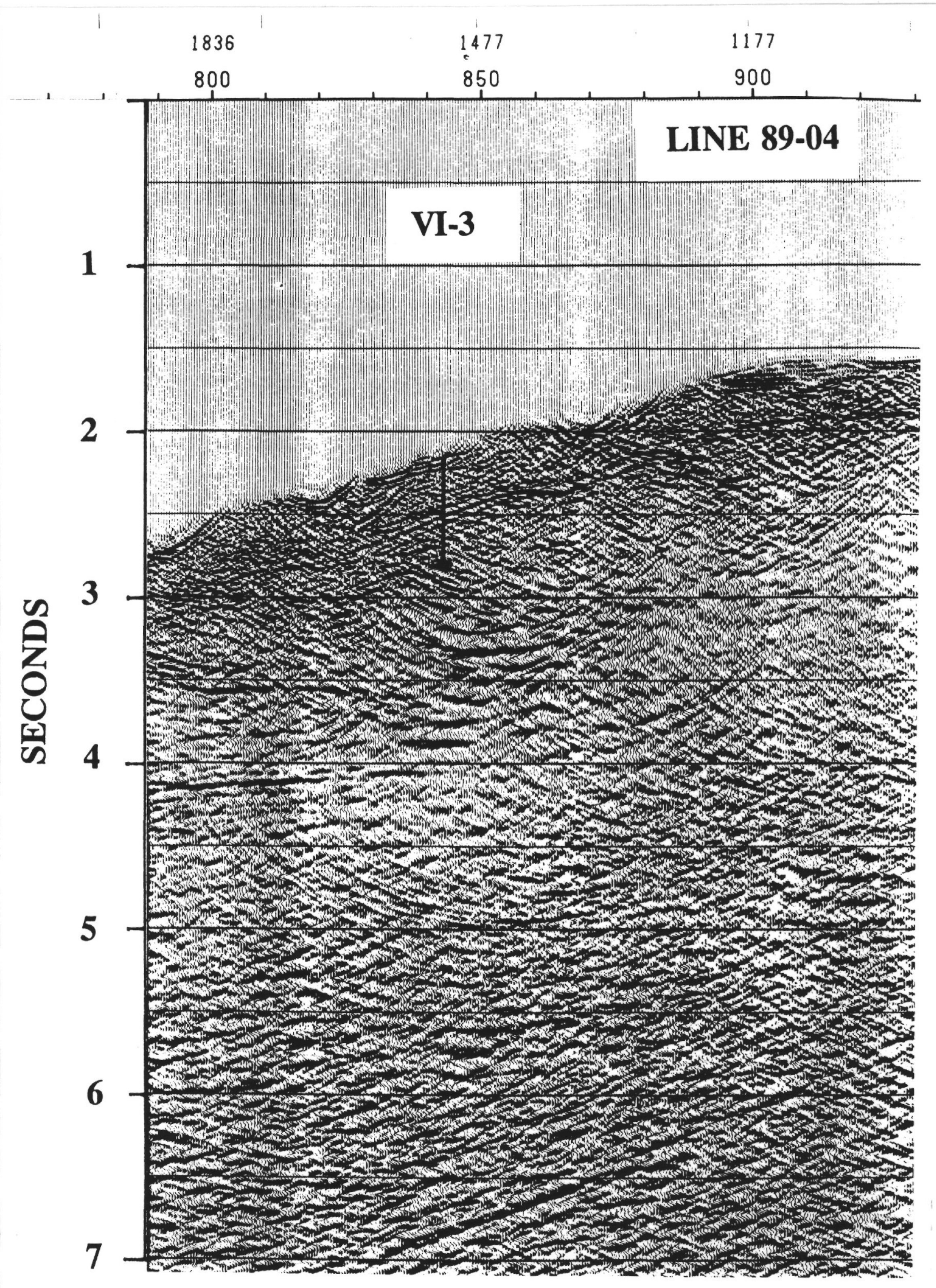
1836
1477
1177
800
850
900
LINE 89-04
VI-3
1
2
3
4
5
6
7
SECONDS

SITE: **VI-3a** (Alternative to Site VI-3) PRIORITY: **2**

---

POSITION: 48°21.77'N, 126°17.32'W

WATER DEPTH: 1200 m

NATURE OF SEDIMENT: Pleistocene to Pliocene; medium to very fine turbidite sand with interbedded muds.

SEDIMENT THICKNESS: 6000 m

SEISMIC RECORD: MCS Line 89-04, shot point 1050.

---

OBJECTIVES:

To assess the effects of progressive deformation at a site characterized by incoherent seismic reflectors and a BSR. To characterize the physical properties and diagenetic deposits associated with deformation, to determine the fluid chemistry and pressure, and to delineate mechanism of gas hydrate formation and the thermal regime in which it occurs.

PROPOSED DRILLING PROGRAM:

APC/XCB to 600 mbsf.

LOGGING AND DOWNHOLE EXPERIMENTS:

Numerous runs with WSTP and PCS tools; check shot VSP; logs to consist of seismic-stratigraphic combination, geochemical combination, and formation microscanner. GEOPROPS and LAST tools may be deployed.

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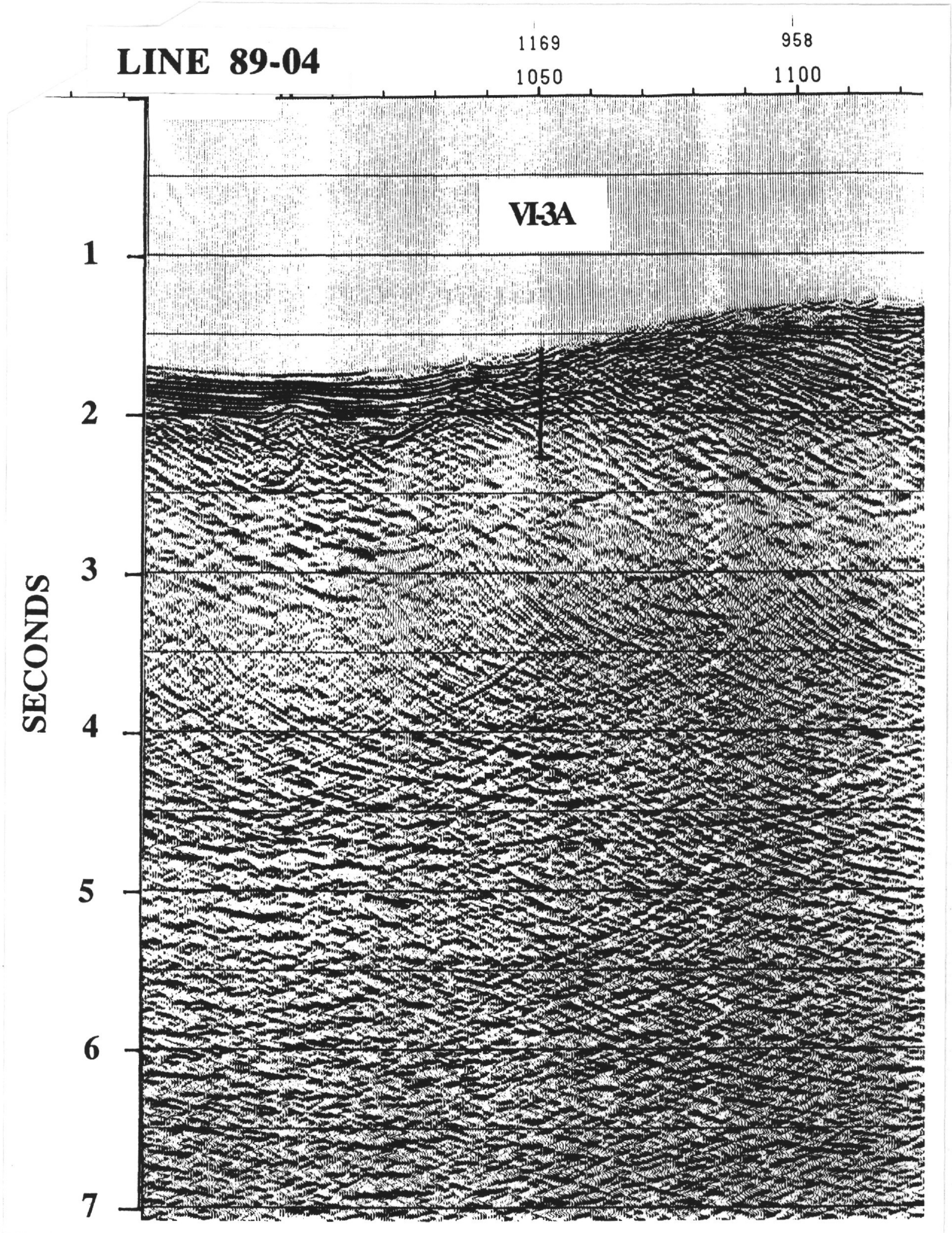
LINE 89-04
1169
1050
958
1100
VI-3A
1
2
3
4
5
6
7
SECONDS

SITE: **VI-5b** (Alternative to Site VI-5) PRIORITY: **2**

---

POSITION: 48°42.27'N, 126°54.36'W

WATER DEPTH: 1290 m

NATURE OF SEDIMENT: Pleistocene to late Pliocene; medium to very fine turbidite sand with interbedded muds.

SEDIMENT THICKNESS: 4000 m

SEISMIC RECORD: MCS Line 89-10, shot point 130 (see Fig. 7).

---

OBJECTIVES:

To delineate mechanisms of gas hydrate formation, to sample and analyze fluids and associated clathrates, and to determine the fluid flow and thermal regime in a region characterized by dispersed fluid discharge.

PROPOSED DRILLING PROGRAM:

Hole A: APC/XCB to 400 mbsf.

Hole B: Offset a minimum of 200 m from pilot hole A, drill reentry hole for ODP borehole seal (CORK); cement 11-3/4-in. surface casing; drill an RCB 9-7/8-in. hole to 400 mbsf; emplace small-diameter, perforated casing below BSR; deploy ODP borehole seal.

Hole C: Offset minimum of 200 m from hole B, XCB 220 - 320 mbsf.

LOGGING AND DOWNHOLE EXPERIMENTS:

Numerous runs with WSTP and PCS tools; check shot VSP; logs to consist of seismic-stratigraphic combination, geochemical combination, and formation microscanner in Hole A; packer/flowmeter experiment within casing and borehole seal deployment in Hole B. GEOPROPS and LAST tools may be deployed.

---

SITE: **VI-5c** (Alternative to Site VI-5) PRIORITY: **2**

---

POSITION: 48°39.82'N, 126°56.55'W

WATER DEPTH: 1437 m

NATURE OF SEDIMENT: Pleistocene to late Pliocene; medium to very fine turbidite sand with interbedded muds.

SEDIMENT THICKNESS: 4000 m

SEISMIC RECORD: MCS Line 89-08, shot point 487.

---

OBJECTIVES:

To delineate mechanism of gas hydrate formation, to sample and analyze fluids and associated clathrates, and to determine the fluid flow and thermal regime in a region characterized by dispersed fluid discharge.

PROPOSED DRILLING PROGRAM:

Hole A: APC/XCB to 400 mbsf.

Hole B: Offset minimum of 200 m from Hole A, drill reentry hole for ODP borehole seal (CORK); cement 11-3/4-in. surface casing; drill an RCB 9-7/8-in. hole to 400 mbsf; and emplace small-diameter, perforated casing below BSR; deploy ODP borehole seal.

LOGGING AND DOWNHOLE MEASUREMENTS:

Numerous runs with the WSTP and PCS tools; check shot VSP; logs to consist of seismic-stratigraphic combination, geochemical combination, and formation microscanner in Hole A; packer/flowmeter experiment within casing and borehole seal deployment in Hole B. GEOPROPS and LAST tools may be deployed.

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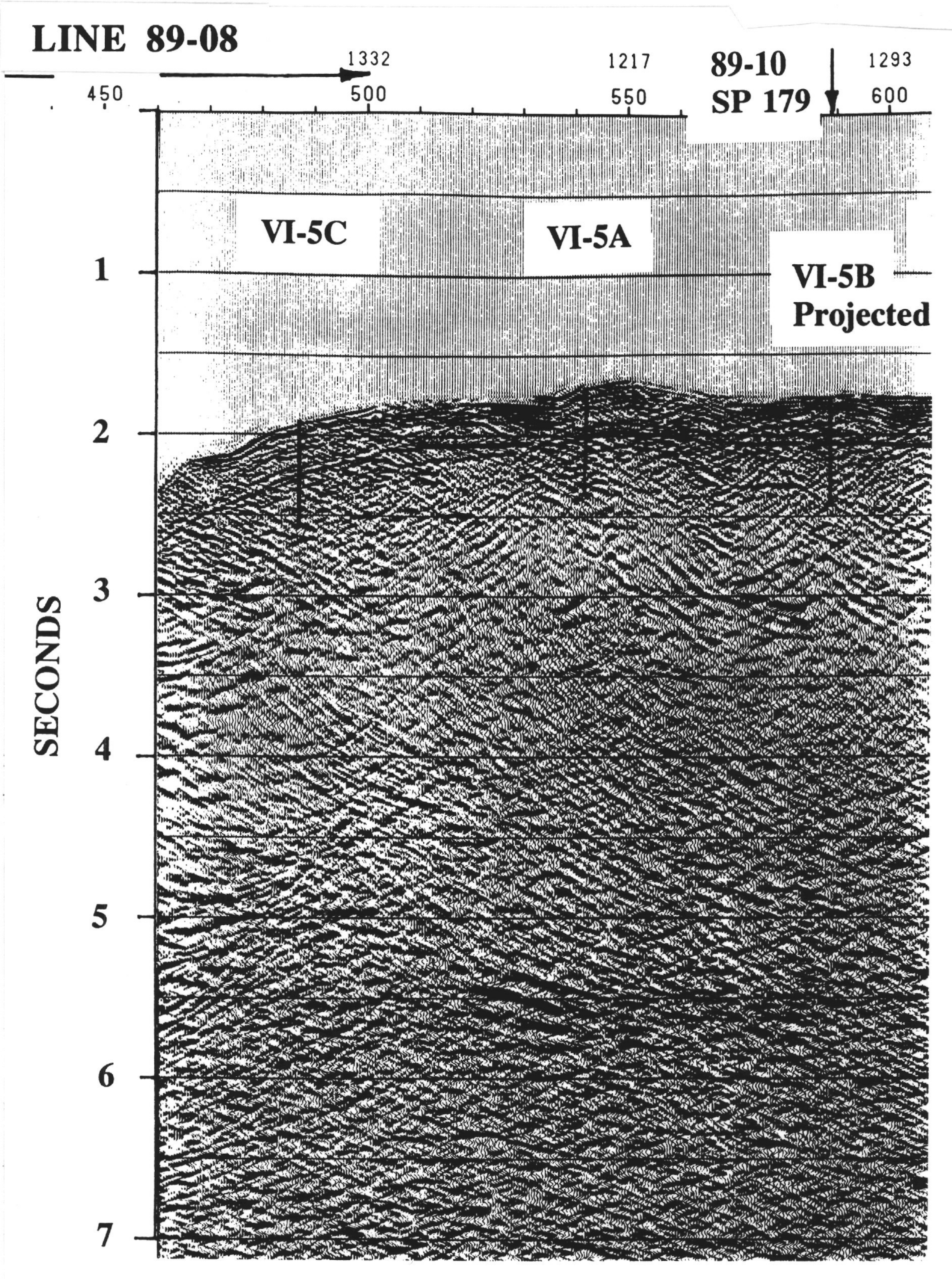
LINE 89-08
1332
1217
1293
450
500
550
600
89-10
SP 179
VI-5C
VI-5A
VI-5B
Projected
1
2
3
4
5
6
7
SECONDS

SITE: **OM-2b** PRIORITY: **2**

---

POSITION: 44°41.10'N, 125°22.00'W

WATER DEPTH: 2860 m

NATURE OF SEDIMENT: Pleistocene to late Pliocene; medium to very fine turbidite sand and silt with interbedded hemi-pelagic muds.

SEDIMENT THICKNESS: 3000 m

SEISMIC RECORD: MCS Line OR-10, shot point 310.

---

OBJECTIVES:

To determine the hydrologic role of incipient thrust faults within the proto-deformation zone, seaward of the toe of the accretionary prism. To examine fluid chemistry, diagenetic products, and evidence for compaction-related dewatering.

PROPOSED DRILLING PROGRAM:

APC/XCB to 500 mbsf.

LOGGING AND DOWNHOLE EXPERIMENTS:

Numerous runs with WSTP and PCS tools; logs to consist of seismic-stratigraphic combination and formation microscanner. GEOPROPS and LAST tools may be deployed.

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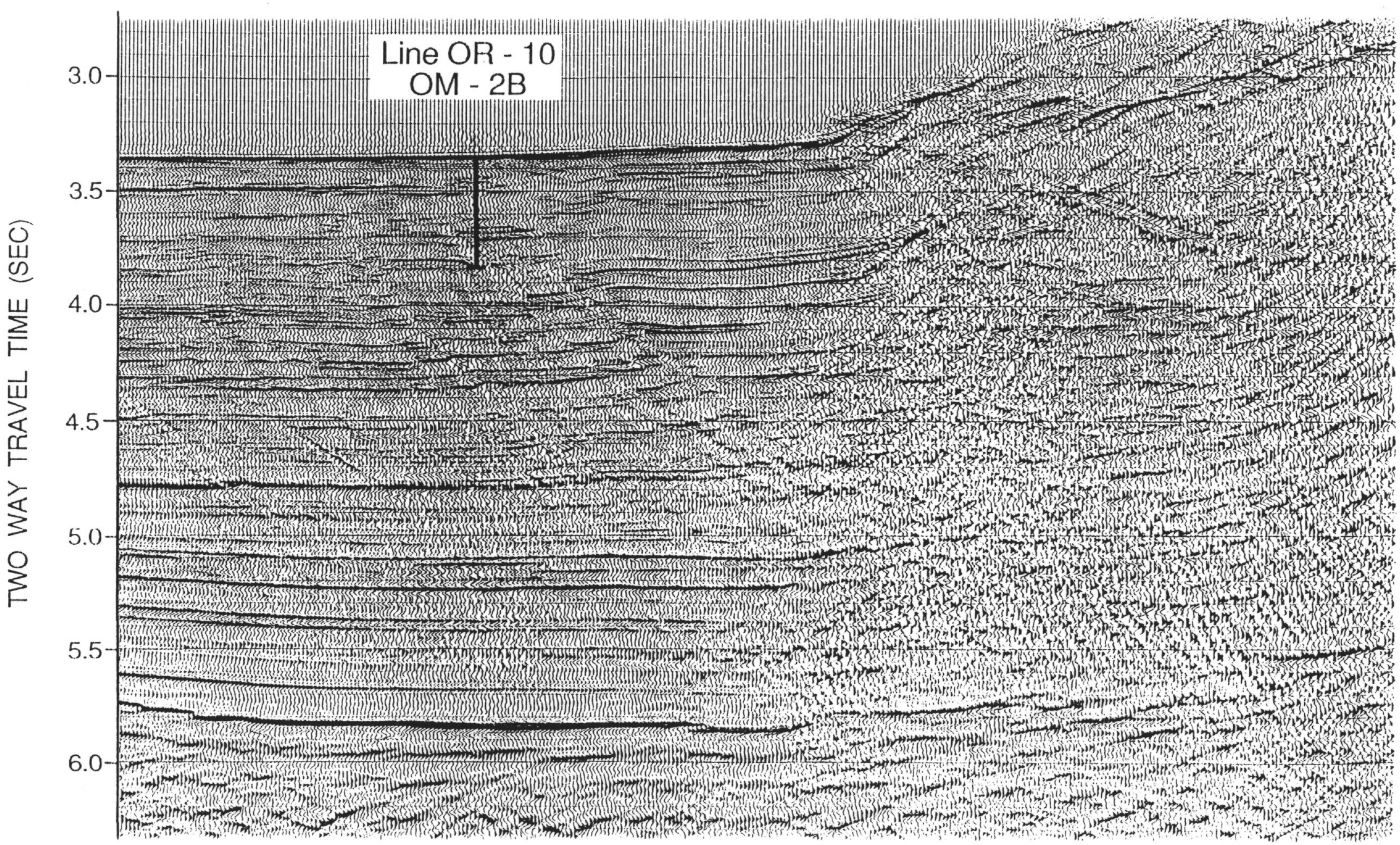
Line OR - 10
OM - 2B
TWO WAY TRAVEL TIME (SEC)
3.0
3.5
4.0
4.5
5.0
5.5
6.0

SITE: **OM-3a** (Alternative to OM-3) PRIORITY: **2**

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POSITION: 40°40.46'N, 125°19.57'W

WATER DEPTH: 2625 m

NATURE OF SEDIMENT: Pleistocene to late Pliocene; medium to very fine turbidite sand and silt with interbedded hemi-pelagic muds.

SEDIMENT THICKNESS: 3500 m

SEISMIC RECORD: MCS Line OR-9, shot point 432.

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OBJECTIVES:

To determine the hydrogeologic regime associated with the frontal thrust penetrated at this site; to characterize the chemistry and hydrology of advecting fluids; to determine the effects of deformation on physical properties and diagenesis of the late Pleistocene sediment sequence.

PROPOSED DRILLING PROGRAM:

Hole A: APC/XCB to 585 mbsf.

Hole B: Offset not less than 200 m from Hole A, drill reentry hole for ODP borehole seal (CORK); cement 11-3/4-in. surface casing; drill an RCB 9-7/8-in. hole to 585 mbsf; emplace small-diameter, perforated casing at level of frontal thrust fault; deploy the ODP borehole seal.

LOGGING AND DOWNHOLE EXPERIMENTS:

Numerous runs with WSTP and PCS tools; oblique VSP experiment; logs to consist of seismic-stratigraphic combination and formation microscanner in Hole A; packer/flowmeter experiment within casing and borehole seal deployment in Hole B. GEOPROPS and LAST tools may be deployed.

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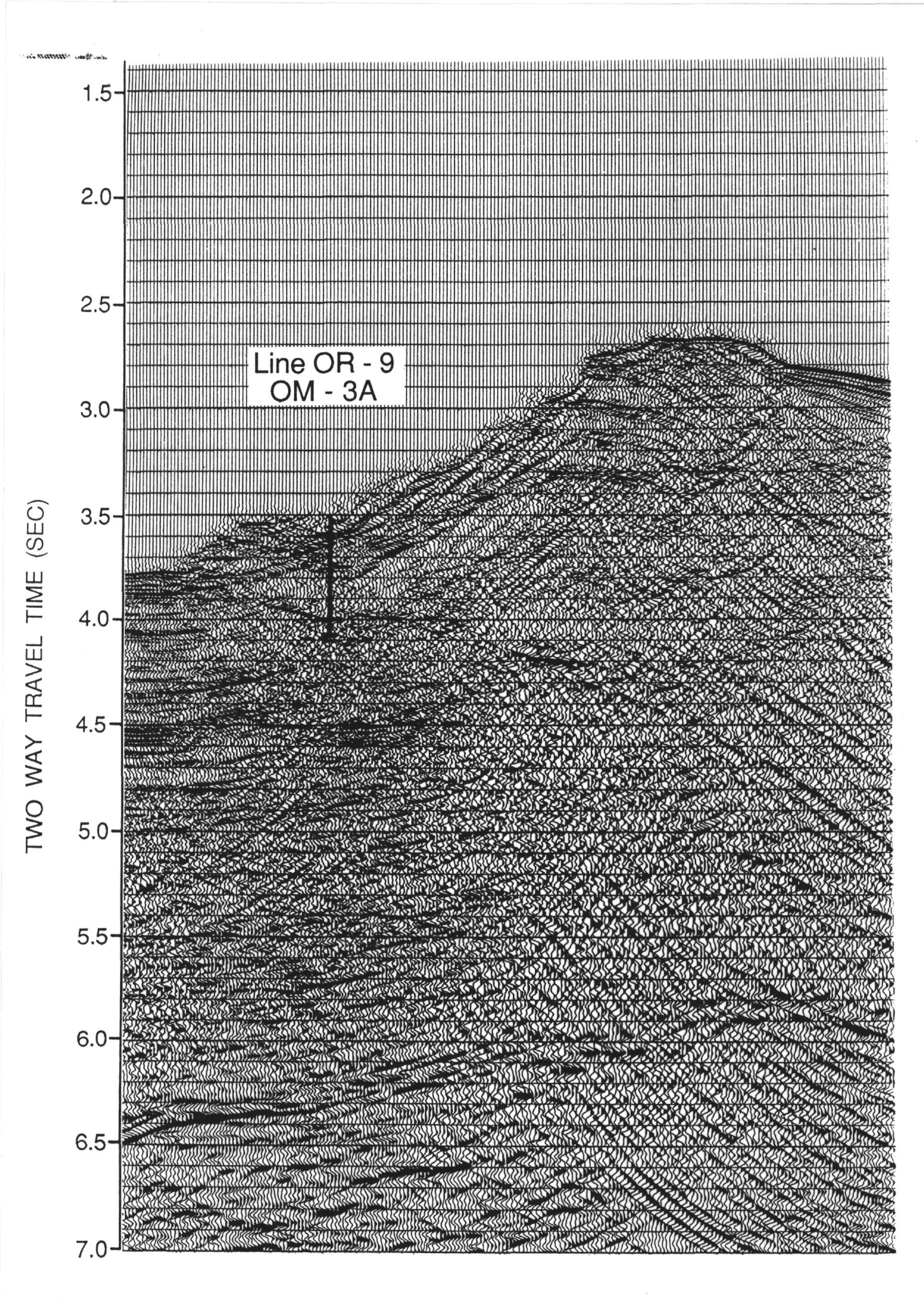
Line OR - 9
OM - 3A
TWO WAY TRAVEL TIME (SEC)
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0

SITE: **OM-4** PRIORITY: **2**

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POSITION: 44°40.44'N, 125°17.63'W

WATER DEPTH: 2025 m

NATURE OF SEDIMENT: Pleistocene; siltstones and interbedded mudstones, silty sands.

SEDIMENT THICKNESS: 4000 m

SEISMIC RECORD: MCS Line OR-9, shot point 542; crossline MCS Line OR-39, shot point 3192.

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OBJECTIVES:

To intercept fluids migrating along a system of backthrusts above the main frontal thrust fault; to determine the nature of deformation within the fault zone, and its hydrologic/physical properties relative to unfaulted sections. To investigate the history of fluid flow as evidenced by diagenetic deposits.

PROPOSED DRILLING PROGRAM:

APC/XCB to 600 mbsf.

LOGGING AND DOWNHOLE EXPERIMENTS:

Numerous runs with WSTP and PCS tools; check shot VSP; logs to consist of seismic-stratigraphic combination and formation microscanner. GEOPROPS and LAST may deployed at this site.

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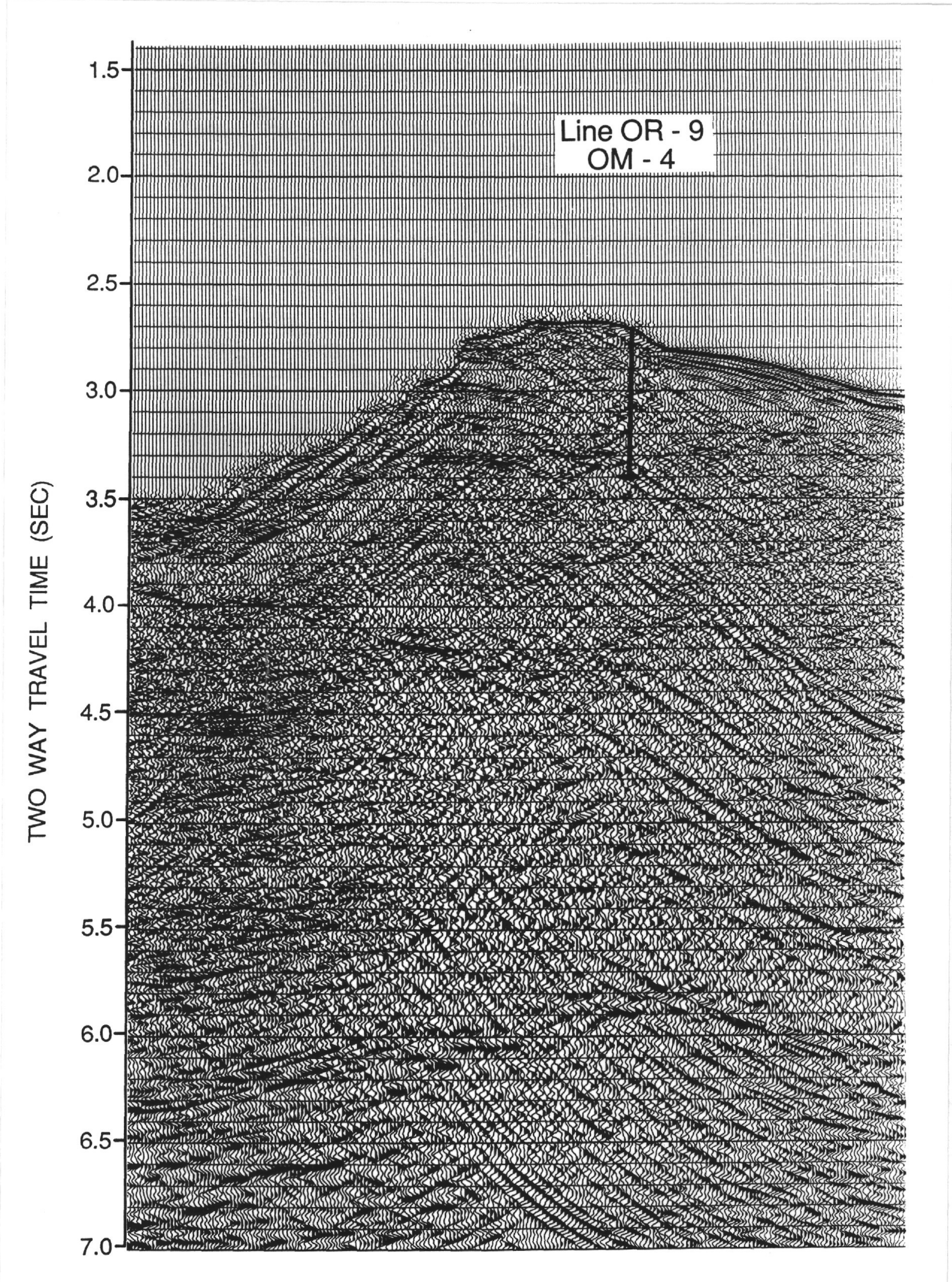
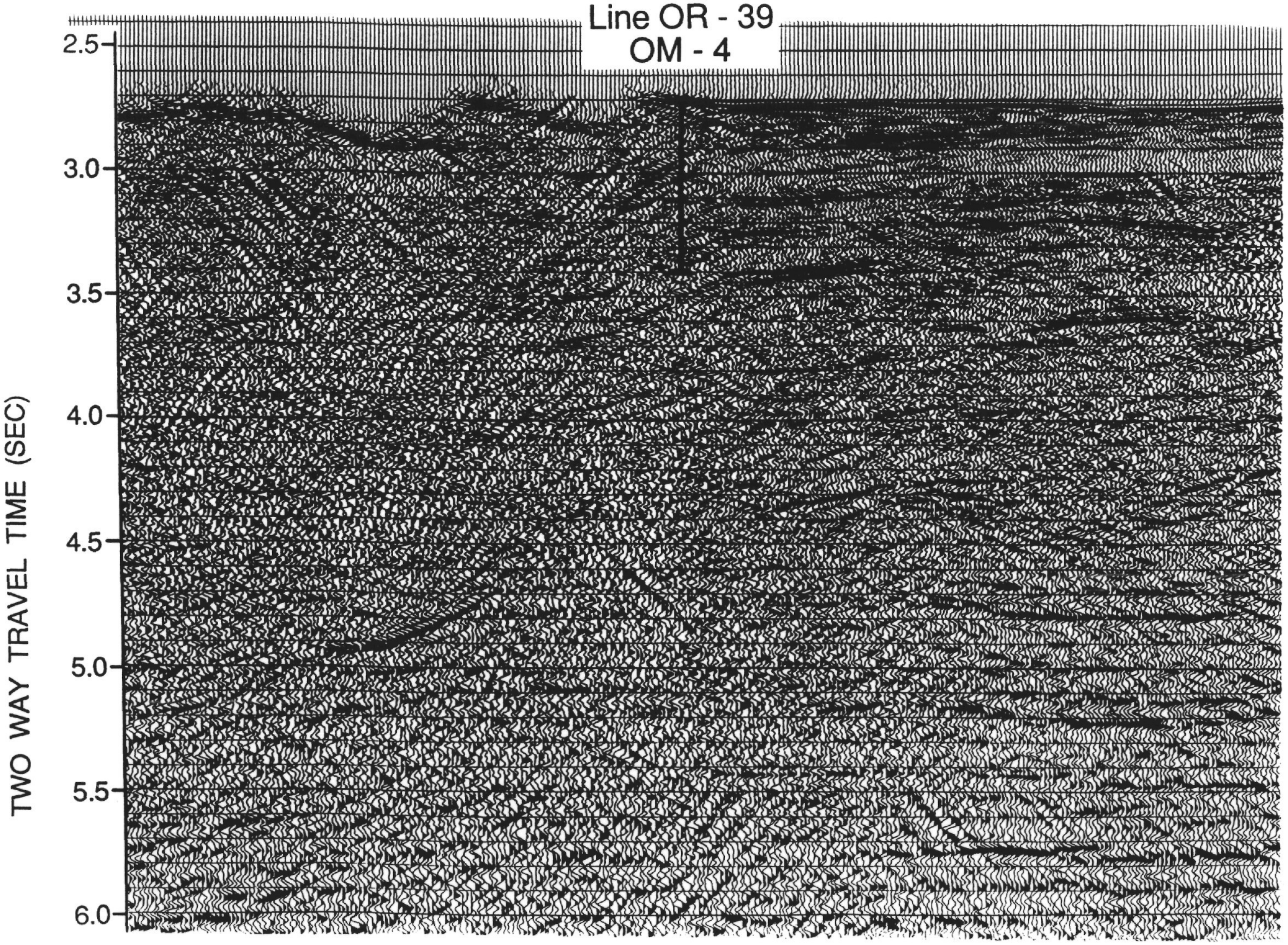

Line OR - 9
OM - 4
TWO WAY TRAVEL TIME (SEC)
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0


Line OR - 39
OM - 4
TWO WAY TRAVEL TIME (SEC)
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0

SITE: **OM-7b** PRIORITY: 2

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POSITION: 44°41.11'N, 125°07.80'W

WATER DEPTH: 760 m

NATURE OF SEDIMENT: Pliocene to Pleistocene; mudstone and micaceous and argillaceous sandstone.

SEDIMENT THICKNESS: 5000 m

SEISMIC RECORD: MCS Line OR-10, shot point 1060.

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OBJECTIVES:

To determine the hydrogeology and fluid chemistry of the Pliocene portion of the accretionary prism; to assess the role of an out-of-sequence thrust fault as an aquifer; to delineate the effect of focused fluid advection and thermal regime on the BSR.

PROPOSED DRILLING PROGRAM:

APC/XCB to 300 mbsf.

LOGGING AND DOWNHOLE EXPERIMENTS:

Numerous runs with WSTP and PCS tools; logs to consist of seismic-stratigraphic combination, geochemical combination, and formation microscanner. GEOPROPS and LAST tools may be deployed.

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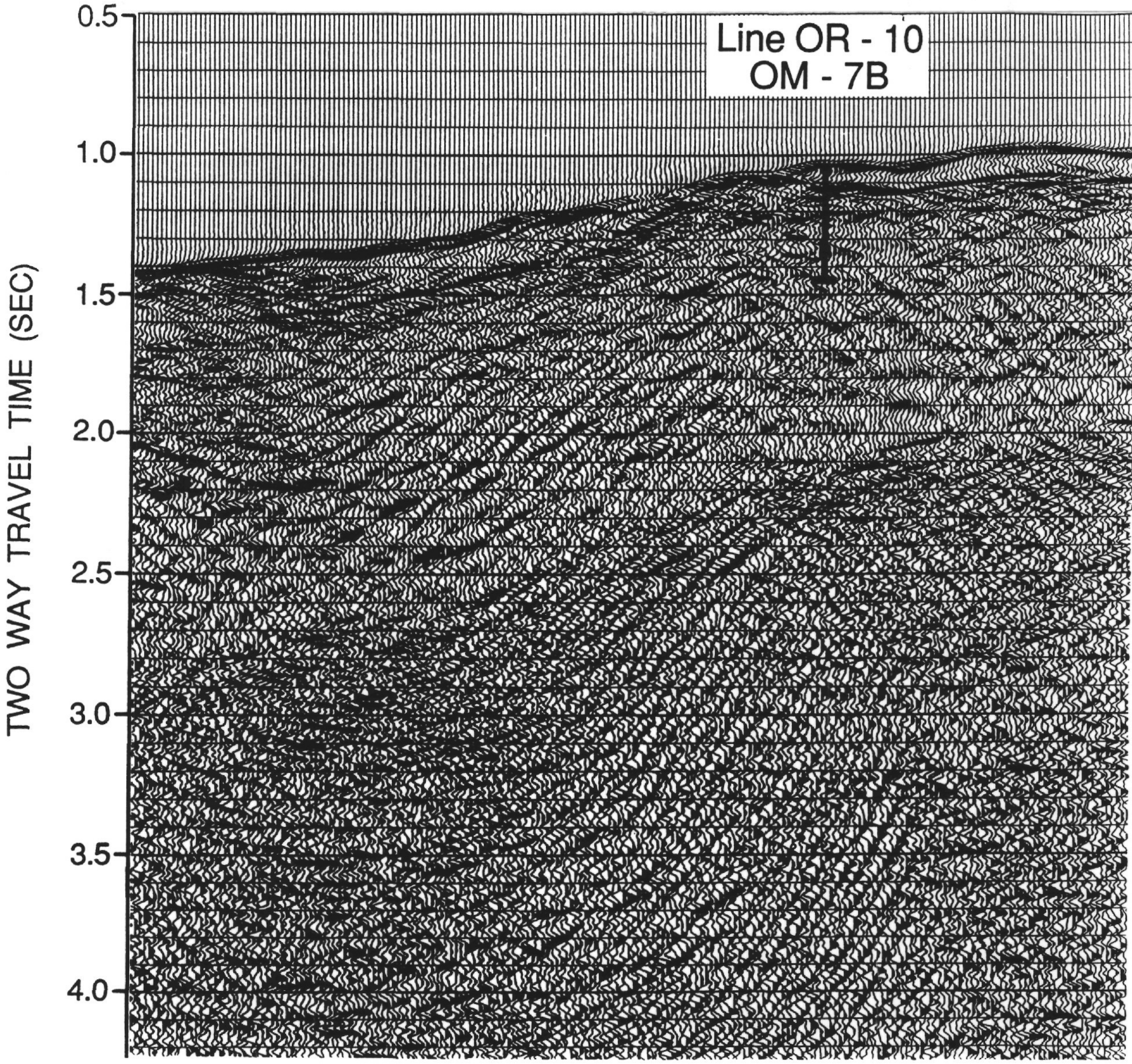
Line OR - 10
OM - 7B
TWO WAY TRAVEL TIME (SEC)
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0

SITE: **OM-8** PRIORITY: **2**

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POSITION: 44°59.52'N, 125°22.26'W

WATER DEPTH: 2400 m

NATURE OF SEDIMENT: Pleistocene; medium to very fine turbidite sand with interbedded mud.

SEDIMENT THICKNESS: 3700 m

SEISMIC RECORD: MCS Line OR-22, shot point 632.

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OBJECTIVES:

To ascertain the chemistry of fluids moving along the seaward-dipping frontal thrust that penetrates nearly to basement; to determine whether some fraction of the fluid is derived from the crust, and if the sediment sourced fluid comes directly from Cascadia Basin or from the accretionary prism. To determine the nature of deformation within the fault zone, and its hydrologic/physical properties relative to unfaulted sections.

PROPOSED DRILLING PROGRAM:

APC/XCB to 660 mbsf.

LOGGING AND DOWNHOLE EXPERIMENTS:

Numerous runs with WSTP and PCS tools; logs to consist of seismic-stratigraphic combination, geochemical combination, and formation microscanner. GEOPROPS and LAST tools may be deployed.

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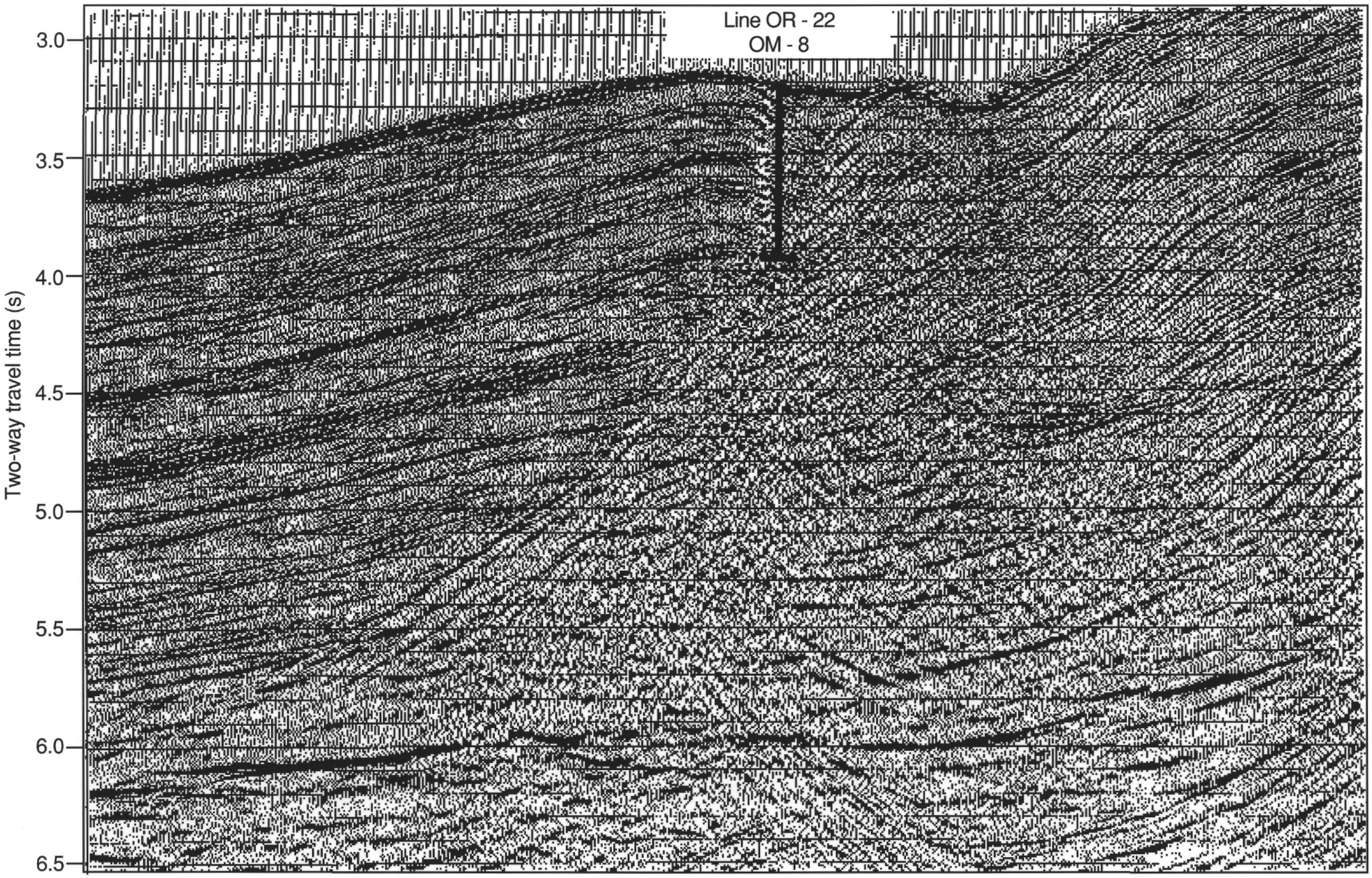
Line OR - 22
OM - 8
Two-way travel time (s)
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5

SITE: **OM-8a** (Alternative to Site OM-8) PRIORITY: **2**

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POSITION: 45°02.63'N, 125°23.39'W

WATER DEPTH: 2440 m

NATURE OF SEDIMENT: Pleistocene; medium to very fine turbidite sand with interbedded muds.

SEDIMENT THICKNESS: 3700 m

SEISMIC RECORD: MCS Line OR-25, 500 m east of shot point 618.

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OBJECTIVES:

To ascertain the chemistry of fluids moving along the seaward-dipping frontal thrust that penetrates nearly to basement; to determine whether some fraction of the fluid is derived from the crust, and if the sediment sourced fluid comes directly from Cascadia Basin or from the accretionary prism. To determine the nature of deformation within the fault zone, and its hydrological/physical properties relative to unfaulted sections.

PROPOSED DRILLING PROGRAM:

APC/XCB to 500 mbsf.

LOGGING AND DOWNHOLE EXPERIMENTS:

Numerous runs with WSTP and PCS tools; logs to consist of seismic-stratigraphic combination, geochemical combination, and formation microscanner. GEOPROPS and LAST tools may be deployed.

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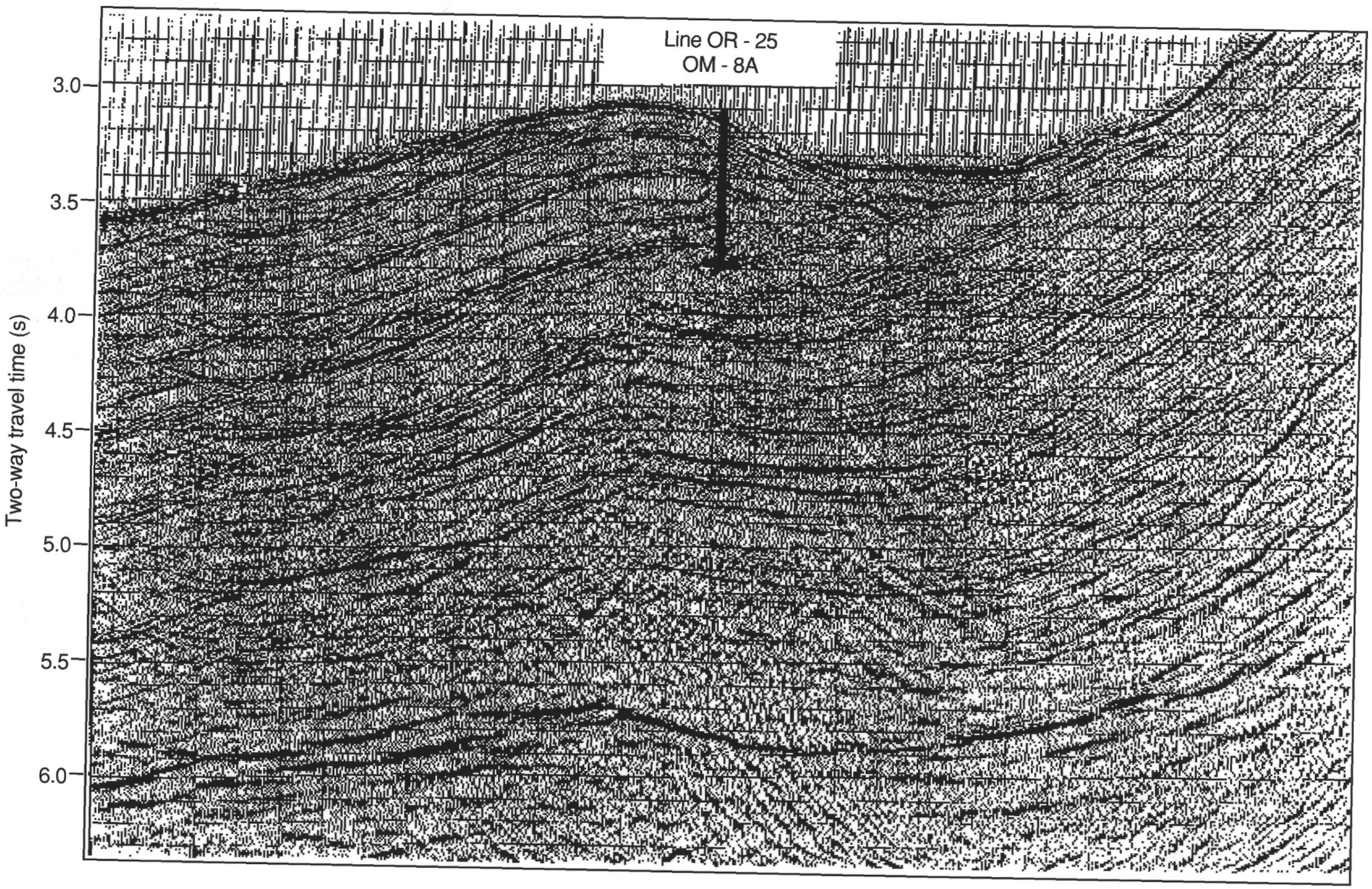
Line OR - 25
OM - 8A
Two-way travel time (s)
3.0
3.5
4.0
4.5
5.0
5.5
6.0

SITE: **OM-10** PRIORITY: **2**

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POSITION: 45°11.00'N, 125°32.10'W

WATER DEPTH: 2620 m

NATURE OF SEDIMENT: Pleistocene; medium to very fine turbidite sand with interbedded muds.

SEDIMENT THICKNESS: 3000 m

SEISMIC RECORD: MCS Line OR-45, shot point 620.

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OBJECTIVES:

To sample the sediments and fluids in a nearly vertical strike-slip fault associated with a recent accretion-related deformation step-out in Cascadia Basin. To determine the nature of deformation within the fault zone, the fault's hydrologic/physical properties, and the history of diagenetic alteration.

PROPOSED DRILLING PROGRAM:

APC/XCB to 500 mbsf (restricted to 600 mbsf).

LOGGING AND DOWNHOLE EXPERIMENTS:

Numerous runs with WSTP and PCS tools; logs to consist of seismic-stratigraphic combination, geochemical combination, and formation microscanner. GEOPROPS and LAST tools may be deployed.

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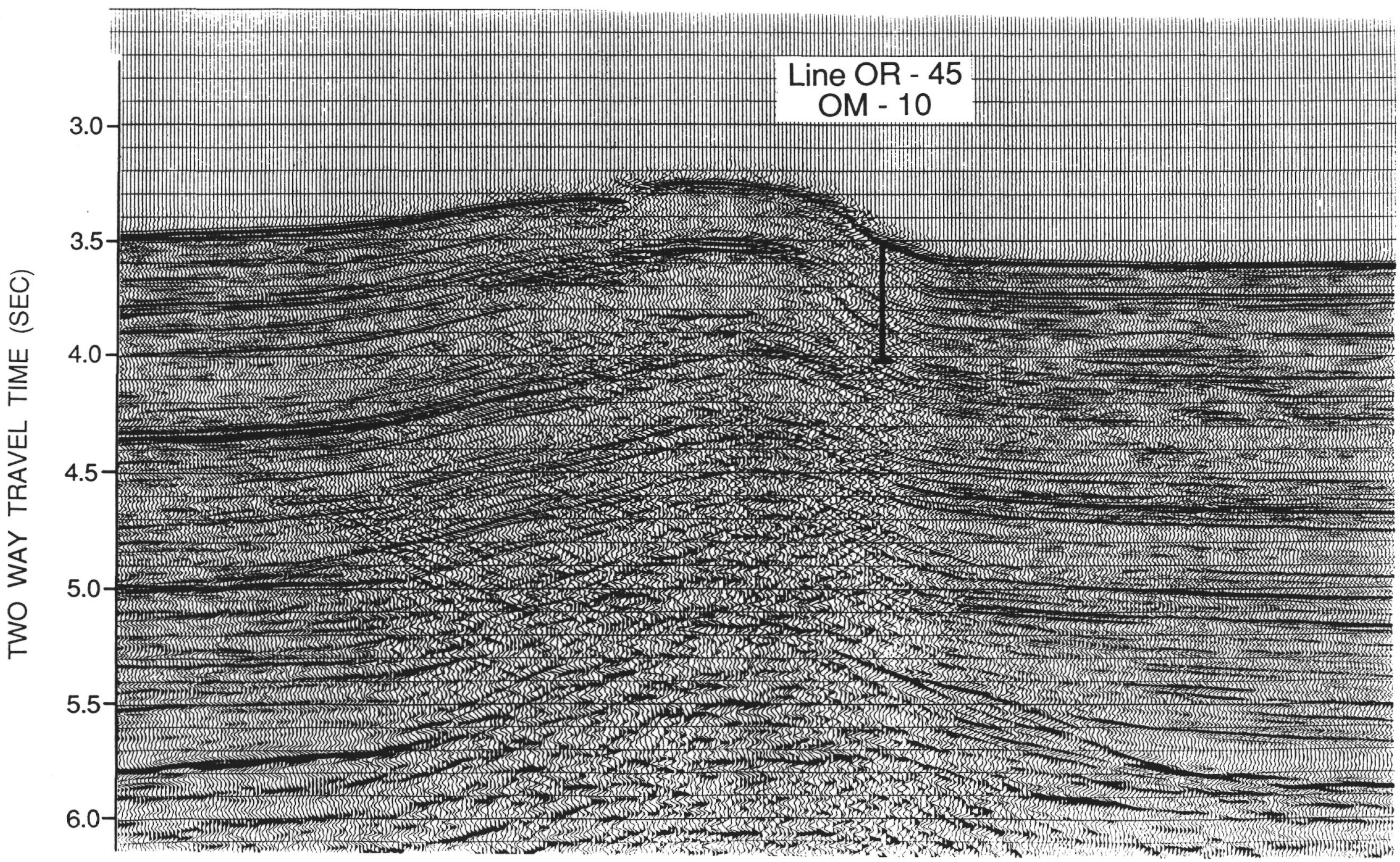
Line OR - 45
OM - 10
TWO WAY TRAVEL TIME (SEC)
3.0
3.5
4.0
4.5
5.0
5.5
6.0

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