Shear Wave Studies of Hydrate Ridge, Oregon Margin: R/V Ewing and JOIDES Resolution Seismic Experiments

EW0208 Cruise Report
R/V Maurice Ewing
August 12 – September 6, 2002

Co-chief scientists

Nathan Bangs
&
Ingo Pecher

Institute for Geophysics
University of Texas at Austin
Austin, Texas

R/V Ewing from the JOIDES Resolution

JOIDES Resolution from the R/V Ewing

Data acquired in coordination with ODP Leg 204
Co-chief scientists: Anne Tréhu & Gerhard Bohrmann

Abstract

This cruise was designed to acquire three different sets of seismic data to map the elastic properties of gas hydrate and free gas beneath Hydrate Ridge, offshore Oregon. Hydrate Ridge is a thrust ridge within the Oregon margin accretionary complex, where high concentrations of methane gas hydrates have been discovered. The quantities of gas hydrates globally are believed to be vast; however, the occurrence, habit, and mechanisms for concentrating gas hydrates are poorly known. The main objective of this cruise was to map out hydrate concentrations and free gas by measuring full elastic properties of hydrate and free gas bearing sediments within Hydrate Ridge.

The primary experiment was a two-ship vertical seismic profile (VSP) experiment conducted with the *Ewing* and the drill ship JOIDES Resolution. This experiment was designed to generate and record both P-wave arrivals and shear waves converted within the hydrate layer. The work was conducted as part of the drilling operation of the Ocean Drilling Program (ODP) Leg 204. The *Ewing* operated as the seismic source vessel to conduct both constant offset VSPs (C-VSPs), and offset ranging, or walkaway, VSPs (W-VSPs). The *Ewing* fired two 105/105 in^3 GI guns to receivers placed in the borehole and recorded on the drill ship. We acquired the C-VSPs at a fixed position from the borehole, which was either 700 or 1000 m south of the drill sites, and a receiver placed at stations every 5 m up the length of the borehole. The W-VSPs required shooting to a receiver station through a range of source offsets from 3,500 m to our closest approach to the Resolution of about 150 m. For each W-VSP, two of these lines were shot in perpendicular directions crossing at the borehole. Despite some unfortunate failures of the borehole receivers and difficulty clamping the tool to the soft sediment encountered in these holes, we managed to acquire C-VSPs at 4 sites, and 6 W-VSPs at three different drill sites.

As a second experiment we acquired seismic data with ocean bottom seismometers recording GI-gun shots. These experiments were designed to record p-wave arrivals and converted shear waves on the seafloor at drill sites and between them, to map the lateral variability of gas hydrates. During the leg we deployed two types of instruments: the Woods Hole 4-component instrument, and the Institute for Geophysics 4-component OBS. We deployed both instruments because of the advantages of each of the different instrument designs for high-resolution data acquisition. In total we had 14 deployments of WHOI instruments of which we lost one and another recorded no data. We had 17 deployments of UTIG instruments and recovered all with recorded data.

The third component of the cruise was high-resolution multichannel seismic imaging of Hydrate Ridge. We acquired approximately 1250 km of seismic reflection data with a 120-channel, 1500-m-long streamer and two 105/105 in^3 GI guns. These data provide a regional context for the drilling and seismic data acquired as part of this two-ship seismic experiment.

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Introduction

This report summarizes cruise EW0208. This cruise was complicated operationally because it was three overlapping seismic acquisition efforts (the VSPs, OBSs, and the MCS data acquisition). Some operations had to be coordinated with the *JOIDES Resolution* (J.R.) and some that had to be conducted without interference from the J.R. operations. The VSPs were shot after the J.R. drilled the boreholes and placed the instruments in them. These operations required 1 – 3 days between boreholes; therefore, operations to acquire the three data sets on EW0208 could not occur sequentially but had to be run at various times throughout the cruise when opportunities allowed. Also, we tried to conduct the OBS data acquisition as far away from the drilling operations as possible to avoid noise interference from drilling, so OBSs transects were shot piecemeal rather than all at once. VSP data were recorded on the J.R. and required initial processing on the J.R., so there was little access to the data and no data analysis on the *Ewing* during the cruise. VSP operations overlapped with both J.R. and *Ewing* operations; however, some operations (i.e. zero-offset VSPs) did not have any direct *Ewing* involvement. We also acquired OBS data on two sets of instruments: the Woods Hole 4-component instruments and the UTIG 4-component instruments. We used both sets of instruments because of their different characteristics exploiting their individual advantages for detecting gas hydrates.

Given the complex nature of this cruise, we simplified the presentation here into three separate summaries of the three data acquisition efforts. There are some examples of each of the data sets, without preliminary interpretation. We also present the data acquisition that is specific to the *Ewing*. Additional details about the VSPs are available from the Leg 204 Initial Reports. This report also gives a combined presentation on the WHOI and UTIG OBS operation.

Marine Mammal Observation

We included three marine mammal observers in the scientific party to watch for mammals during seismic operations. Observers posted continuous watches from the *Ewing*'s bridge. Operations were suspended when mammals were within ¼ mile of the *Ewing*, which happened on ~ 6 occasions during the cruise. Each of these occasions was logged in the main lab logbook, and by the marine mammal observers. Additional details are available through Lamont-Doherty Earth Observatory Marine Office.

Scientific Personnel

Nathan Bangs – Chief Scientist; UTIG nathan@utig.ig.utexas.edu
Ingo Pecher – Co-chief Scientist; UTIG ingo@ig.utexas.edu
Yosio Nakamura – UTIG OBSs; UTIG yosio@ig.utexas.edu
Steffen Saustrup – UTIG MCS/Computer Tech; UTIG steffen@ig.utexas.edu
Ben Yates- UTIG OBS Engineer; UTIG yates@ig.utexas.edu
John Gerboc – Systems Analyst; UTIG johng@utig.ig.utexas.edu
Hao Xun – Watchstander; UTIG hao@ig.utexas.edu
Dhananjay Kumar – Watchstander; UTIG kumar@ig.utexas.edu
Stacy Supak – Watchstander; Columbia University supak@ldeo.columbia.edu
Johanna Chevallier – Watchstander; OSU jchevall@coas.oregonstate.edu
Ken Peal- Senior - Engineer; WHOI kpeal@whoi.edu
Beecher Wooding - Research Specialist, WHOI; bwooding@whoi.edu
Victor Bender - Senior Engineering Assistant; WHOI vbender@whoi.edu
David Dubois - Senior Research Assistant; WHOI ddubois@whoi,edu

Technical Staff

Ethan Gold - Technician
Carlos Guiterrez – Airgun Technician
Karl Hagel – Electrical Technician
Don Kennedy – Schlumberger Engineer
Francisco Matos – Electrical Technician
Michael Rawson – Mammal Observer
Joseph Stennet – Science Officer
Justin Walsh – Airgun Technician
Kevin Warner – Mammal Observer

Ewing Crew

James O'Loughlin – Master
Jay Thomas – Chief Mate
Scott McGeough – 2^{nd} Mate
Richard Thomas – 3^{rd} Mate
Kelly Tomas – Bosun
Wakefield Walker – A/B
Felepe Hontiveros – A/B
Elizabeth Scanland – A/B
William Brannon – O/S
Arnold Sypongco – O/S
Rhonda Benoit – Mammal Observer
Stephen Pica – Chief Engineer
Miguel Flores – 1^{st} Engineer
Nicholas Neill – 2^{nd} Engineer
Thomas Hickey – 3^{rd} Engineer
Ian McRae – Oiler
Guillermo Uribe – Oiler
Alfred Potts – Oiler
Jack LaVox – Steward
Michael Burdish – Cook
Kathleen Uto – Utility

Scientific Instrumentation

Schlumberger radio airgun triggering system
14 Ocean bottom seismometers (UTIG)
15 Ocean bottom seismometers (WHOI)
Syntron 240-channel seismic streamer (LDEO)
2-Generator/Injector Airguns (LDEO)
Syntron Syntrak 480-24 digital recording system (LDEO)
Spectra navigation system (LDEO)
Sun Blade data processing computer (UTIG)
Sun Ultra 60 data processing computer (UTIG)
Dell PC (UTIG)

Background

This cruise was designed to investigate the occurrence and distribution of free gas and gas hydrates within Hydrate Ridge, offshore Oregon, through seismic experiments, primarily shear-wave studies. These data were acquired as a coordinated effort with ODP Leg 204.

ODP leg 204 was designed to study of gas hydrates and free gas in an accretionary wedge with high fluid-flux and strong small-scale lateral variability. Data from logging and coring provides critical constraints on hydrate and free gas occurrences. However, these results will be inherently limited to the drill sites leaving gaps in the regional picture of the hydrate system. This cruise conducted a series of collaborative seismic experiments to extend the borehole results to the surrounding region for a study of the gas hydrate system within Hydrate Ridge. Although standard geophysical techniques, i.e. V_p analysis, have been used to map hydrates regionally, they have proven limited in detecting the typical small concentrations of hydrate and free gas. Analysis of full elastic properties, i.e. P-wave velocity (V_p), S-wave velocity (V_p) and density (ρ), are a promising new analysis approach. Recent studies suggest V_s is significantly more sensitive to the increase of sediment strength caused by gas hydrates (Guerin et al., 1999, Pecher et al., 1999), and V_p/V_s ratios are known to be extremely sensitive to the presence of free gas (Domenico, 1977). The cruise was planned to comprise three seismic efforts. 1) The main objective of this cruise is a piggyback, two-ship experiment to complement planned downhole and regional geophysical experiments by acquiring essential in situ S-wave data that will extend the geophysical analysis to an analysis of full elastic properties. 2) A related objective was to acquire high-resolution seismic reflection/refraction data with ocean bottom seismometers (OBSs) to map elastic properties between boreholes. 3) We also acquired high-resolution 2-D regional seismic lines to extend inferences about the hydrate and free gas distribution to the broader region of Hydrate Ridge and the surrounding continental slope. Each of these results ties into the three-dimensional (3-D) seismic reflection and four-component (4-C) seismic refraction site survey study acquired on the R/V Thompson in June/July 2000.

Our primary focus is shear wave studies because of their success in examining gas hydrates (e.g. ODP Leg 164). In order to examine shear waves within Hydrate Ridge, EW0208 acquired three VSP data sets: (1) a constant-offset VSP (c-VSP) to record P-to-S converted waves and measure large-scale V_s, (2) a walkaway VSP (w-VSP) to investigate fine-scale V_s, and (3) and a novel experiment to use OBSs at the seafloor for recording of signals generated in the borehole during APC coring (APC/OBS experiment). We also used a dense deployment of ocean bottom seismometers (OBSs) to extend the V_s model away from the borehole. The two-ship experiment together with drilling and the planned regional 3-D/4-C survey comprise a unique, comprehensive study of the distribution of gas hydrates and free gas in the high-flux environment of a convergent margin.

Gas hydrate samples retrieved from cores at Site 1244 during Leg 204. These solid pieces probably formed within veins formed within faults.

Why are gas hydrates important?

Gas hydrate is an ice-like substance that contains methane or other low molecular weight gases in a lattice of water molecules. Methane hydrates are stable under submarine temperature and pressure conditions generally found near the seafloor at water depths greater than 500 m. They are quite common beneath the continental slope of both active and passive continental margins, where methane originates from the decomposition of organic matter.

In the past several years, international interest in gas hydrates has increased considerably because of the large volumes of methane stored in the hydrate and underlying gas region represent a significant fraction of the global methane budget (Kvenvolden, 1988) and may be a future energy resource (Haq, 1998). Methods to determine volume and concentration of gas hydrates in sediments are critical for assessing hydrate reserves and hydrate dynamics; however, methods are still in their infancy.

Methane hydrates may affect slope stability. They may increase sediment shear strength as cement within the gas hydrate stability zone (GHSZ). Dissociation of gas hydrates then may lead to sediment weakening. Generation and trapping of gas at the base of gas hydrate stability (BGHS) may cause overpressuring and destabilize sediments

Methane is a powerful greenhouse gas and methane hydrates may therefore be causative factor in global change. Changes in the oxygen isotope signature of marine sediments have been attributed to sudden, widespread dissociation of potentially vast amounts of sub seafloor gas hydrates and release of methane (a greenhouse gas) in response to changing environmental conditions (Dickens et al., 1997). There may be a feedback effect between methane release and global warming (Revelle, 1983; Kvenvolden, 1988; Nisbet, 1990). In contrast, Paull et al. (1991) have argued that methane is released during global cooling in response to sea level drops during initiation of ice ages. These effects, however, remain speculative, and will remain speculative until the volume of gas stored in the gas hydrate reservoir, its behavior during changing environmental conditions, and its mechanical effects on sediment stability can be adequately measured.

Shear waves and gas hydrates

For the past 25 years, the main approach used to evaluate the presence of gas hydrate in seafloor sediments has been through a proxy known as the bottom simulating reflection (BSR), a seismic reflection at the BGHS that mimics the seafloor, cuts across stratigraphic reflections, and has a polarity reversed from the normal seafloor reflection. BSRs have been studied extensively in particular during two ODP Legs (MacKay et al., 1994, Holbrook et al., 1996) and it is now generally accepted that most strong BSRs are mainly caused by free gas leading to a significant decrease of V_p and associated constant V_s (Domenico, 1977). Gas hydrates have been encountered in many areas without BSRs. BSRs do not offer much insight about gas hydrate concentration above the BGHS. More direct indicators of gas hydrates in sediments are therefore needed for gas hydrate quantification.

Seismic methods for quantifying hydrate concentrations are showing new promise when V_s is measured along with V_p. Generally, partial replacement of pore water (V_p: 1.5 km./s, no shear transmission) by solid gas hydrates (V_p: 3.65 km/s, V_s: 1.89 km/s;

Helgerud et al., 1999) is expected to increase sediment velocities. However, V_p analysis alone has been poor in detecting the replacement effect. The effect of gas hydrates on seismic properties depends strongly on the microscopic distribution of gas hydrates in the sediments, which is still unknown, and a concentrations of a few percent hydrate in pore space has an effect on V_p that is usually below detectable limits. Recently, several laboratory and borehole studies (Guerin et al., 1999; Helgerud et al., 1999; Pecher et al, 1999; Sakai, 1999) demonstrate that V_s is considerably more sensitive to gas hydrates than V_p. A V_s contrast is the main parameter that controls conversion of P- to S-waves. Recording of P-to-S converted waves (PS-waves) and subsequent V_s analysis is emerging as a powerful tool for lithologic determination in oil and gas exploration, which should also be directly applicable to measuring hydrate concentrations. PS-waves were first observed in a gas hydrate province during ODP Leg 164 in a w-VSP experiment on the Blake Ridge (Pecher et al., 1997a) where conversion is linked to gas hydrate concentration (Pecher et al., 1997b).

Hydrates on the Oregon continental margin

The Juan de Fuca plate is subducted obliquely beneath North America at a rate of about 4.5 cm/yr offshore the northwestern United States and southwestern Canada. At present, most of the sediment on the subducting plate, which contains large volumes of sandy and silty turbidites, appears to be accreted to the continental margin, either by offscraping at the deformation front or by underplating beneath the accretionary complex some 10s of kilometers east of the deformation front (MacKay et al., 1992; MacKay, 1995).

Like in many accretionary complexes worldwide, this environment has resulted in the extensive presence of gas hydrate. Hydrate and its geophysical proxies appear to be particularly well-developed beneath Hydrate Ridge, a 25 km long and 15 km wide ridge in the young accretionary complex. Hydrate Ridge appears to be capped by hydrate, as indicated by a nearly ubiquitous and strong BSR. Seafloor camera tows and diving with both manned and remotely operated submersibles first revealed massive carbonates and communities of vent-dependent organisms on the northern peak several years ago (Linke et al., 1994). In 1996 vigorous streams of methane bubbles were first observed emanating from vents on the seafloor on the northern peak of Hydrate Ridge (Suess et al., 1999), indicating supersaturation of methane in the fluid venting from beneath the BSR.

Until recently, the southern part of Hydrate Ridge was thought to be dominated by diffuse fluid flow. Regionally, there are no significant departures in BSR depth from that predicted by the seawater/hydrate phase boundary in existing seismic data (Zwart et al., 1996). In 1996, a 700 m long seafloor video-camera tow (Fig. 1B) across the southern peak of Hydrate Ridge showed a smooth seafloor characterized by soft sediment and only occasional white patches of massive hydrate, chemosynthetic clams and bacterial mats (Suess and Bohrmann, 1997; Bohrmann et al., 1998); approx. 50 kg of massive hydrate were recovered from the SE end of the tow (Bohrmann et al., 1998). The inference that fluid flow was dominantly diffuse, however, conflicts with the complex subsurface seismic signature, which includes multiple crosscutting reversed-polarity reflections above and beneath the BSR, suggesting a variety of subsurface fluid transport mechanisms.

Active focused fluid flow was confirmed by Alvin dives during summer, 1999, which documented a major episode of bubble release from the southern summit and showed that a “mud volcano” at the center of a “pockmark” southwest of the southern crest of the ridge was actually a carbonate pinnacle harboring rich communities of vent organisms. The Alvin dives, combined with high-resolution deep towed side-scan, also indicate that massive hydrate at the seafloor is more extensive than previously thought, covering approx. 1 km^2 at the southern summit. The main goal of this project is to examine the relationship between hydrate occurrence and fluid flow by mapping the subsurface distribution of hydrates from elastic properties.

Scientific Objectives

The seismic experiments are targeted to achieve the following specific objectives:

- *To measure V_s in gas hydrate-bearing sediments:* The c-VSP allow the first-ever vertically continuous measurement of the large-scale V_s in gas hydrate-bearing sediments. The w-VSP allows determination of the small-scale Vs structure of conversion horizons.
- *To calibrate rock physics models of gas hydrate-bearing sediments for remote quantification of gas hydrates*: We will use V_s from above together with V_p from the z-VSP to calibrate rock physics models of gas hydrate-bearing sediments. These models then allow a prediction of the effect of gas hydrates on these sediments and may form the backbone for quantification of gas hydrates from V_s.
- *To study the nature of the "bright spot" at the seafloor close to HR-1:* Densely-spaced OBSs may allow us to determine whether the "bright spot" at Site 1249 is caused by a hydrate/carbonate mat, how far it extends laterally and into the subsurface, and if it is related to gas hydrate and free gas anomalies deeper in the subsurface.
- *To link borehole results to data from the regional 3-D/4-C survey for a study of gas hydrate distribution across all of southern Hydrate Ridge*. V_s obtained at the borehole will be a good "starting model" for a regional determination of V_s from PS-waves recorded during the 2000 *R/V Thompson*, 3-D/4-C survey. The rock physics models from our analysis will then allow the first-ever analysis of regional gas hydrate distribution.
- *To test a new method to generate seismic energy in the borehole:* The advanced piston corer (APC) that is used as a standard instrument during ODP legs potentially generated a strong seismic signal. During the course of the OBS acquisition, we recorded this energy, which may contain P-, S-, and interface-wave components, at the seafloor. This would be a novel technique for ODP to shoot "reverse VSPs" (source in the borehole) with no added cost to the experiment.

Summary of Offset VSP Acquisition

Objectives

The primary goal of the offset VSP acquisition was to record zero-offset (Z-VSP) constant-offset (C-VSP) and walkaway VSPs (W-VSPs) at selected drill sites. The offset VSPs were intended to generate converted shear arrivals that could be used to map out hydrate concentrations regionally away from the boreholes. Preliminary examination of the data show converted shear arrivals; however, the relationship with hydrates is still uncertain.

Downhole VSP Instrumentation

The VSP data were recorded on three different downhole instruments on the J.R. This is a summary of the tools and how they were used.

VSI – Vertical Seismic Imager

The Vertical Seismic Imager (VSI) is a borehole seismic wireline tool optimized for VSP and walkaway in both cased hole and open hole, vertical, and deviated wells. The VSI consists of multiple 3-axis geophones in series separated by “hard wired,” acoustically isolating spacers. However, because of difficulties using the tool as a set of multiple receivers, the tool was dismantled and used as single 3-component receiver stations. The tool diameter is 3-3/8 inches, with temperature and pressure ratings to 175°C target and 20,000 psi, respectively.

For vertical VSP operations, the shuttles are mechanically clamped against the borehole wall and sources (e.g. GI guns) on the JOIDES Resolution are fired between 5 and 15 times by control hardware in the Schlumberger MAXIS unit. For constant-offset and walkaway VSP operations, sources are fired on another ship (e.g. R/V Maurice *Ewing*) by Macha radio control from the Schlumberger MAXIS unit. The VSI tool is then unclamped and pulled uphole. The VSI records the full seismic waveform for each firing. These waveform data are stacked by the MAXIS recording software and may be output in LDF (internal Schlumberger format) or SEG-Y formats.

The vertical incidence and constant offset surveys were conducted by alternating source firings between the *D/V JOIDES Resolution* and the *R/V Maurice Ewing* at each VSI depth station. This “ping-pong” firing was continued through all depths for the zero-offset and constant-offset VSPS. Walkaway VSP experiments, in which sources were fired from the *Ewing* alone as it moved along two crossing lines intersecting near the drill site, followed the Z-VSPs and C-VSPs as a separate tool run.

WST-3 Three-component Well Seismic Tool

The WST-3 is a Schlumberger three-axis check shot tool used for both zero offset (check shot) and offset vertical seismic profiles (VSP). The WST-3 consists of three geophones, which press against the borehole wall and record the acoustic waves generated by the air guns. Data output is in SEG-Y format.

Tool Specifications:

Temperature Rating: 350° F (175° C)
Pressure Rating: 20 kpsi (13.8 kPa)
Tool Diameter: 3.625 in (9.21 cm)
Tool Length: 19.9 ft (6.07 m)
Tool Weight: 310 lbs. (141 kg)
Min. Hole Diameter: 5 in. (12.7 cm) with "short" arms
Max. Hole Diameter: 19 in. (48.3 cm) with "long" arms
Geophone frequency: 10 Hz
Low-cut frequency: 0.2 Hz
Low-cut slope: 18 dB per octave
High-cut frequency: 250 Hz for 1 ms
High-cut slope: 36 dB per octave
Sampling rate: 1 ms
Dynamic range per waveform (shot): 90 dB
Total dynamic range: 156 dB
Anti-aliasing filters: 330 Hz / 24 dB per octave
Data format: 16 bit FP (12 bits mantissa, 4 bits exponent)

The WST-3 can be used in both checkshot and offset vertical seismic profile experiments. The WST-3 is clamped against the borehole wall at intervals of approximately 5m, and the air gun fired five to seven times. The resulting waveforms are stacked and a travel-time is determined from the median of the first breaks in each trace. The WST-3 is always the last tool run and it is always run alone. The WST-3 must be powered with a 400hz power supply to avoid 60hz noise generated when a 60hz power supply is use. Acquisition procedures were similar with the WST-3 as with the VSI.

WST-1 Single-component Well Seismic Tool

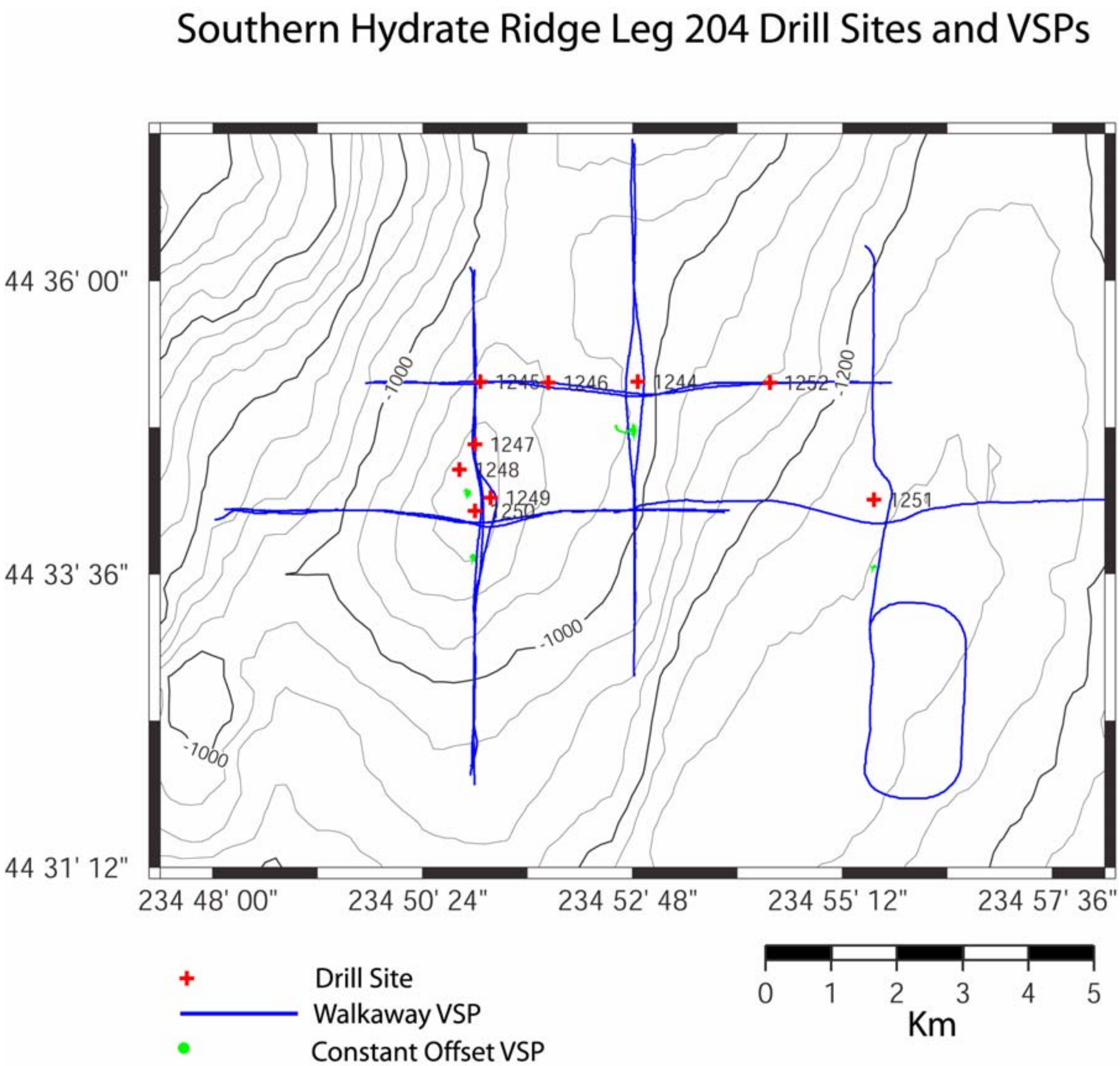
The WST is a single axis check shot tool used for zero offset VSPs. It consists of a single geophone pressed against the borehole wall that is used to record the acoustic waves generated by an air gun located near the sea surface. The WST is clamped against the borehole wall at intervals of approximately 5m, and the air gun fired five to seven times. The resulting waveforms are stacked and a travel time is determined from the median of the first breaks in each trace. In general, the acoustic velocities, and resulting depth travel time pairs, determined from the sonic tool differ significantly from the seismic velocities because of frequency dispersion (e.g. the sonic tool works at 10-20KHZ vs. 50 100 Hz in seismic data) and because the sound is forced to travel along the borehole wall, a path this is quite different from the one taken by the air gun signal generated during a seismic reflection survey.

Tool Specifications:

Temperature Ratings: 350° F (175° C)
Pressure Ratings: 20 kpsi (13.8 kPa)
Tool Diameter: 3 5/8"
Tool Length: 31.3 ft (9.6 m)

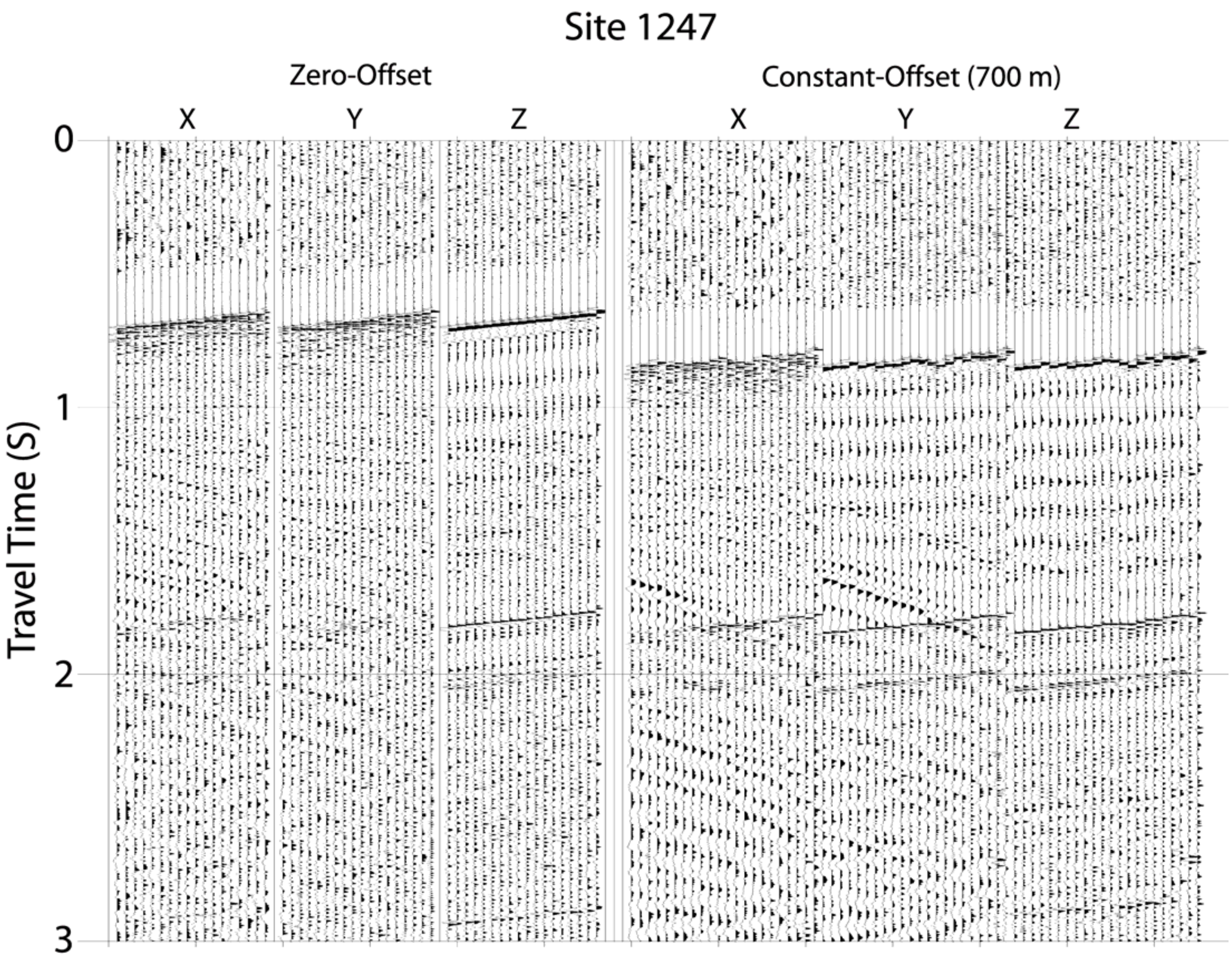
VSP Sites

We acquired VSP data at four sites: Sites 1244, 1247, 1250, and 1251. This is a summary of the data with some examples.



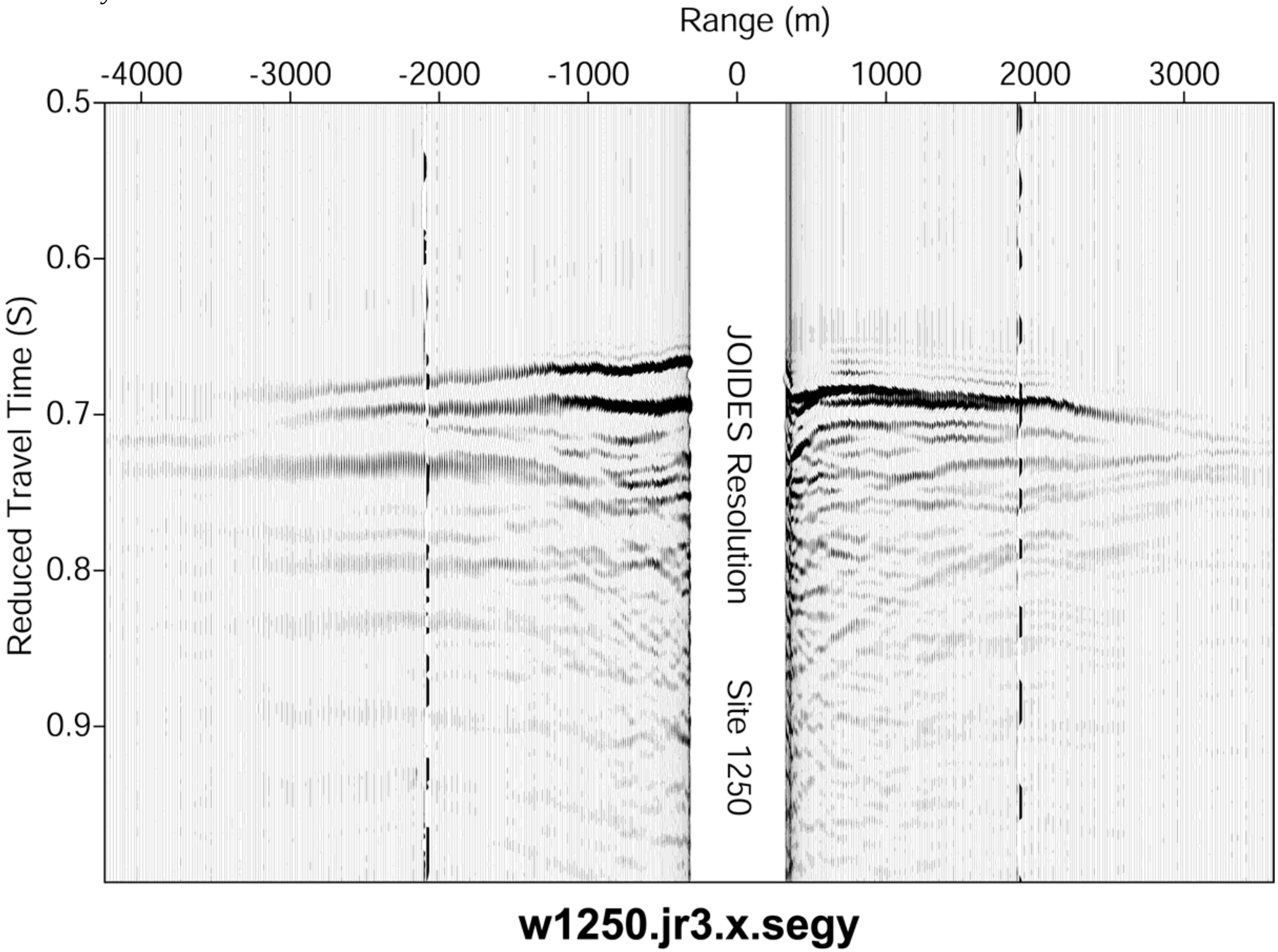
Track map showing the constant-offset VSPs and the walkaway VSPs with respect to the Leg 204 drill sites. All constant-offset VSPs were shot south of the drill sites, at either 700 or 1,000 m offset. Walk away VSPs range from ±3.5 km offset.

Zero Offset and Constant Offset VSPs

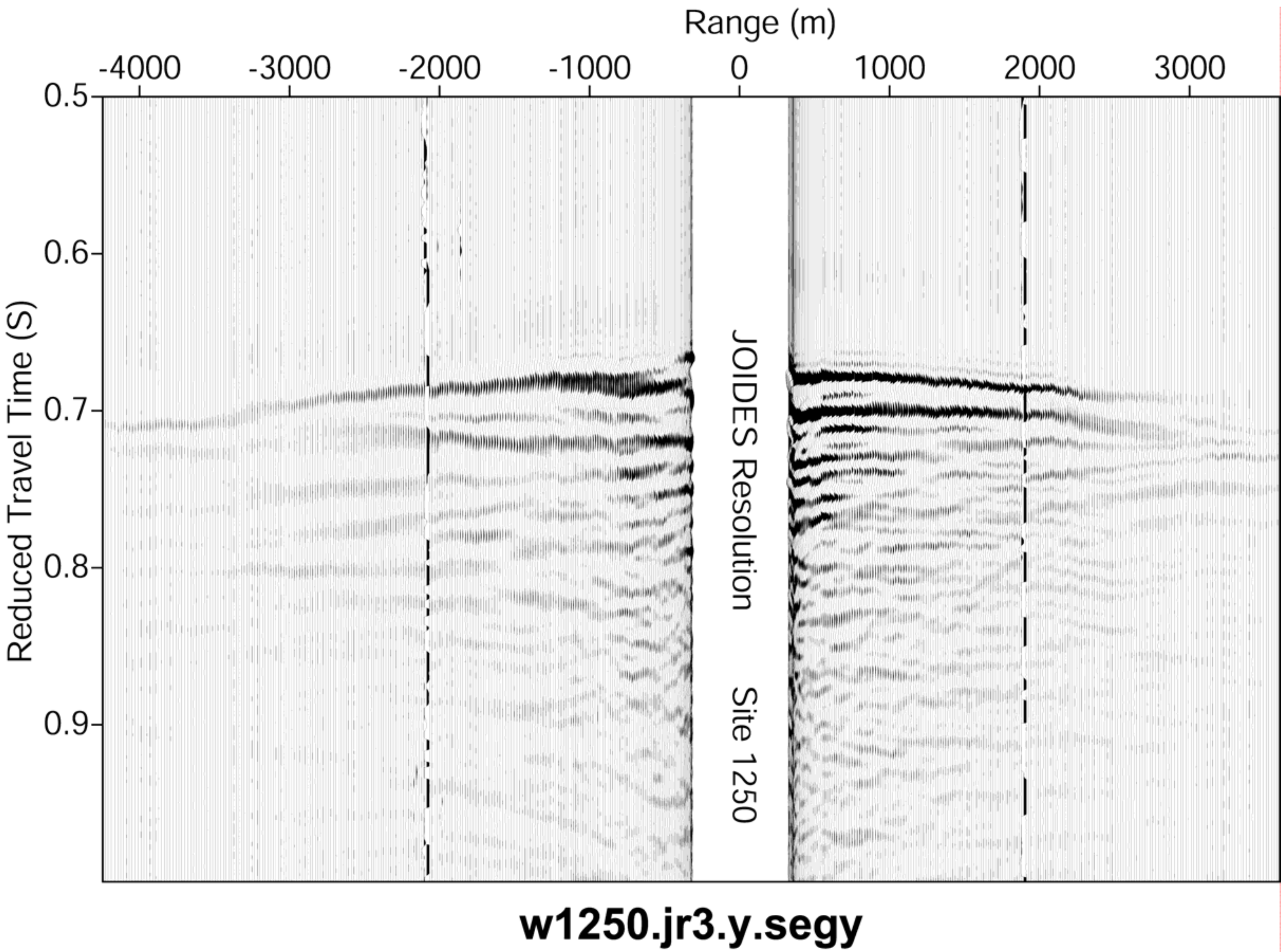


Z-VSP and C-VSP for Site 1247. The three panels on the left show the x, y, and z components of the Z-VSP recorded at 22 receiver stations. The three panels on right are C-VSP data. Z-VSP data were shot with the single GI gun on the J.R., and C-VSP data were shot with 2-GI guns from the *Ewing*. Each trace is a stack of the data acquired at each station from 214 to 109 mbsf at 5 m intervals. C-VSP data are not yet corrected for range variation.

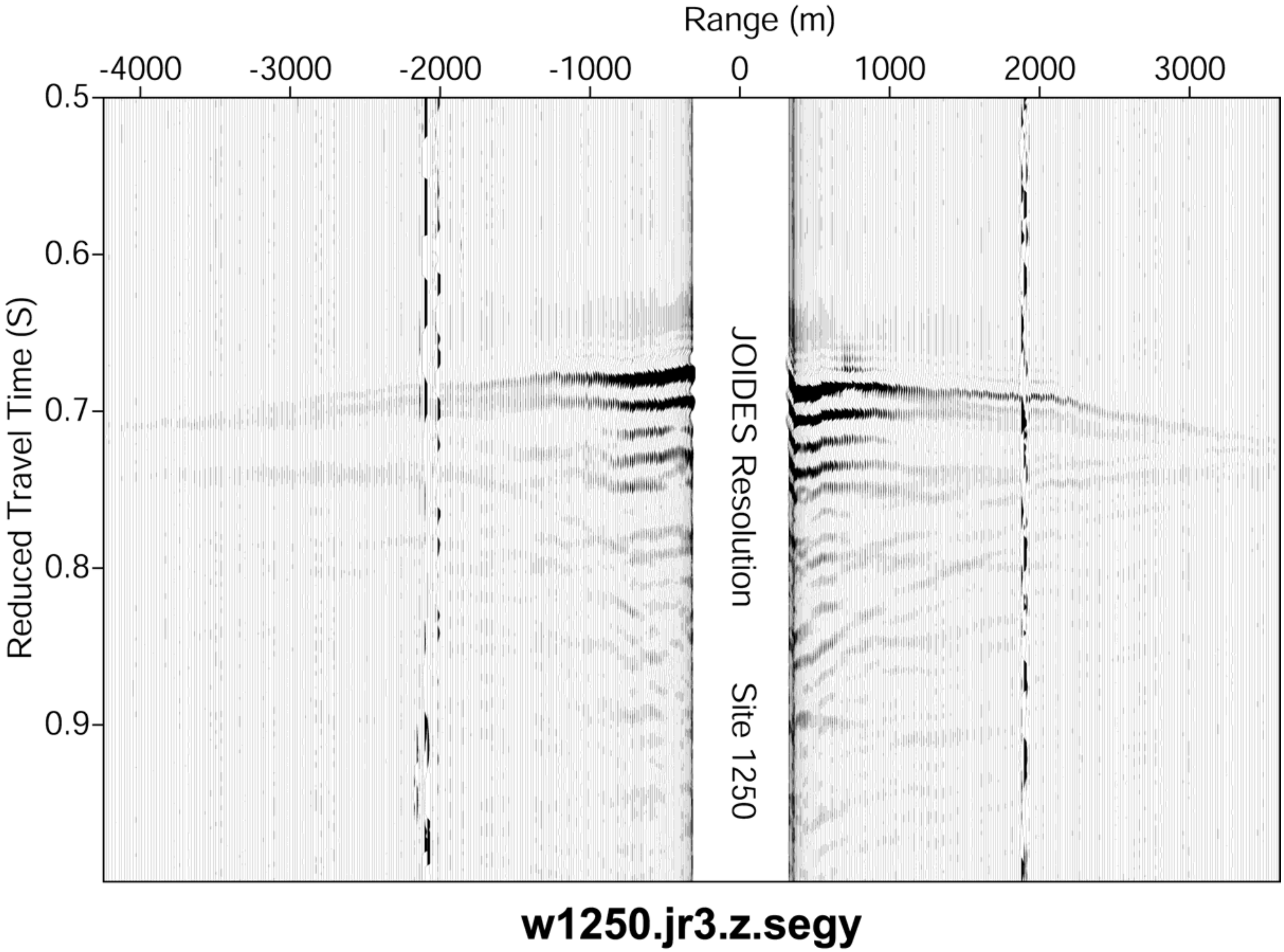
Walkaway VSP – Site 1250



Horizontal (x-component) of Site 1250 Walkaway VSP recorded at 138 mbsf. Data are plotted by range. The data gap in the center is due to excursion of the *Ewing* around the *JOIDES Resolution*.



Horizontal (y-component) of Site 1250 Walkaway VSP recorded at 138 mbsf. Data are plotted by range. The data gap in the center is due to excursion of the *Ewing* around the *JOIDES Resolution*.



Vertical (z-component) of Site 1250 Walkaway VSP recorded at 138 mbsf. Data are plotted by range. The data gap in the center is due to excursion of the *Ewing* around the *JOIDES Resolution*.

VSP Site Summaries

Site 1245

Operation Summary:

JD 230 – 231 / August 18th – 19th

The plan at this site was to conduct a constant offset VSP at 700 m south of the JOIDES Resolution, followed by a set of 3 or 4 walkaway VSPs using the three-station VSI tool. Drilling finished at ~380 mbsf, and breakout and washouts were a problem below ~ 250 mbsf. The operation took place in moderate seas and high winds, ~ 25 kts. The tool was lowered into the hole and test shots fired from both the J.R. and from *Ewing*. After numerous attempts to clamp the tool in position at the bottom of the hole and record clean shots, no good data was recorded. After testing depths all the way up the hole, we eventually gave up on all offset VSPs. The tool was retrieved to find that all three of the extender arms were broken, and one was sheared off. When the tool was initially clamped, there was no slacking off of the wire. The seas and no slack probably contributed to the loss of the arms. The backup tool, WST-3, did not make the helicopter shipments in time for Site 1245, so we made the decision to go on to Site 1251. In the mean time, repair parts for the VSI were shipped to the J.R.

Data Summary:

No offset VSP data were acquired.

Site 1251

Operation summary:

JD 230 – 231 / August 18th – 19th

Our plans at this site were for a constant-offset VSP from 700 mbsf to the base of pipe at ~ 70 mbsf, and four walkaway VSPs. Because of the problems with hole conditions below 250 mbsf, this hole was drilled to 235 mbsf only. At this site weather conditions were good with winds < 15 kts, which eliminated problems with ship's heave. The WST-3 tool was lowered into the hole and we ran tests shots. We had a hard time clamping the tool for the constant offset VSP, and station positioning down the hole was not evenly spaced as planned. Clamping problems were primarily in the shallow sections of the hole. We then moved the WST-3 back down the hole and began the VSP. After searching for a good spot to clamp the tool, we began the walkaway VSP. We shot the VSP from S to N, followed by the W to E line. The closest approach to the J.R. on this line was about 300 m. The decision not to run more walkaway VSPs at this site was made on the J.R. because of time, and expectations that time would be better spent at other sites. We chose an offset of 1,000 m because of the greater water depth here than at the other sites. This was based on modeling. Walkaway VSP 1251WE.1 has a gap in acquisition because the guns were shut down due to sea lions.

Site 1251 Data Summary:

Water depth:	1220 mbrf	
Hole position 1251H:	44 34.2089N	125 4.4514W

Site 1251 Constant Offset VSP

Tool:	WST-3
Depth range:	1406 mbrf to 1313 mbrf
Depth range:	186 mbsf to 93 mbsf
Station interval:	5 m
Shot numbers:	28 – 218
Start/End times:	230:15:26:14 – 230:17:26:12
Ewing position:	44 33.654 N 125 04.440 W; 1000 S of J.R.

Site 1251 Walkaway VSP - NS

Heading:	S to N
Station Depth:	1318 mbrf
Station Depth:	98 mbsf
Offset ranges:	-3.5 km – ~300 m
Shot numbers:	468 – 1058
Start/End times:	230:21:36:49 – 230:23:41:40
Shot interval:	~13 s
Recording length:	6 s

Site 1251 Walkaway VSP - WE

Heading:	W to E
Station Depth:	1318 mbrf
Station Depth:	98 mbsf
Offset ranges:	-3.5 km – ~300 km
Shot numbers:	1 – 345
Start/End times:	231:00:31:09 – 231:01:52:26
Shot interval:	~13 s
Recording length:	

Site 1244

Site 1244 Operation Summary:

JD 233 – 234 / August 21st – 22nd

This site was drilled to ~250 mbsf to avoid problems with the unstable hole conditions deeper in the hole, which plagued other sites. We ran the tool down to the bottom of the hole, and shot the constant offset VSP. This worked with few problems. Following the constant offset VSP we shot a walkaway at 140 mbsf. This went smoothly, helped by very calm weather. Here the decision was made to shoot just one more, which we placed at 115 mbsf. This decision was based on the expectation of better results at other holes.

Site 1244 Data Summary:

Water depth:	906 mbrf	
Hole position 1244E:	44 35.1709 N	125 07.1719 W

Site 1244 Constant Offset VSP

Tool:	WST-3
Depth range:	1155 mbrf to 990 mbrf
Depth range:	249 mbsf to 84 mbsf
Station interval:	5 m
Shot numbers:	29 – 485
Start/End times:	233:11:09:00 – 233:16:27:51
Ewing position	44 34.776 N 125 07.182 W; 700 S of J.R.

Site 1244 Walkaway VSP 1 - NS

Tool:	WST-3
Heading:	S to N
Station Depth:	1020 mbrf
Station Depth:	114 mbsf
Offset ranges:	-3.5 km – ~200 km
Shot numbers:	1 – 479
Start/End times:	234:00:48:18 – 234:2:27:16
Shot interval:	~10s
Recording length:	6 s

Site 1244 Walkaway VSP 2 - NS

Tool:	WST-3
Heading:	S to N
Station Depth:	1045 mbrf
Station Depth:	139 mbsf
Offset ranges:	-3.5 km – ~200 km
Shot numbers:	1 – 564
Start/End times:	233:17:55:23 – 233:19:27:16
Recording length:	6 s
Shot interval:	~10s

Site 1244 Walkaway VSP 1 - WE

Tool:	WST-3
Heading:	W to E
Station Depth:	1020 mbrf
Station Depth:	114 mbsf
Offset ranges:	-3.5 km – ~200 km
Shot numbers:	475 – 1017
Start/End times:	234:03:34:10 – 234:05:00:05
Recording length:	6 s
Shot interval:	~10s

Site 1244 Walkaway VSP 2 - WE

Tool:	WST-3
Heading:	E to W
Station Depth:	1045 mbrf
Station Depth:	139 mbsf
Offset ranges:	-3.5 km – ~200 km
Shot numbers:	201 – 770
Start/End times:	233:20:34:50 – 233:23:28:10
Recording length:	6 s
Shot interval:	~10

Site 1247

Site 1247 Operation Summary:

JD 236 / August 24th

VSPs at Site 1247 were not part of the original plans. This site was added because of changes in the drilling operation. The VSP at Site 1247 was slow to start because of tool problems. The WST-3 tool, which is the only tool that had worked successfully so far on the cruise, did not function. There was an attempt to fix it, but it failed. As a backup we tried the single component WST tool, which after lowering into the hole, did not succeed. The tool worked, but the records were poor. In a final attempt to conduct a VSP, the VSI tool was reconfigured and converted to a single station 3-component tool. The VSI tool worked well up to near the top of the hole where the tool would no longer make a good clamp. The data from the top of the hole were noisy and of questionable quality. When the J.R. retrieved VSI tool it had a broken extender arm. While drilling this site, we planned walkaway VSPs. However, the decision was made to not risk the remaining two VSI tool sections and to move on to Site 1250.

Site 1247 Data Summary:

Water depth:	846 mbrf
Hole position 1247B:	44 34.6589 N 125 09.0766W

1247 Constant Offset VSP

Tool:	Single-Station VSI
Depth range:	1060 mbrf to 930 mbrf
Depth range:	214 mbsf to 84 mbsf
Station interval:	5 m
Shot numbers:	43 – 487
Start/End times:	236:17:27:24 – 236:20:43:29
Ewing position:	44 34.281 N 125 09.076 W; 700 S of J.R.

Site 1250

Site 1250 Operation Summary:

JD 238 – 239 / August 26th – 27th

Site 1250 was the last site for VSPs. This site was drilled to ~185 mbsf. The constant offset VSP started in the bottom of the hole and continued until the tool would not clamp well to the borehole (above 113 mbsf). Fearing that the tool was again broken, it was pulled out of the hole and examined. The tool was fine, and it was run down the hole once again. We began the walkaways with a site at 138 mbsf, which went very well. The seas were exceptionally calm, with winds less than 5 kts. After searching for a shallow clamping spot, the tool was clamped at 91 mbsf and S-N and W-E lines were run. After the second walkaway VSP, we decided there was enough time remaining to run a final walkaway VSP at the bottom of the hole. The tool was lowered to 173 mbsf and we ran the final two walkaway VSP lines. The last walkaway VSP, VSP1250WE.3 (JR-8/9), has a gap in data acquisition because of a computer crash on the *Ewing*. Time ran out for circling and reshooting.

Site 1250 Data Summary:

Water depth:	807 mbrf	
Hole position 1250F:	44 34.1166N	125 09.0025W

Site 1250 Constant Offset VSP

Tool:	Single-Station VSI
Depth range:	980 mbrf to 890 mbrf
Depth range:	173 mbsf to 83 mbsf
Station interval:	5 m
Shot numbers:	15 – 485
Start/End times:	238:14:57:00 – 238:17:35:42
Ewing position:	44 33.755 N 125 09.019 W; 700 S of J

Site 1250 Walkaway VSP 1 - NS

JR Line #: 3
Tool: Single Station VSI
Heading: S to N
Station Depth: 945 mbrf
Station Depth: 138 mbsf
Offset ranges: -3.5 km – ~200 km
JR Shot numbers: 183 – 643
Ewing Shot numbers: 372 – 832
Start/End times: 238:21:42:18 – 238:23:06:59
Recording length: 6 s
Shot interval: ~12

Site 1250 Walkaway VSP 1 - WE

JR Line #: 4
Tool: Single Station VSI
Heading: W to E
Station Depth: 945 mbrf
Station Depth: 138 mbsf
Offset ranges: -3.5 km – ~200 km
JR Shot numbers: 644 – 1101
Ewing Shot numbers: 834 – 1291
Start/End times: 238:23:52:10 – 239:01:14:40
Recording length: 6 s
Shot interval: ~12

Site 1250 Walkaway VSP 2 - NS

JR Line #: 5
Tool: Single Station VSI
Heading: S to N
Station Depth: 898 mbrf
Station Depth: 91 mbsf
Offset ranges: -3.5 km – ~200 km
JR Shot numbers: 3 – 446
Ewing Shot numbers: 1292 – 1736
Start/End times: 239:3:33:26 – 239:04:54:50
Recording length: 6 s
Shot interval: ~12

Site 1250 Walkaway VSP 2 - WE

JR Line #: 6
Tool: Single Station VSI
Heading: W to E
Station Depth: 898 mbrf
Station Depth: 91 mbsf
Offset ranges: -3.5 km – ~200 km
JR Shot numbers: 449 – 860
Ewing Shot numbers: 1738 – 2150
Start/End times: 239:8:30:38 – 239:09:48:01
Recording length: 6 s
Shot interval: ~12s

Site 1250 Walkaway VSP 3 - NS

JR Line #: 7
Tool: Single Station VSI
Heading: S to N
Station Depth: 980 mbrf
Station Depth: 173 mbsf
Offset ranges: -3.5 km – ~200 km
JR Shot numbers: 876 – 1290
Ewing Shot numbers: 2152 – 2574
Start/End times: 239:08:30:38– 239:09:48:01
Recording length: 6 s
Shot interval: ~12s

Site 1250 Walkaway VSP 3 - WE

JR Line #: 8
Tool: Single Station VSI
Heading: W to E
Station Depth: 980 mbrf
Station Depth: 173 mbsf
Offset ranges: -3.5 km – ~200 km
JR Shot numbers: 1303 – 1587
Ewing Shot numbers: 2575 – 2868
Start/End times: 239:10:42:53 – 239:11:36
Recording length: 6 s
Shot interval: ~12s
Comment: Part 1: continued on line 9

Site 1250 Walkaway VSP 3.2 - WE

JR Line #: 9
Tool: Single Station VSI
Heading: W to E
Station Depth: 980 mbrf
Station Depth: 173 mbsf
Offset ranges: -3.5 km – ~200 km
JR Shot numbers: 1 – 113
Ewing Shot numbers: 1 – 2981
Start/End times: 239:11:51 – 239:12:08
Recording length: 6 s
Shot interval: ~12s
Comment: Part 2: continuation of Line 8

Summary of OBS Acquisition

General Strategy

The goal of the OBS deployments was an extension of velocities, in particular V_s, measured in the boreholes to investigate velocity variations across Hydrate Ridge. We were using two types of instruments, UTIG's OBSs and the WHOI's OBS-IP instruments. A relatively dense spacing of the OBSs was considered essential for being able to identify PS-waves from the same horizons conversion horizons in adjacent OBS records. We deployed OBSs along two transects, a twenty-instrument transect connecting Sites 1250 and 1251 and a seven-instrument transect between Sites 1245 and 1244. Zero-offset, constant-offset, and walkaway VSPs at Sites 1244, 1250, and 1251, as well as a zero-offset VSP at Site 1245/1244 will offer borehole calibration for the OBS transects. The 1245 transect also connects two transects acquired in 2000 during Geomar's HYDGAS survey.

We shot lines along the transects (heading of approximately 90°), roughly across strike of Hydrate Ridge, with a maximum offset of 15 km, and lines parallel to the strike of Hydrate Ridge (15°) across each OBS with a maximum offset of 7.5 km. We also shot two short lines parallel to the transects. These lines are potentially very useful for a 3-D component rotation based on experience from the HYDGAS survey (D. Klaeschen, pers. comm., 2002). We did not record streamer data while shooting the 1250/1251 lines. About half of the shot lines were later re-shot with MCS data. During the 1245 deployment, we recorded coincident MCS data while shooting to the OBSs.

Prior to shooting, we ranged to the WHOI OBSs, which allowed us to estimate the OBS drift caused by currents. The shooting profiles were then adjusted accordingly.

We deployed two additional instruments close to Site 1249 to record potential signals generated by the Advanced Piston Corer (APC) while drilling at this site. At the beginning of the cruise (8/13) we deployed and released one of the new WHOI instruments to test their release mechanism in deeper water.

Instrument Specifications

WHOI provided us with fifteen newly developed instruments, which are part of the OBS-IP. The OBSs had not been tested in water deeper than a few meters or in a seismic experiment. In order to alleviate the risk from using untested instruments, and to complement the WHOI instruments with instruments that different characteristics that could be potentially important for detecting hydrates (e.g. higher sampling rates), ten UTIG instruments were also used.

Key Specifications:

OBS instrument specifications

	WHOI	UTIG
No. of components	4	4
Sampling rate	5 ms	3 ms
Anti-aliasing filter		50 Hz (geophones) 80 Hz (hydrophone)
Sampling depth	24 bit	16 bit (14+2 dynamic ranging)
Disk size	20 Gbyte	1.25 Gbyte (3 instruments) 500 Mbyte (other instruments)
Approx. recording length (at above settings)	1 month	6 days (1.25 Gbytes) 2.5 days (500 Mbytes)
Ranging to instrument	yes	no

Transect 1250/1251: 1250

Twenty instruments were deployed at 356 m spacing along the 1250/1251 transect (two instruments were deployed to the West of the western borehole, Site 1250, and to the East of the eastern borehole, Site 1251). This transect was split into two separate deployments because of interfering operations of the J.R. We first deployed ten instruments close to Site 1250 while the J.R. was drilling at Site 1251.

Operations

We deployed ten OBS, five WHOI and five UTIG instruments. We ranged to several OBSs, estimated their positions on the seafloor, and adjusted shot lines to accommodate the estimated drift. Ranging to the instruments was disturbed by acoustic signals from elsewhere. We speculate that these signals were generated on the *R/V Sonne*, which was operating in the proximity. We then shot 13 lines without any major incidents, except for a slight deviation of line 1 because of the *R/V Sonne*. We recovered the instruments after attempting to shoot offset-VSPs at Site 1245. OBS D07 at station 6 did not re-surface although it responded to acoustic commands. We re-deployed an instrument at this location after the OBS deployment at 1250 (station 6a).

Narrative

JD	Hour	
228	05:54	OBS Deployment
	10:38	End OBS Deployment
	12:00	Ranging (stations 2, 4, 6 S/N, 10)
	15:00	End ranging
	19:45	Shooting, lines 1, 3, 5, 7, 9, 8, 21, 2, 4, beginning of 6
229	08:03	Stop shooting OBS 6 at shot 352 to go to J.R. (line re-shot later)
231	03:34	Start shooting, lines 10, 6 (again), 23, 22
	13:39	EOL 22
	14:30	Ranging (stations 6 W/E, 8)
	16:00	End ranging
	18:30	OBS recovery

232	03:39	End OBS recovery, OBS D07, station 6, did not surface
237	10:09	Deployment OBS 6a
	11:00	Ranging across OBS 6a, shift line to W.
	17:36	Start shooting line 6a
	19:47	EOL 6a
		Pulling in guns, deploying OBSs for APC experiment
238	00:00	Start shooting line 21b
	05:58	EOL 21b
	08:00	OBS 6a recovered

Incidents

JD	Hour	
228	21:00	Line 1, deviation from course because of Sonne
229	01:45	Line 5, computer crash close to BOL, line re-started
229	20:18-20:27	Line 21, interrupt shooting, whales
231	10:09	Line 22 aborted 7 mins. into line because of J.R.; re-shot later

Data

All instruments recorded flawlessly on all channels. Some insignificant noise on some of the OBSs may be attributed to the J.R. operating in the vicinity. Shooting had to be interrupted along the transect-parallel line (line OBS 21) because of a sighting of whales.

Transect 1250/1251: 1251

Operations

The operation of the eastern part of the 1250/1251 OBS transect occurred during drilling for Site 1244 and was complicated because we had to maintain flexibility in our schedule to be ready for VSPs at Site 1244. We decided to first deploy five WHOI instruments, which could record much longer than the UTIG instruments, up to one month, and start shooting N/S lines across the OBS transect. We could break off these profiles and complete them after the VSP operation without losing any significant time. After completing the VSPs, we deployed the UTIG instruments and resumed shooting.

The shot lines were adjusted after ranging to the five WHOI instruments. We recorded very consistent and reliable ranges unlike for the previous deployment (the *Sonne* had left the area). After completing the ranging, we had to wait several hours before we could start shooting: The receiver package of the OBSs releases to the ground from a soluble wire, which can take up to seven hours to dissolve after deployment.

After the OBS deployment, we tried to force OBS D07 at station 6 to release by dragging a cable in a circle and tightening the noose. Unfortunately, this attempt was not successful and caused some problems with the winch.

Narrative

JD	Hour	
232	06:30	OBS deployment, WHOI, st. 12, 14, 16, 18, 20
	08:21	End OBS deployment, start ranging
	12:39	Ranging completed
	14:48	Start shooting, lines 12, 14, 16, 18, 20

233	06:34	EOL line 20, recover guns, transit to J.R. for VSP work
234	07:22	OBS deployment, UTIG, st. 11, 13, 15, 17, 19
	13:57	Start shooting, lines 24, 11, 13, 15, 17, 19, 18 again, 26, 25
235	20:01	EOL line 25
	20:32	Start trying to force OBS D07 (st. 6) to release by dragging a cable
236	05:00	Unsuccessful
	06:00	Start recovery of OBSs, st. 20, and 18
	07:27	Recovery of OBS 18
		Break off recovery for VSP at Site 1247
	21:04	Resume recovery, WHOI st. 12, 14, 16 and UTIG instruments
237	06:54	End OBS recovery, all instruments back on board

Incidents

JD	Hour	
233	01:24	Line OBS 18: Problems with shooting software, missing shots; re-shooting line on JD 235
233	04:30-06:00	Syntron shot no. erratic, but Helmsman OK

Data

One instrument did not record on its hydrophone component. All the other instruments recorded flawlessly.

Transect 1245/1244

Operations

The WHOI engineers discovered a potential design flaw with their instruments and considered re-deploying them too risky. It was therefore decided to use seven UTIG instruments. The instruments were deployed at 393-m spacing between Sites 1245 and 1244. The UTIG OBSs are not capable of doing ranging. We did not attempt to guess the instruments' drift to locate the shooting lines. While shooting to the OBSs, we also acquired MCS data. The operation was smooth except for having to interrupt the survey temporarily because the J.R. was too close to the planned OBS shooting lines.

Narrative

239	17:44	OBS deployment, UTIG, st. 31-37
	19:08	End OBS deployment
	20:00	Start deploying streamer
	21:15	Streamer deployed
	22:06	Start shooting OBS/MCS lobs 41, 31, 37, 37-2, 36, 42, 43, 35
240	07:34	EOL lobs 35
		Shooting regional lines HR 2 and 3
241	01:05	Start shooting remaining OBS/MCS lines 33 and 32
	11:13	EOL lobs 32
		Range to and retrieve OBSs for APC experiment first
	17:53	Start OBS recovery st. 31-37
	22:34	All OBSs on board

Incidents

240	02:30	In line lobs 41, needed to speed up from 3 to 3.5 knots for rest of survey

Data

All but one instrument recorded flawlessly. One had a bad hydrophone record.

APC experiment

The rationale here was to record Scholte waves possibly generated by the APC.

Operations

Anne Tréhu provided us with coordinates 25 and 100 m to the west of the planned drillsite 1249H. We deployed OBS 6a and estimated from ranging that it had drifted almost 140 m to the west. Over-correcting the deployment position for drift was considered more harmful than under-correcting because one instrument might land to the east of the borehole. Therefore, we deployed the instruments at the same latitude as and 100 m to the east of the targeted seafloor position on the seafloor. The deployment locations were very close (~150 – 200 m) to the current position of the J.R. We had prepared alternate locations (21b, 22b) to the east of the prospective borehole. We performed ranging to these instruments before recovery, after the J.R. had left the area. Ranging to OBS 21a was very difficult (still, we should have enough points to reliably determine its position), to OBS 22a, ranging went very smoothly.

Data

OBS 21a seems to have recorded flawlessly. We haven't attempted to extract any potential APC signals, yet. Unfortunately, OBS 22a did not record anything except right after its deployment.

Narrative

JD	Hour	
237	21:16	Deployment OBS 21a
	21:32	Deployment OBS 22a
	20:00	Start deploying streamer
	21:15	Streamer deployed
	22:06	Start shooting OBS/MCS lobs 41, 31, 37, 37-2, 36, 42, 43, 35
242	14:04	Start ranging
	16:23	Start recovery
	17:35	Both OBSs on board

MCS seismic over OBS lines

Seismic reflection profiles provide critical structural information for the interpretation of high-resolution OBS data. Coincident MCS data were recorded during the 1245/1244 transect. They also sufficiently cover most of western part of the 1250/1251 transect. We re-shot every other OBS line of the eastern part as well as the "trunk" line along the transect with MCS data. The resulting spacing of ~700 m between the transect-parallel lines should give us ample seismic reflection coverage.

Additional Tables

Planned Co-ordinates (BOL & EOL) and actual shooting timing for OBS lines

Line	BOL			EOL		
	Time	Lat	Lon	Time	Lat	Lon
obs1	19 43 51 (228)	44 30.157	125 10.776	22 20 42 (228)	44 37.980	125 07.834
obs2	00 04 00 (230)	44 30.163	125 10.507	02 47 00 (230)	44 37.986	125 07.564
obs3	22 35 00 (228)	44 37.992	125 07.294	01 33 00 (229)	44 30.168	125 10.237
obs4	03 25 00 (230)	44 37.998	125 07.025	06 05 00 (230)	44 30.174	125 09.968
obs5	02 45 00 (229)	44 30.180	125 09.698	05 27 00 (229)	44 38.003	125 06.756
obs6	06 12 34 (231)	44 30.186	125 09.428	08 53 42 (231)	44 38.009	125 06.486
obs6a	17 11 36 (237)	44 38.009	125 06.575	19 46 50 (237)	44 30.186	125 09.517
obs7	05 50 00 (229)	44 38.015	125 06.217	08 19 26 (229)	44 30.192	125 09.160
obs8	12 01 00 (229)	44 38.021	125 05.947	14 30 00 (229)	44 30.197	125 08.890
obs9	08 34 00 (229)	44 30.203	125 08.620	11 15 00 (229)	44 38.027	125 05.678
obs10	03 34 00 (231)	44 38.032	125 05.408	05 50 08 (231)	44 30.209	125 08.350
obs11	22 51 59 (234)	44 30.194	125 08.082	01 28 00 (235)	44 38.017	125 05.140
obs12	14 48 00 (232)	44 30.199	125 07.813	17 30 25 (232)	44 38.023	125 04.870
obs13	02 34 10 (235)	44 38.029	125 04.601	04 05 08 (235)	44 30.205	125 07.543
obs14	18 04 37 (232)	44 38.034	125 04.331	20 49 00 (232)	44 30.211	125 07.273
obs15	05 45 41 (235)	44 30.217	125 07.004	08 32 48 (235)	44 38.040	125 04.062
obs16	21 26 43 (232)	44 30.223	125 06.735	00 11 00 (233)	44 38.046	125 03.792
obs17	09 02 33 (235)	44 38.052	125 03.522	11 30 00 (235)	44 30.228	125 06.465
obs18	00 45 00 233)	44 38.058	125 03.254	03 15 09 (233)	44 30.234	125 06.196
obs18X	15 36 20 (235)	44 38.058	125 03.254	17 06 00 (235)	44 33.688	125 04.903
obs19	12 15 00 (235)	44 30.240	125 05.926	14 50 00 (235)	44 38.063	125 02.984
obs20	03 52 13 (233)	44 30.246	125 05.657	06 32 58 (233)	44 38.069	125 02.714
obs21	16 12 00 (229)	44 33.825	125 20.669	22 19 34 (229)	44 34.364	124 55.515
obs21b	24 00 00 (237)	44 33.825	125 20.669	05 57 58 (238)	44 34.364	124 55.515
obs22	12 45 00 (231)	44 34.365	125 10.057	13 39 00 (231)	44 34.450	125 06.116
obs23	11 30 00 (231)	44 33.910	125 06.093	12 29 00 (231)	44 33.826	125 10.034
obs24	13 57 31 (234)	44 34.401	124 52.821	19 52 43 (234)	44 33.862	125 17.975
obs25	19 06 22 (235)	44 34.423	125 07.362	20 01 58 (235)	44 34.508	125 03.421
obs26	17 49 19 (235)	44 33.968	125 03.398	18 41 20 (235)	44 33.884	125 07.339
lobs31	08 11 11 (240)	44 31.258	125 10.431	10 41 52 (240)	44 39.081	125 07.488
lobs32	08 57 23 (242)	44 31.258	125 10.133	11 13 00 (242)	44 39.082	125 07.190
lobs33	05 15 39 (242)	44 39.082	125 06.891	07 20 30 (242)	44 31.258	125 09.834
lobs34	01 07 00 (242)	44 31.259	125 09.536	03 12 53 (242)	44 39.082	125 06.593
lobs35	05 25 01 (241)	44 39.082	125 06.295	07 34 02 (241)	44 31.259	125 09.238
lobs36	18 48 57 (240)	44 39.083	125 05.997	20 08 47 (240)	44 31.259	125 08.940
lobs37	11 46 19 (240)	44 39.083	125 05.698	14 01 32 (240)	44 31.260	125 08.642
lobs37-2	15 00 03 (240)	44 31.122	125 07.170	17 37 24 (240)	44 39.221	125 07.170
lobs41	00 06 00 (240)	44 35.181	124 55.797	05 00 05 (240)	44 35.160	125 20.332
lobs42	00 18 00 (241)	44 34.902	125 06.411	00 46 56 (241)	44 34.899	125 09.717
lobs43	01 27 00 (241)	44 35.439	125 09.718	01 13 37 (241)	44 35.442	125 06.412

			Planned deployment		Actual deployment			Pickup coordinates			
Stat.	OBS	Type	Lat.	Lon.	Lat.	Lon.	Depth	Lat.	Lon.	Depth	Comments
1	92-2	UTIG	44 34.112	125 09.288	44 34.085	125 09.293	hydr. off	44 33.999	125 09.405 *	828.8	
2	D08	WHOI	44 34.118	125 09.018	44 34.099	125 09.022	805.4	44 33.946	125 09.204 *	806.1	
3	92-7	UTIG	44 34.123	125 08.748	44 34.118	125 08.764	hydr. off	44 34.027	125 08.750 *	780.4	
4	D02	WHOI	44 34.129	125 08.479	44 34.114	125 08.483	818.4	44 34.011	125 08.560 *	803.1	
5	93-11	UTIG	44 34.135	125 08.210	44 34.148	125 08.233	hydr. off	44 34.086	125 08.378 *	823.9	
6	D07	WHOI	44 34.141	125 07.940	44 34.129	125 07.939	878.4	n/a	n/a	n/a	did not surface
6a	D09	WHOI	44 34.141	125 07.940	44 34.133	125 07.997	866.4	44 34.134	125 08.170	846.6	re-deployment
7	94-8	UTIG	44 34.147	125 07.671	44 34.144	125 07.678	hydr. off	44 34.132	125 07.729 *	864.4	
8	D09	WHOI	44 34.152	125 07.401	44 34.141	125 07.397	892.4	44 34.029	125 07.418 *	899.0	
9	94-10	UTIG	44 34.158	125 07.131	44 34.151	125 07.134	hydr. off	44 34.125	125 07.098 *	917.9	
10	D05	WHOI	44 34.164	125 06.862	44 34.146	125 06.854	hydr. off	44 34.043	125 06.865 *	956.5	
11	94-11	UTIG	44 34.170	125 06.593	44 34.163	125 06.599	982.3	44 34.028	125 06.738	972.4	
12	D01	WHOI	44 34.175	125 06.323	44 34.173	125 06.329	1037.9	44 34.380	125 06.455	1021.0	
13	94-12	UTIG	44 34.181	125 06.054	44 34.180	125 06.061	1088.6	44 34.052	125 06.236	1075.7	
14	D14	WHOI	44 34.187	125 05.784	44 34.183	125 05.775	1113.4	44 34.012	125 06.054	1106.0	
15	94-13	UTIG	44 34.193	125 05.515	44 34.192	125 05.527	1140.3	44 34.084	125 05.655	1142.3	
16	D08	WHOI	44 34.199	125 05.245	44 34.190	125 05.230	1159.1	44 34.610	125 05.428	1161.0	
17	94-15	UTIG	44 34.204	125 04.976	44 34.208	125 04.951	1185.0	44 34.100	125 05.062	1186.0	
18	D06	WHOI	44 34.210	125 04.707	44 34.193	125 04.714	1202.9	44 33.938	125 05.028	1204.9	
19	94-16	UTIG	44 34.216	125 04.437	44 34.211	125 04.443	1223.9	44 34.013	125 04.847	1206.9	
20	D03	WHOI	44 34.222	125 04.167	44 34.204	125 04.160	1230.8	44 33.920	125 04.435 *	1233.7	
21a	D02	WHOI	44 34.222	125 08.837	44 34.221	125 08.845	779.4	44 34.095	125 08.900	782.0	
22a	D13	WHOI	44 34.222	125 08.779	44 34.219	125 08.774	782.4	44 34.061	125 08.842	780.4	
31	92-2	UTIG	44 35.170	125 08.959	44 35.164	125 08.977	873.3	44 34.905	125 09.147	866.4	
32	92-7	UTIG	44 35.170	125 08.661	44 35.168	125 08.676	837.7	44 34.931	125 08.840	831.8	
33	93-11	UTIG	44 35.170	125 08.363	44 35.167	125 08.381	839.7	44 34.885	125 08.588 *	811.0	
34	94-8	UTIG	44 35.170	125 08.065	44 35.167	125 08.076	857.5	44 34.849	125 08.334 *	826.8	
35	95-10	UTIG	44 35.171	125 07.767	44 35.163	125 07.781	884.2	44 34.908	125 07.992 *	864.4	
36	94-11	UTIG	44 35.171	125 07.469	44 35.167	125 07.481	895.1	44 34.922	125 07.702 *	880.2	
37	94-13	UTIG	44 35.171	125 07.170	44 35.173	125 07.178	898.1	44 34.983	125 07.295 *	889.1	

(*) Not explicitly written down as "along-side" coordinates; may be coordinates when instruments were on board

WHOI OBSs: times, field record nos. (FLDR), and trace record nos. (TRACR)

Line	Recording Time		FLDR		TRACR		Comments
	Start	End	Start	End	Start	End	
obs1	228 19:43:52	228 22:20:27	1	601	1	2404	
obs3	228 22:29:37	229 01:08:20	1	601	2405	4808	
obs5	229 02:45:25	229 05:25:17	1	601	5065	7468	1
obs7	229 05:47:47	229 08:19:21	7	601	7469	9848	2
obs9	229 08:34:06	229 11:14:08	1	601	9849	12252	
obs8	229 12:00:57	229 14:27:27	43	601	12253	14488	3
obs21	229 16:10:58	229 22:19:29	6	1333	14489	19800	4
obs2	230 00:10:33	230 02:46:41	13	601	19801	22156	5
obs4	230 03:26:45	230 06:04:54	1	601	22157	24556	
obs10	231 03:33:20	231 05:50:07	1	601	25937	28340	
obs6	231 06:15:00	231 08:53:50	1	601	28341	30744	6
obs23	231 11:33:31	231 12:27:58	1	210	30745	31732	7
obs22	231 12:46:11	231 13:37:36	1	210	31733	32572	7
obs12	232 14:50:23	232 17:30:24	1	601	1	2404	
obs14	232 18:07:16	232 20:48:53	1	601	2405	4808	
obs16	232 21:26:36	233 00:11:14	1	601	4809	7212	
obs18	233 00:45:00	233 03:15:09	1	601	7213	9496	8
obs20	233 03:54:48	233 06:33:56	1	601	9497	11900	9
obs24	234 13:59:44	234 19:52:38	1	1334	11945	17280	
obs11	234 22:51:20	235 01:26:47	19	601	17281	19612	10
obs13	235 02:35:53	235 05:04:08	1	601	19613	22016	11
obs15	235 05:48:01	235 08:32:45	1	601	22017	24420	
obs17	235 09:02:32	235 11:30:40	1	601	24421	26824	
obs19	235 12:12:20	235 14:49:02	1	601	26825	29228	
obs18a	235 15:36:20	235 17:05:46	1	340	29229	30588	12
obs26	235 17:49:05	235 18:41:19	1	235	30589	31424	
obs25	235 19:06:17	235 20:01:57	1	210	31425	32264	13
obs6a	237 17:14:09	237 19:46:50	1	601	1	2404	
obs21b	238 00:04:22	238 05:57:57	1	1334	2405	7740	

Comments:

(1) Circled back to BOL after system crashed after some 37 shots

(2) Missed first 7 shots in manual switchboard

(3) Problem with shooting at BOL (reverse direction)

(4) Had to be re-stored (original log file was corrupted)

(5) No comment in log abt. BOL

(6) Had to break off obs6 initially, 230 06:30:13-230 08:03:56 -> re-shoot

(7) Aborted attempt to shoot obs22 first; missed lead-in for obs23 -> re-try

(8) Missing shots close to BOL, see (12)

(9) Circled back to BOL after having shooting problems at BOL

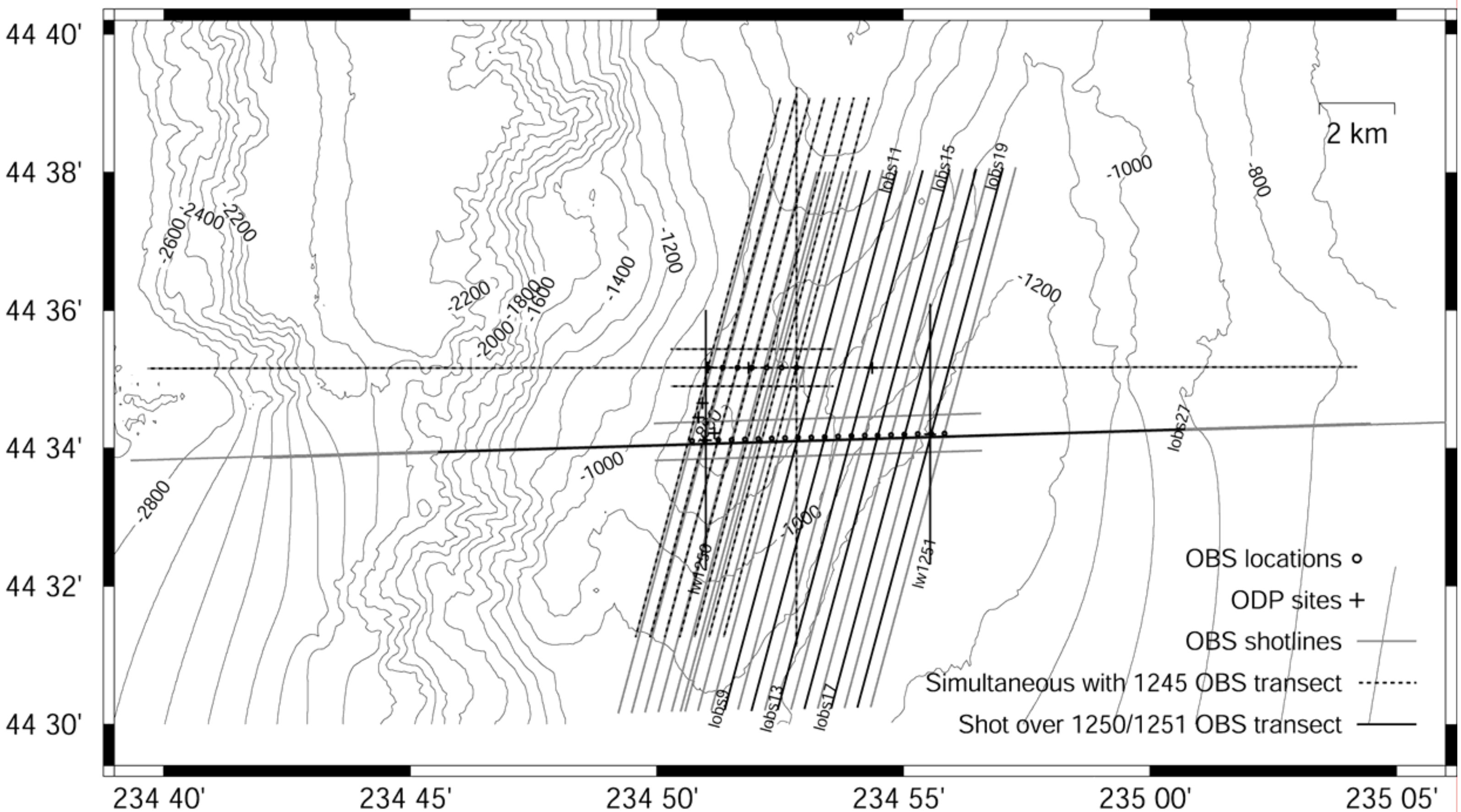
(10) BOL at shot no. 19 correct

(11) Line log says EOL at 04:05 (probably typo)

(12) N half of line, re-shot because of missing shots in first run

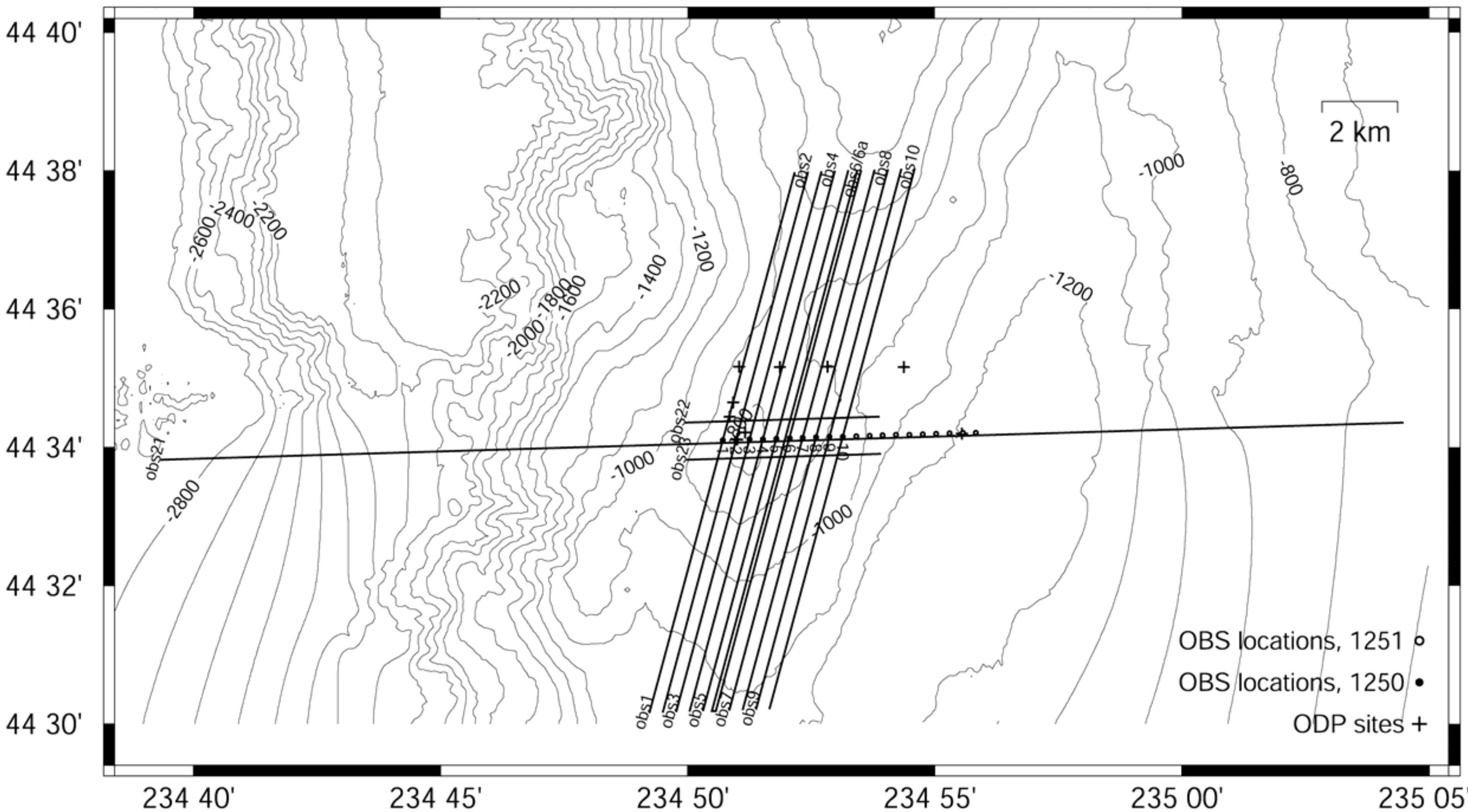
(13) Not clear, why shorter than obs26...

Hydrate Ridge MCS along OBS lines



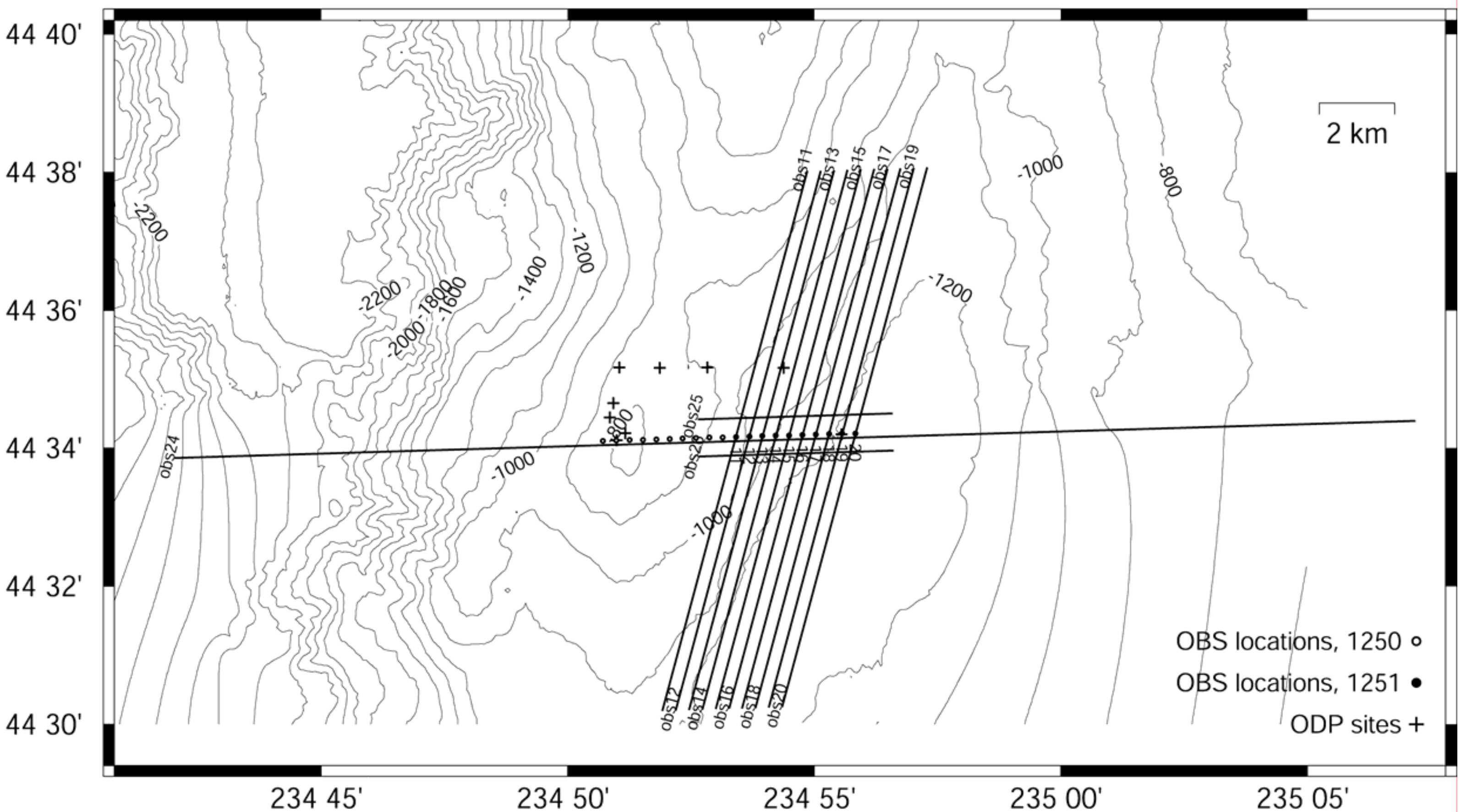
Location map showing all of the OBS lines shot during EW0208. The OBSs are located at ~350 m spacing on the 1250/1251 transect, and 400 m spacing on the 1245 transect. UTIG and WHOI instruments were deployed alternately on the 1250/1251 transect.

Hydrate Ridge OBS deployment 1250



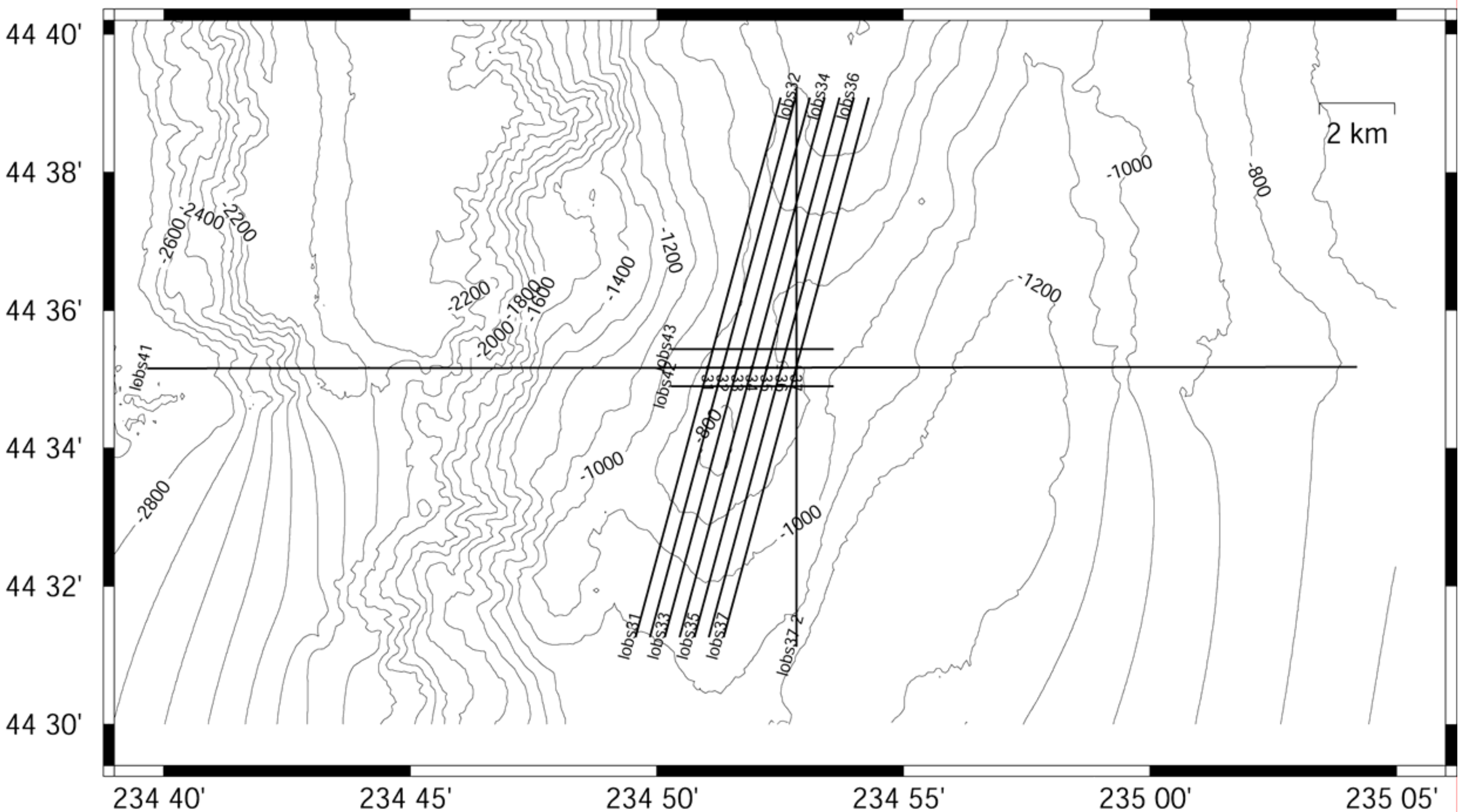
OBS lines shot during the first OBS deployment.

Hydrate Ridge OBS deployment 1251

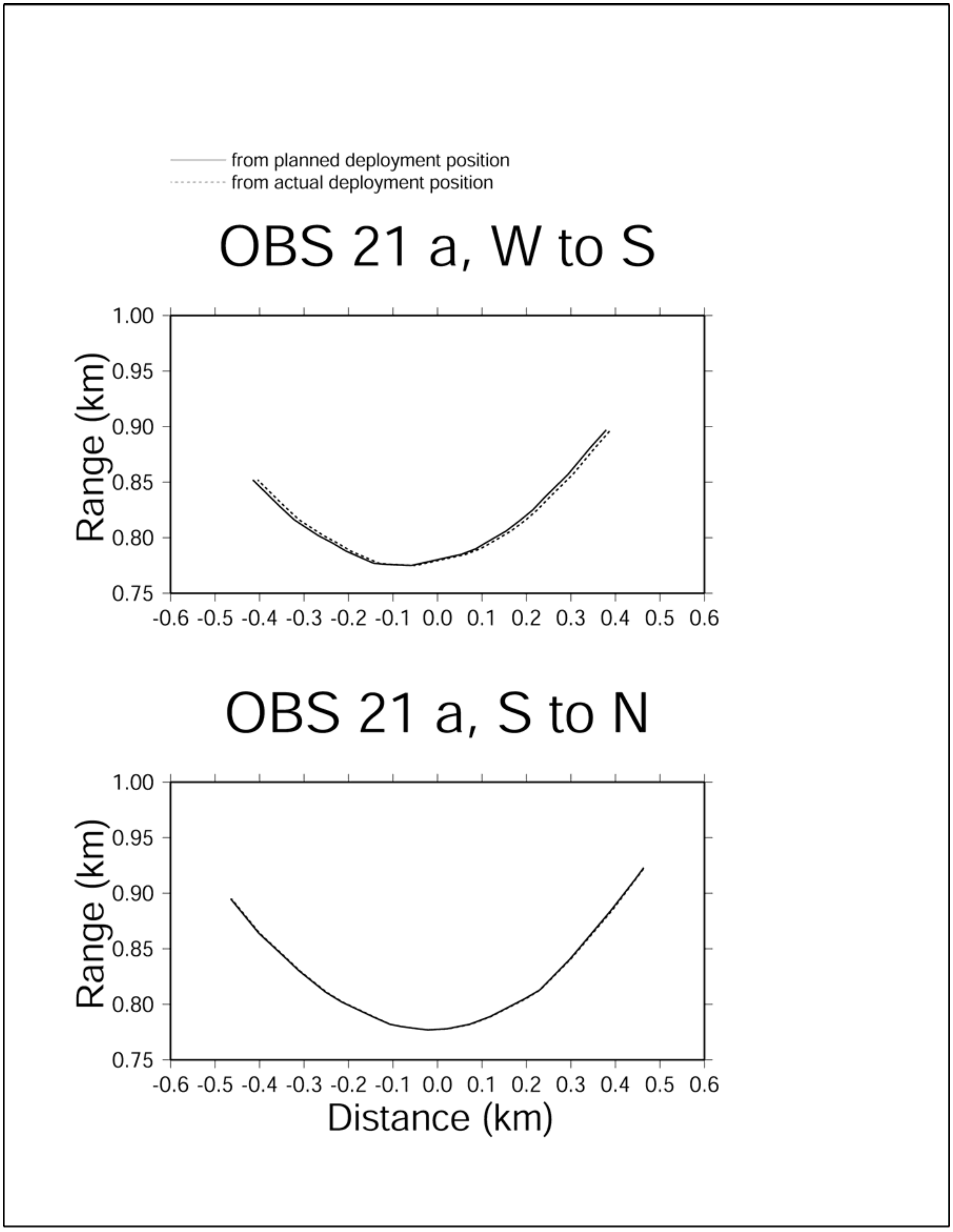


OBS lines shot during the second OBS deployment.

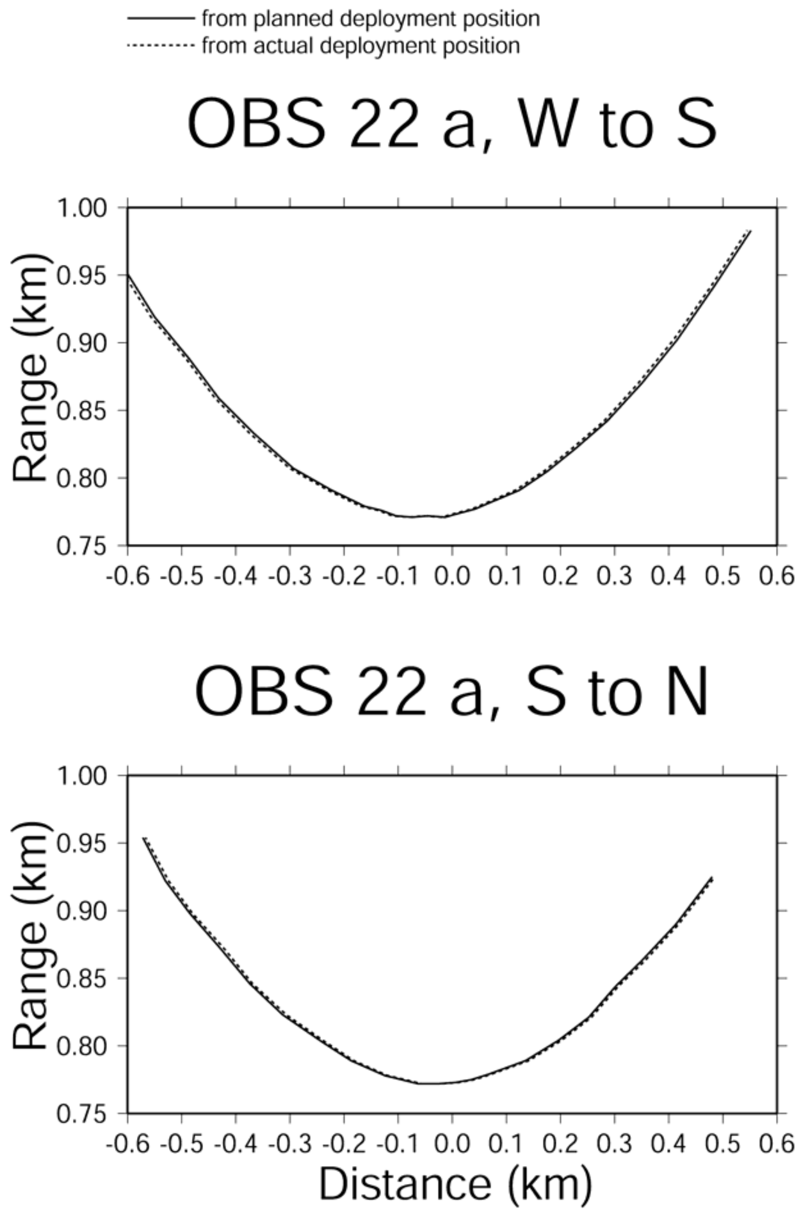
Hydrate Ridge OBS deployment 1245



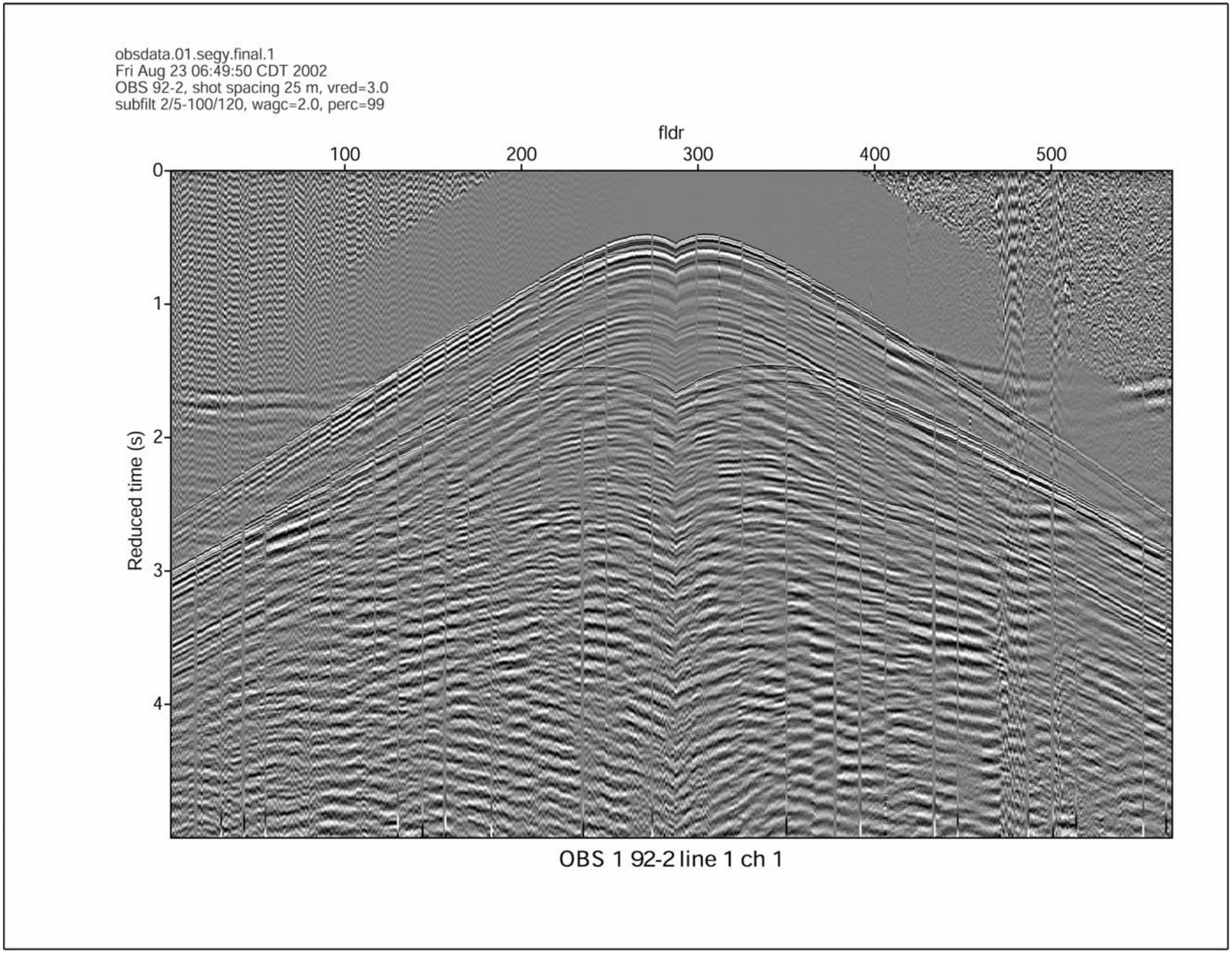
The OBS lines shot during the third OBS deployment.



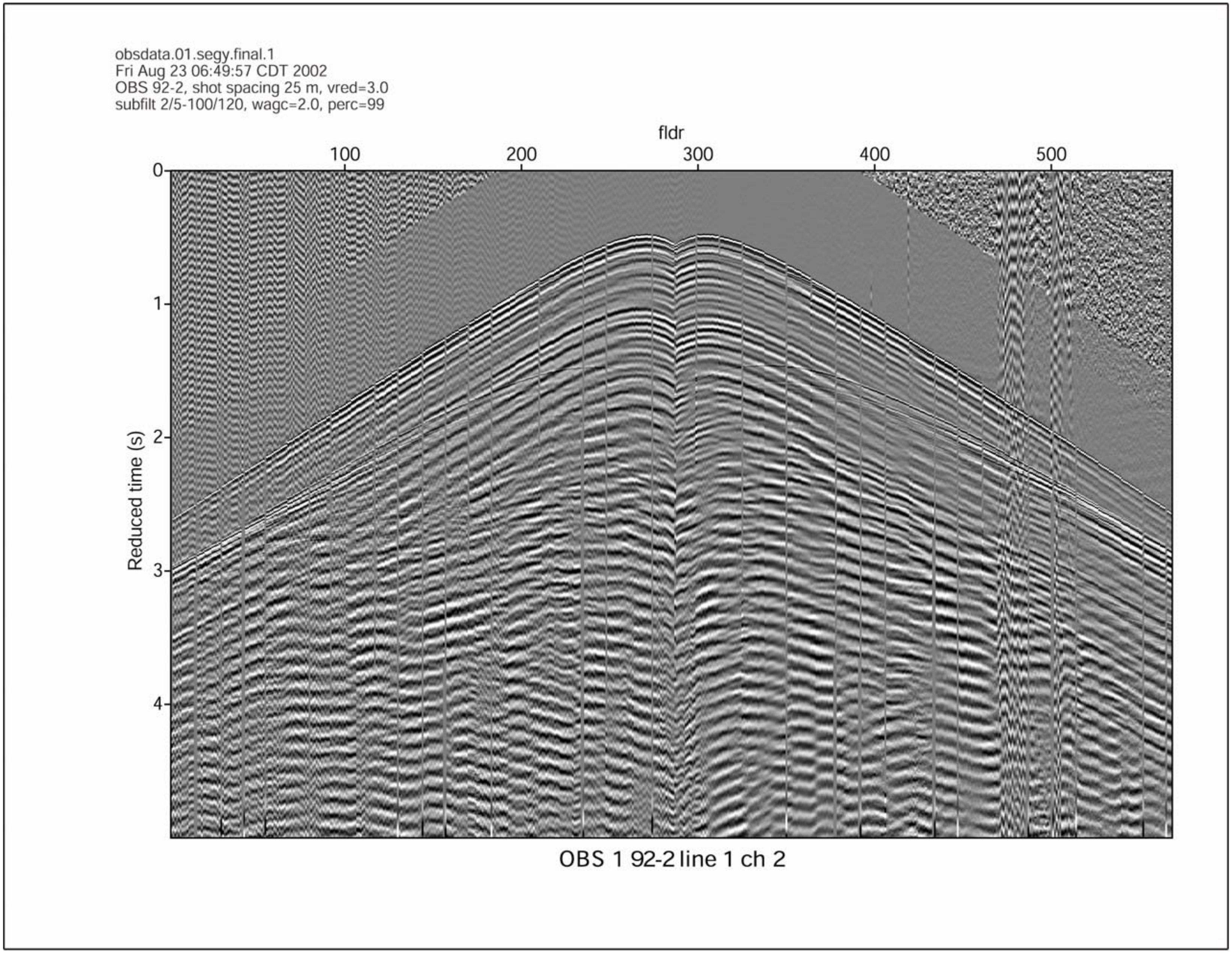
Results from ranging to OBS 21.



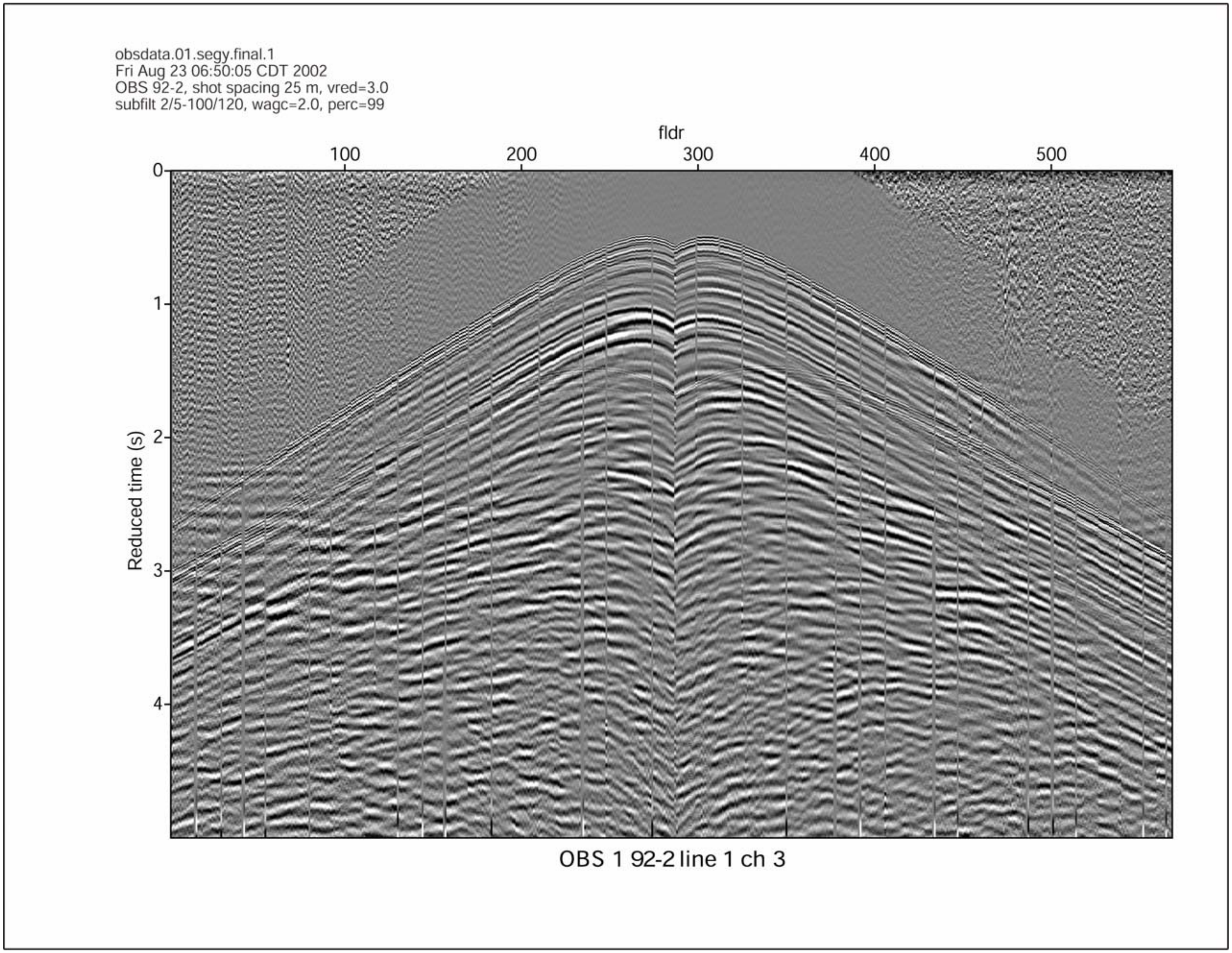
Results from ranging to OBS 22.



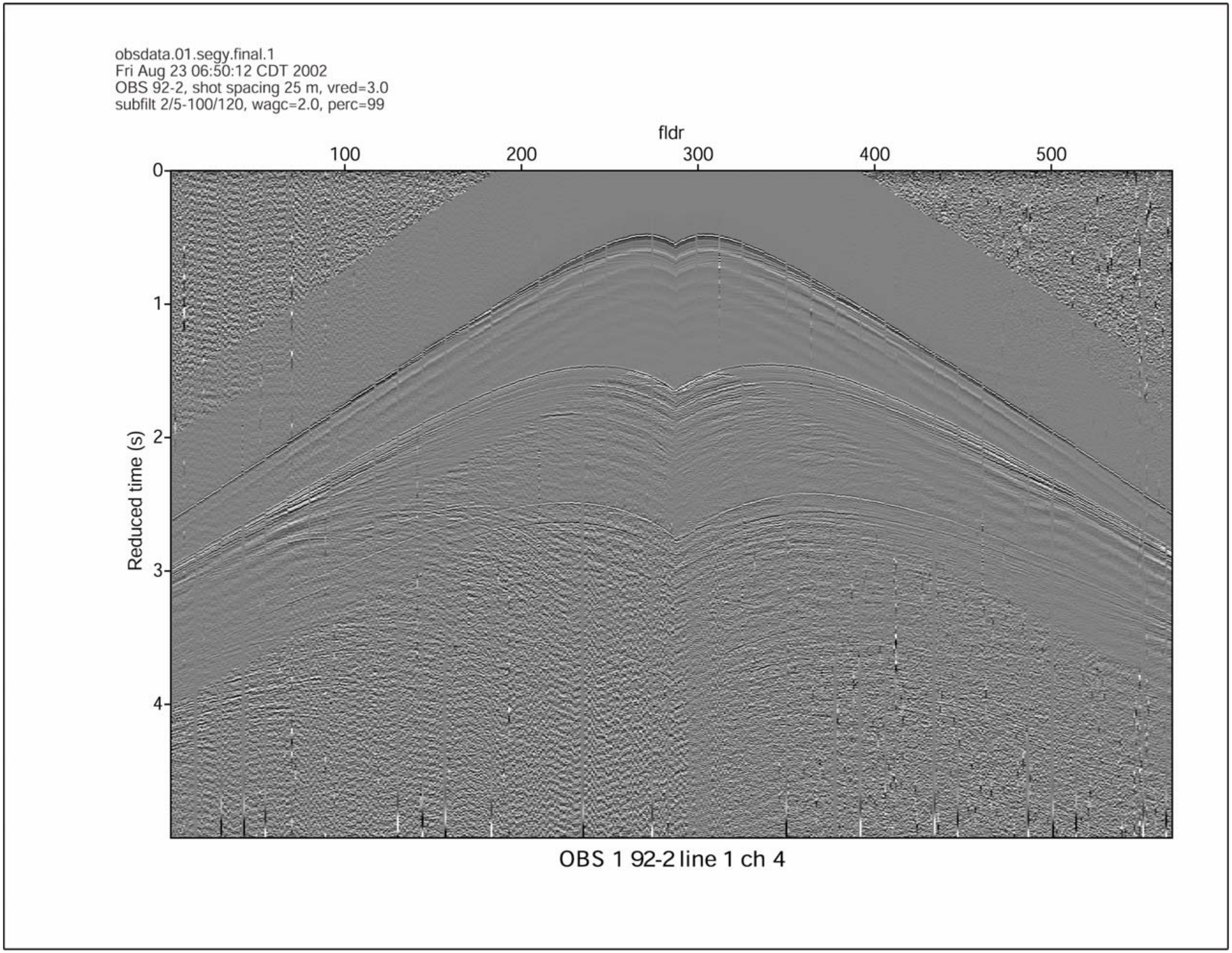
UTIG OBS 1, ch1. See map for location



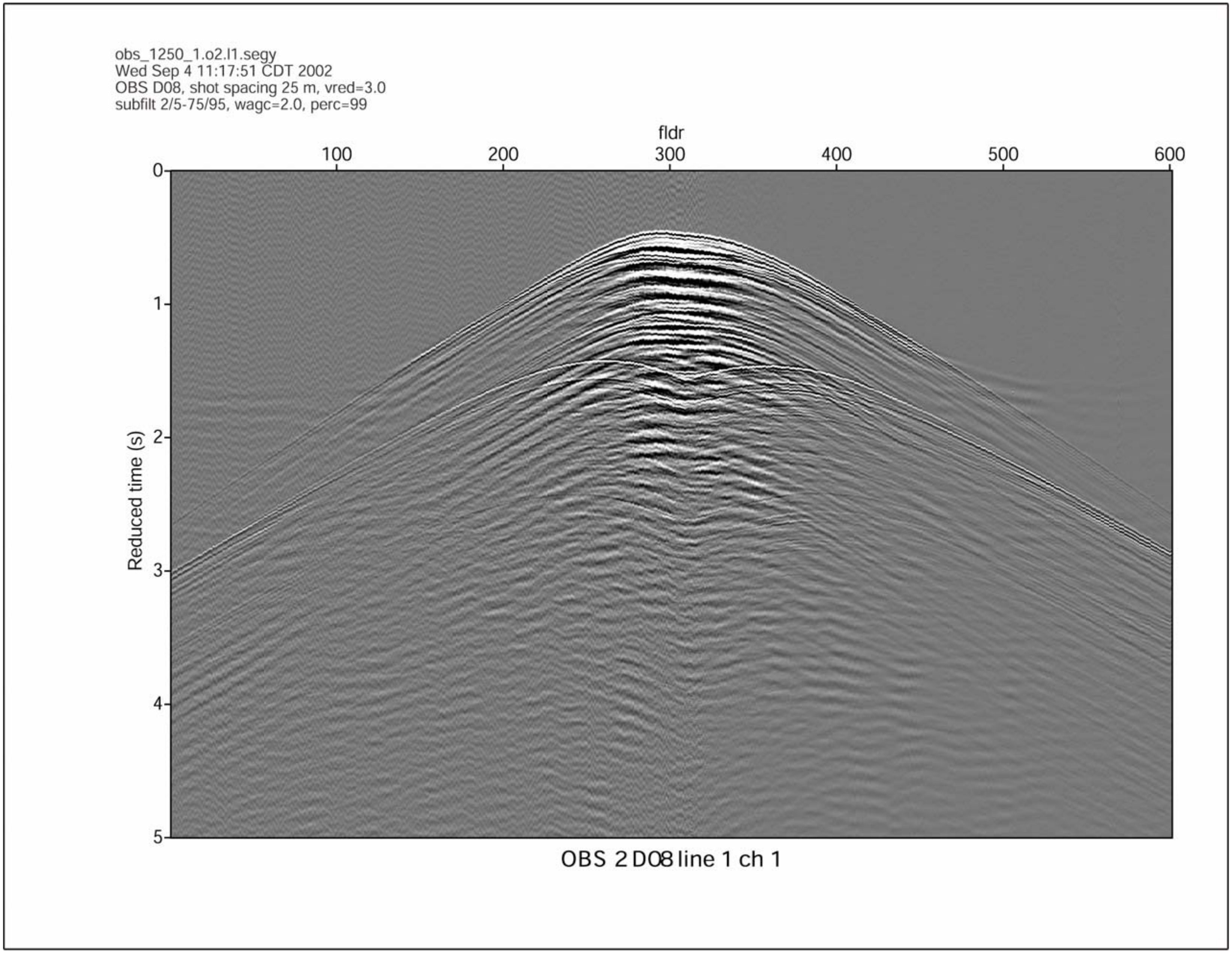
UTIG OBS 1, ch2. See map for location



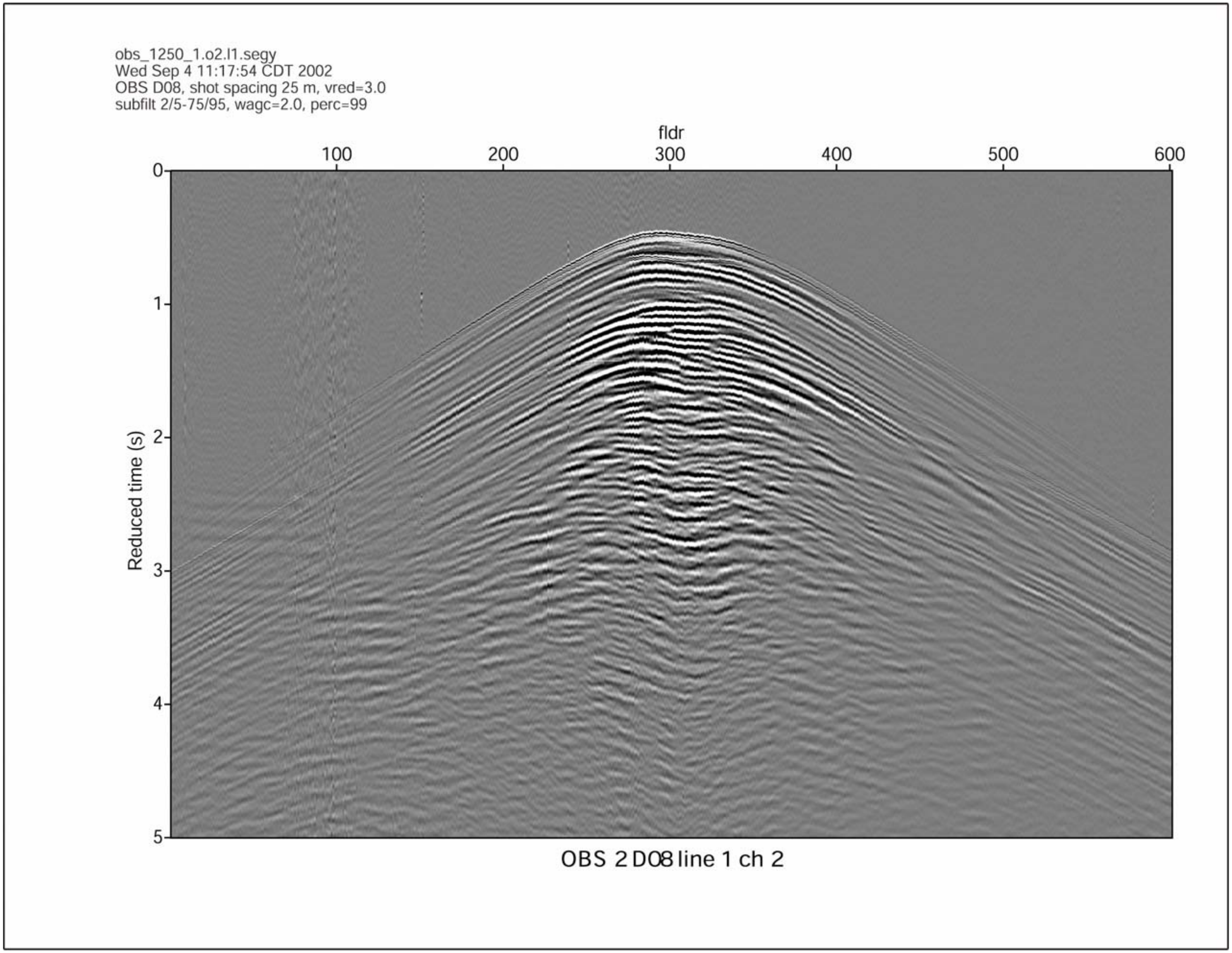
UTIG OBS 1, ch3. See map for location



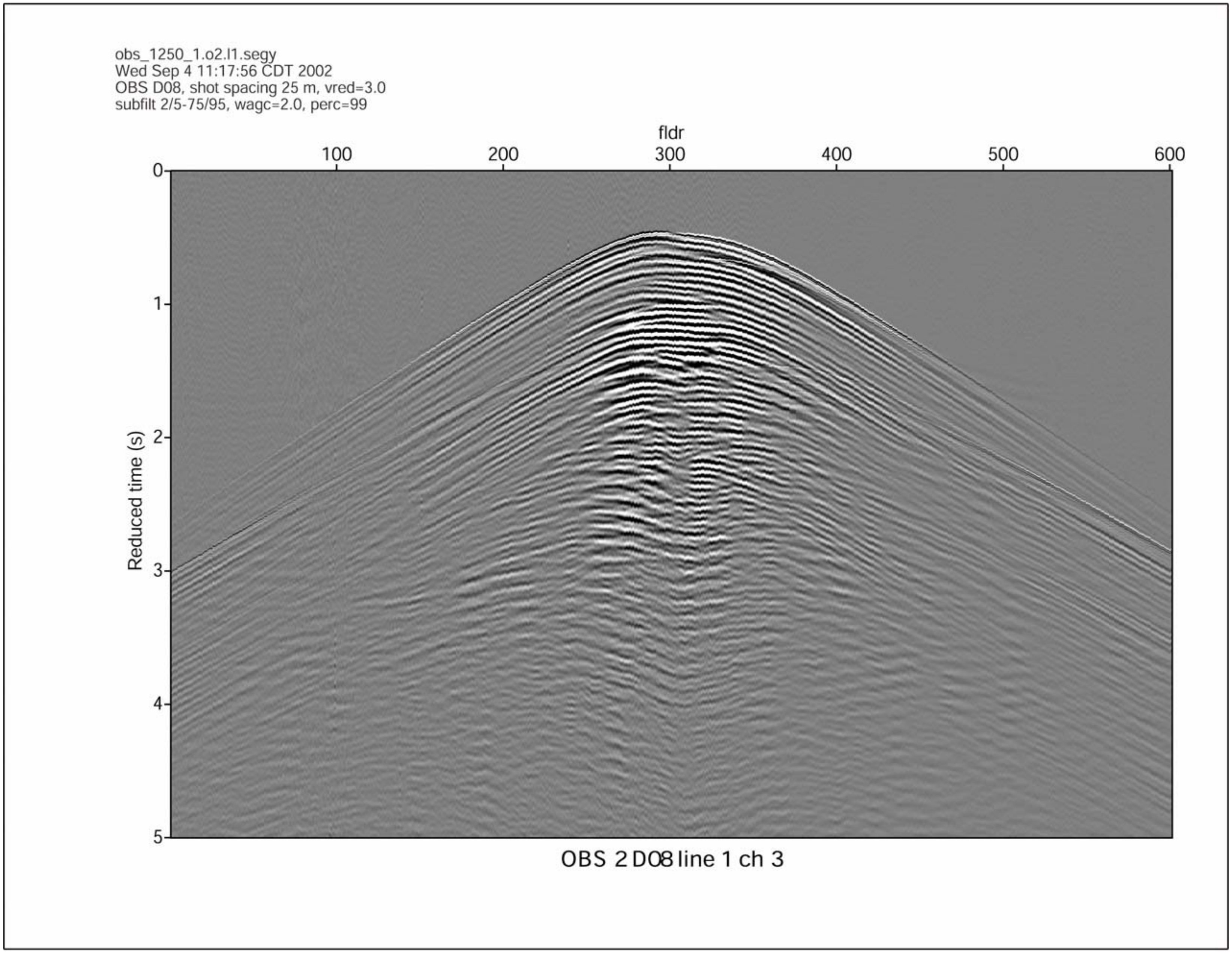
UTIG OBS 1, ch4. See map for location



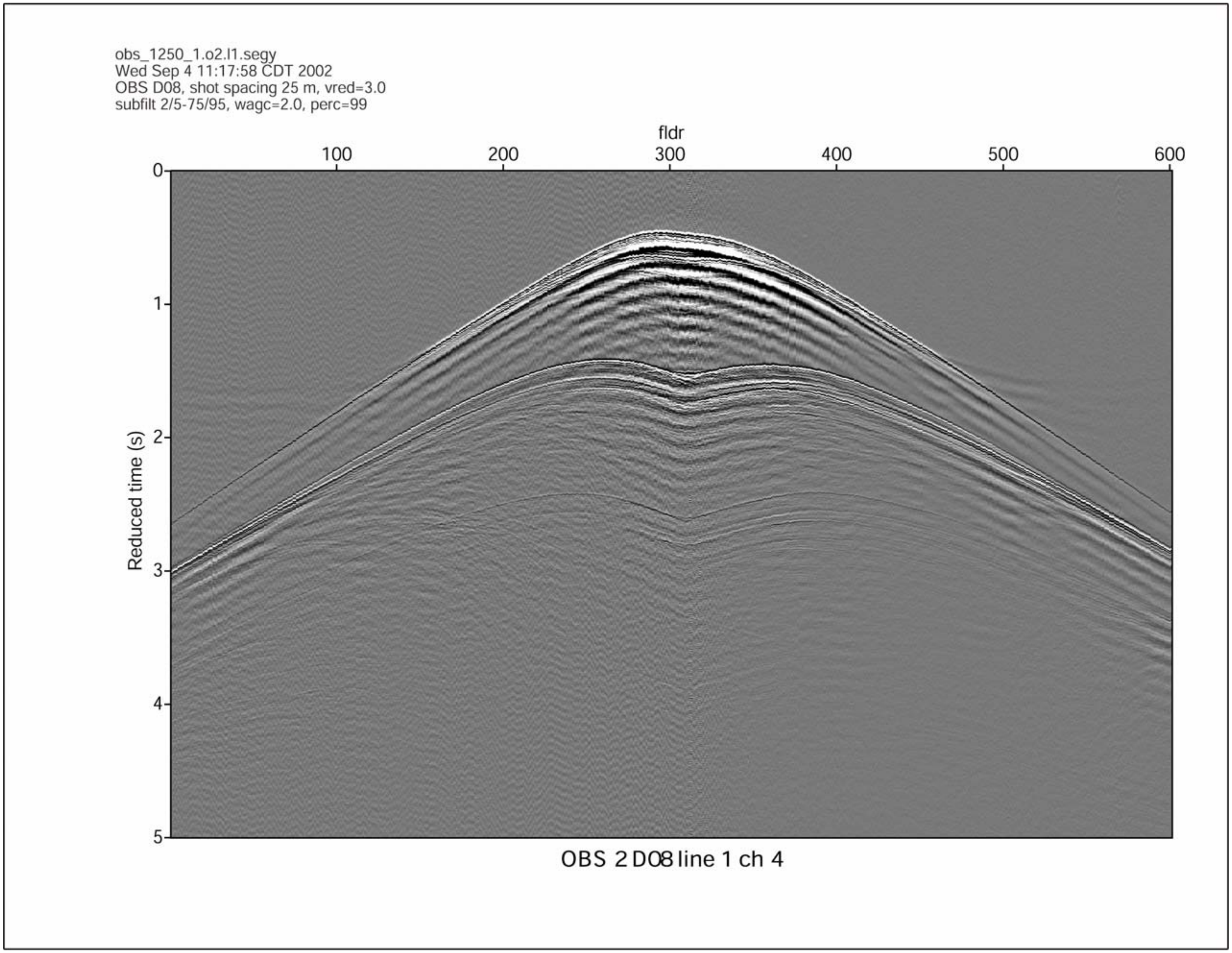
WHOI OBS 2, ch1. See map for location



WHOI OBS 2, ch2. See map for location



WHOI OBS 2, ch3. See map for location



WHOI OBS 2, ch4. See map for location

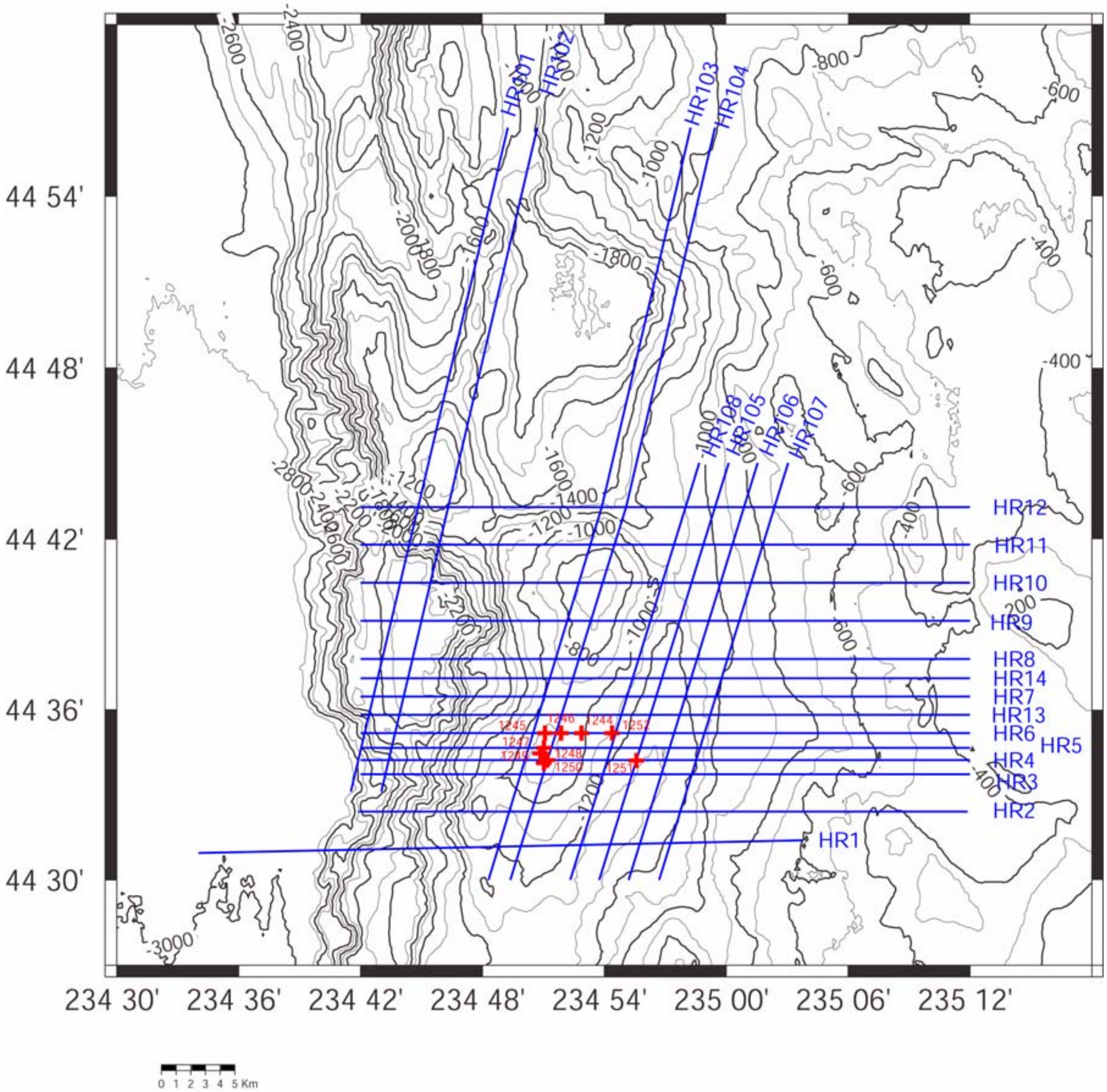
Summary of MCS Acquisition

Survey Objectives

The main goals of the MCS surveying were to examine the hydrate and free-gas system regionally across Hydrate Ridge and in the surrounding slope, and secondly to constrain some of the tectonic and sedimentation processes that have contributed to the structural and stratigraphic development within Hydrate Ridge. Specifically these goals are: 1) acquire high-resolution seismic lines across Hydrate Ridge with sufficiently long offsets to examine the amplitude-with-offset changes of primary seismic reflections. 2) map the regional characteristics of gas hydrates across southern and northern Hydrate Ridge and up the slope beyond the outcropping of gas hydrate at the seafloor. 3) map the regional stratigraphy of the slope cover on top of and surrounding Hydrate Ridge to constrain the uplift of Hydrate Ridge. 4) map the regional fault systems that bound Hydrate Ridge and control Hydrate Ridge tectonics. Line HR101 – HR104 extend from the Alvin Canyon fault system at the southern boundary of Hydrate Ridge, to the Daisy Bank fault system on the northern side of Hydrate Ridge. 5) examine the subsurface structure of gas vent systems inferred from side scan sonar.

The survey was designed to have closely spaced regional lines crossing the Leg 204 drill sites, and running perpendicular and parallel to the main structural trends.

Map of New MCS Lines Acquired During EW0208



Instrumentation and Acquisition Parameters

The MCS data were acquired with *Ewing's* Syntron streamer and Syntrack recording system. All data were written on 3490 tapes in SEGD format.

Streamer

Length:	1500m active section
Group Spacing:	12.5 m
Bird Spacing:	150 m

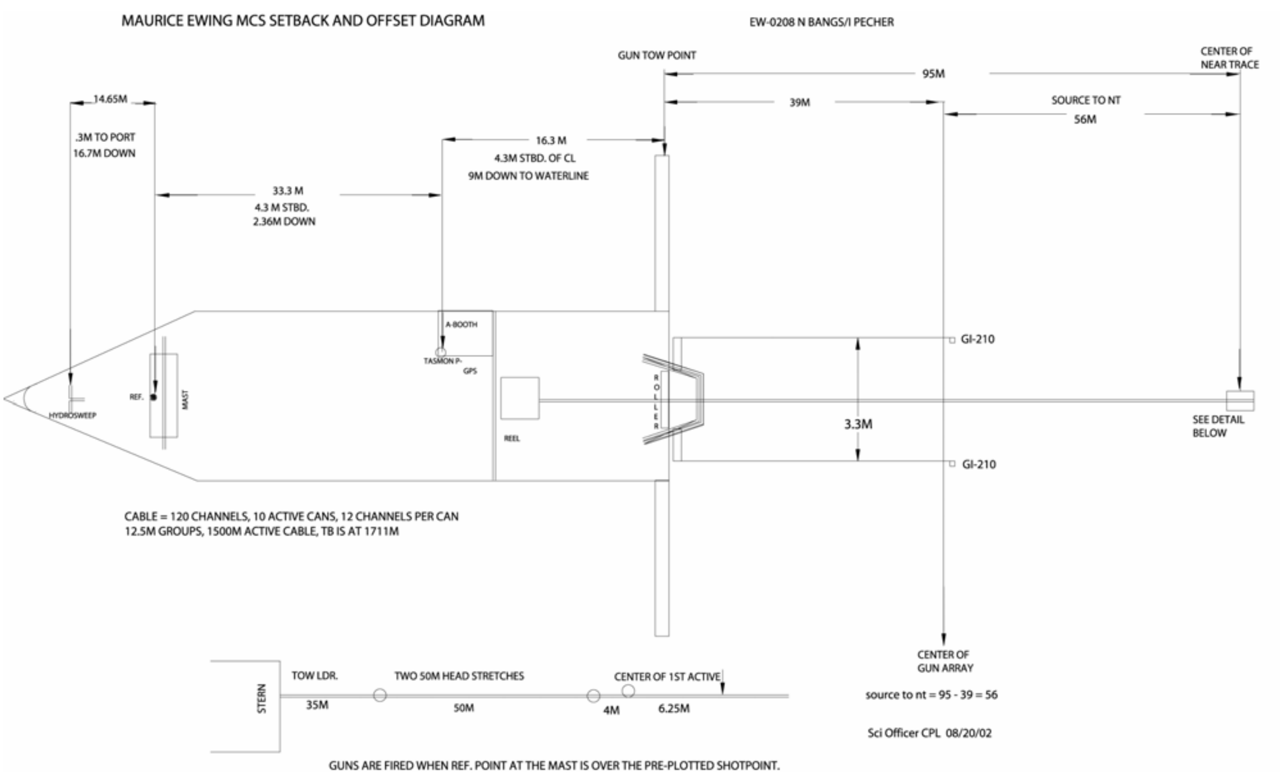
Towing depth: 4 m
Number of Channels: 120
Recording Length: 6 s

Source

Guns: 2- 105/105 GI guns
Towing depth: 2.5 m
Air Pressure: 2000 psi
Shot interval: 20 m, shot on distance

Navigation

Tasmon Differential GPS

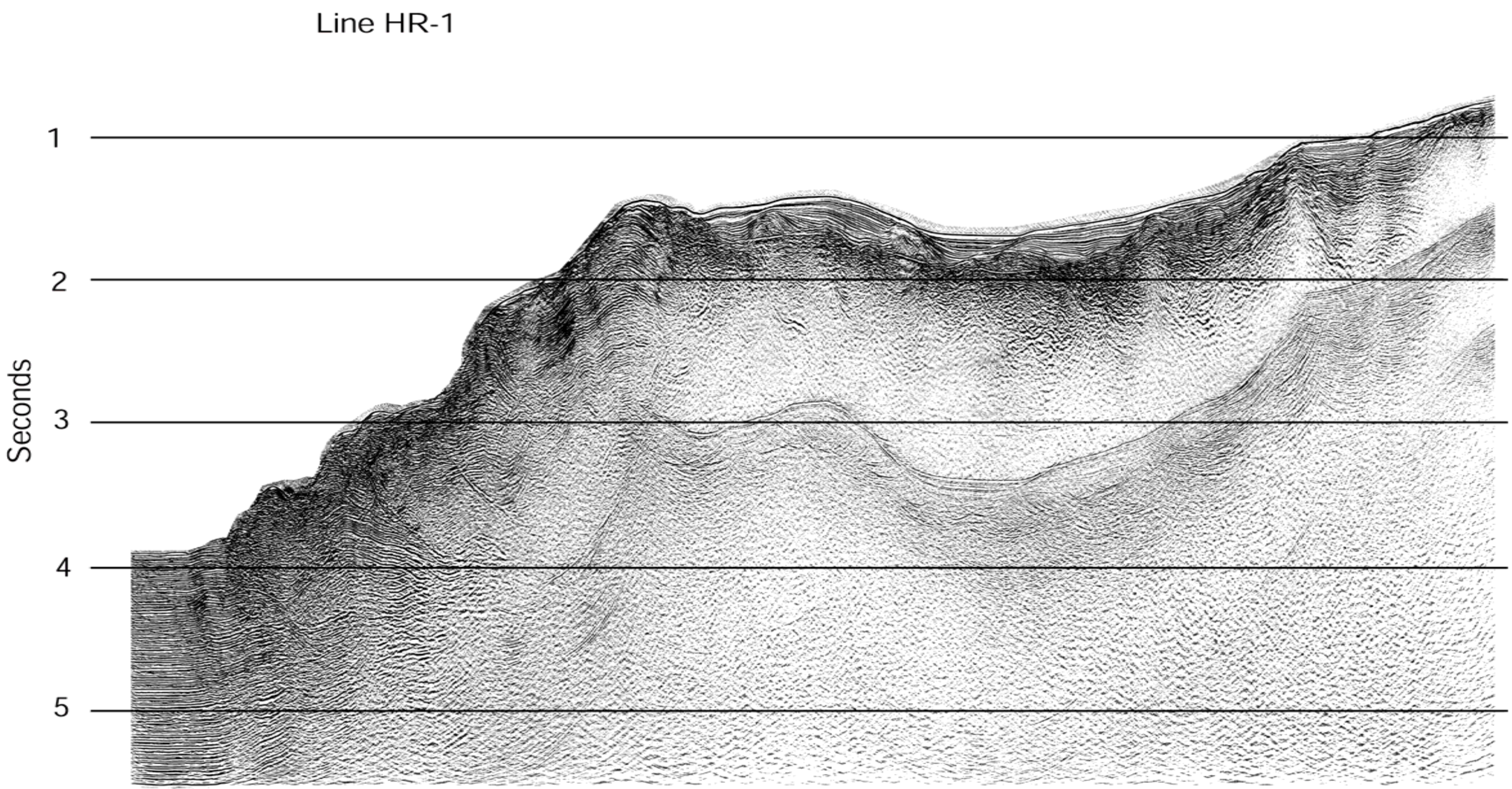


Offset diagram of the layout of the guns and streamer during MCS acquisition for EW0208.

Narrative

We acquired the first MCS line, HR1, on Aug 14th during a slack period while waiting for the J.R. to prepare for the first VSP. This was the only line acquired before the main MCS data acquisition, which began on Aug 29th.

The majority of the data were acquired at the end of the cruise. We deployed the streamer, replacing a bad section, and began shooting on JD 241, Aug. 29^{th} . We shot for approximately 2 days. On JD 243, we retrieved the streamer to pick up the remaining OBSs, OBS 21- 22, and 31-37. After these OBSs were recovered, we redeployed the streamer and replaced one bad streamer can. During the acquisition we shot several sonobuoys to acquire a source signature. We did not use the sonobuoy launcher so that they would record shots as they passed by the guns. During the acquisition that followed the sonobuoys, we began to see noisy traces and suspected the sonobuoys had become tangled with the streamer. On JD 246, we recovered the streamer halfway to check for tangled sonobuoys and found none. We redeployed the streamer and concluded the noise was simply due to swell. The streamer was retrieved for the last time on September 5, at 9:00 PM local time.



Preliminary stacked and migrated seismic line HR-1 as an example of the MCS data. See map for line location.

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Appendix I

Ewing 0208 Hydrate Ridge 2: Final UTIG SEG-Y Files

The final SEG-Y files for the UTIG OBSs, found in /net/zippier/d0/EW0208/obs/finalsegy, have been created through the following processing steps. In the following, unless noted otherwise, all file directories start at /net/zippier/d0/EW2080/obs, which is also linked from /net/zippy/d1/home/staff/yosio/obs, or ~yosio/obs.

1. OBS raw data, originally recorded on 2.5" hard disks, were read into SUN disk files obsdata.* in directory /rawdata using program obsdisk2sun in /progs. For stations 34, 35, 36 and 37, the last several minutes of data that could not be read on the SUN were read on a Macintosh PowerBook using HDT Primer and spliced to the SUN-read files.

2. Clock calibration data were taken from OBS dialog capture files in /captures.

3. Shot files were created by taking the shot times and coordinates from ts.n* files, bathymetry data from hb.n* files and ship's heading from mmet.n* files, all from the processed *Ewing* navigation data in /data/processed/0208 of grampus. Copies of files that were used in OBS data processing are also in /ewingnav. The main program used in creating shot files is navcorrh2.f in /progs. The program first moves the recorded coordinates for each shot to the stern of the ship using the heading of the ship and then moves them in direction parallel to the ship's track to the shot location. The water depth for each shot is computed by interpolating to the time when the Hydrosweep transducer was at or near the shot point. The parameters used for these corrections are: navigation reference to stern of the ship = 16.9 m; direction of the navigation reference from the stern = +14.8° from the ship's heading; source setback from the stern = 39 m; Hydrosweep to shots = 103 m. A supplementary program getwdhdg.f in /progs was used to extract the depth and heading information from hb.n* and mmet.n* files.

4. Using OBSTOOL, the raw data were first converted to raw SEG-Y files in /rawsegy. The main log directory for the OBSTOOL processing is /logs.

5. Each OBS station was located by inverting the arrival times within 500-m distance picked on channel 4, the hydrophone channel, from two lines crossing over the station for latitude, longitude and clock correction. The inversion was first attempted by using the deployment depths except for stations 1 through 9, for which the deployment depths were not available. The result showed a large scatter in computed clock corrections. The depths at the closest approaches during shooting were then substituted for the second inversion, and the result was more consistent. It was noted then that the initial clock correction was highly correlated with the difference between the deployment and closed approach depths, with an approximate slope of 1 ms per 1.5 m. It was therefore apparent that the initial scatter of clock corrections was primarily due to incorrect depths used. There were a few outliers, notably with stations 31, 32, 33 and 35. Each of these stations drifted significantly from its deployment location and the differences among the three values of depths, one for the deployment location and one for each of the two closest approaches, were highly variable, indicating relatively large depth variations at the site and that none of the three measured depths were reliable. The depths of these outliers were therefore adjusted to the trend of the other stations. The relevant files for these picks are in directory /logss.

6. It was noticed that there was a statistically significant difference between the clock corrections of the first five stations and the rest of the stations, amounting to about 6 ms. A

further examination of the bathymetry data between the times of shooting of the seismic lines to these stations and recovery of the instruments revealed a systematic difference. It was obvious that there was a change in the processing of the Hydrosweep center beam bathymetry data between these events. From the difference in the processed depths, the average sound speed used during the shooting was estimated to be about 20 m/s higher than that used during the recovery. A sound-speed profile based on a measurement taken towards the end of the shooting, and thus was not available during the shooting, shows an average sound speed of about 1482 m/s at the depths of these stations. Thus, there was obvious that the depths that were made available to us during the shooting were not corrected for the sound speed profile and a standard 1500 m/s was assumed for these depths. This possibility was later confirmed by the ship's technical staff. The depths during the shooting to stations 1 through 9 were therefore corrected for this difference.

7. Each OBS instrument was oriented by inverting the ratio of the two horizontal channels, channels 2 and 3, picked for a time window of 30 ms following each arrival picked on channel 1, vertical, for all lines within 1 km of the station. The relevant files for these picks are in directory /logsl. The result of the two-step inversion, given in file obsloc.dat in /logs shows the following:

   01 44.56771 -125.15544 827 1482 292.0 -0.006
   03 44.56848 -125.14675 781 1482 287.2 -0.004
   05 44.56877 -125.13747 837 1482 25.0 -0.006
   07 44.56879 -125.12815 865 1482 182.7 -0.004
   09 44.56899 -125.11902 913 1482 112.2 -0.006
   11 44.56813 -125.11025 978 1483 108.2 -0.004
   13 44.56858 -125.10136 1090 1483 284.0 -0.005
   15 44.56873 -125.09241 1144 1484 1.5 -0.005
   17 44.56918 -125.08270 1188 1484 269.0 -0.007
   19 44.56944 -125.07416 1216 1484 339.1 -0.006
   31 44.58523 -125.15123 885 1482 182.6 -0.006
   32 44.58526 -125.14623 852 1482 37.3 -0.004
   33 44.58528 -125.14128 826 1482 120.8 -0.007
   34 44.58531 -125.13640 851 1482 246.0 -0.006
   35 44.58516 -125.13130 868 1482 319.8 -0.006
   36 44.58528 -125.12633 893 1482 237.2 -0.007
   37 44.58539 -125.12122 894 1482 23.6 -0.006

   where each line shows, from left to right, the station code, latitude and longitude in decimal degrees, depth in m, average sound speed in water in m/s, instrument orientation in degrees from north of H1 component, and clock correction in s.

8. The resulting clock corrections show highly consistent values at all stations of -5.6 ± 1.1 ms (S.D.), indicating that the recorded shot times were late by this amount. Therefore, each shot time was corrected for this amount in the final SEG-Y files.

9. The final SEG-Y files were created with the following parameters: number of channels = 4; advanced window opening = 0; window shift = 3 km/s; trace length = 15 s; shot depth = 2.5 m; anti-alias frequency = 50 Hz (actually, anti-alias frequency for channel 4 was 80 Hz, but OBSTOOL does not allow different inputs for different channels); turn-on mute = varied from 0.6 to 4.4 s, measured on trial record sections with no mute; delay time = standard 16-bit; horizontals were rotated to channel 2 = radial, positive away from source, channel 3 = transverse, positive clockwise as seen from the source. Channel 1 polarity is positive

downward and channel 4 polarity is positive for increasing pressure. File obsdata.st.segy.final.ln is for station st from line ln. There are 5x10 + 5x9 + 7x11 = 172 final SEG-Y files in directory /finalsegy.

The following PostScript files show various intermediate plots of the OBSTOOL processing:

/logss/obsloc_llc.*.ps	observed and computed water-wave arrival times
/logss/obsloc.*.ps	deployment, computed and recovery locations of each instrument with shot locations of the crossing lines
/logss/clockf.*.ps	clock drift with computed corrections at close approaches, shot delay removed
/logsl/obsloc_az.*.ps	observed horizontal polarizations and those expected from the computed instrument orientation

Appendix II

EW0208 MCS Line Summary

Line	Tapes	Plot Dir	Bad Chans	SEGY DAT	FOCUS DAT	Comments
HR1	1-8	ltr	14,51,60-72*	1	1	
LOBS41	9-17	rtl	4,14,60-72*	1,2	1,2	
LOBS31	18-22	ltr	4,14,60-72*	2	2	
LOBS37	23-27	rtl	4,14,60-72*	2	2	
LOBS37-2	28-32	ltr	4,14,60-72*	2,3	2,3	*Chan 60-72 mute below 5.4s
LOBS36	33-37	rtl	4,14,60-72*	3	3	
LOBS42	38-39	ltr	4,14,60-72*	3	3	
LOBS43	40-41	rtl	4,14,60-72*	3	3	
LOBS35	42-47	rtl	4,14,60-72*	4	4	no tape 44
HR2	48-56	ltr	4,14,60-72*	4	4	no tape 56
HR3	58-66	rtl	4,14,60-72*	4,5	4,5	
LOBS34	67-71	ltr	4,14,60-72*	5	5	
LOBS33	72-76	rtl	4,14,60-72*	5,6	5,6	
LOBS32	77-81	ltr	4,14,60-72*	6	6	
HR8	82-90	ltr	4,13	6	6	
HR9	91-99	rtl	4,13	7	7	
HR10	100-108	ltr	4,13	7,8	7,8	
HR11	109-117	rtl	4,13	8	8	
HR12	118-126	ltr	4,13	8,9	8,9	
HR107	127-133	rtl	4,13	9	9	
HR105	134-140	ltr	4,13	9,10	9,10	
HR106	141-144	rtl	4,13	10	10	
HR104	148-159	ltr	4,13	10,11	10,11	
HR103	160-171	rtl	4,13	11,12	11,12	
HR3a	172-177	rtl	4,13	12	12	
HR102	178-188	ltr	4,13	12,13	12	Sonobuoy Tape 180
HR101	189-199	rtl	4,13	13,14		
HR4	200-209	ltr	4,13	14		
HR6	210-213	rtl	4,13	14,15		
HR6a	214-220	rtl	4,13	15		
HR7	221-224	ltr	4,13	15		
HR7a	225-232	ltr	4,13	15,16		
HR5	233-242	rtl	4,13	16,17		no tape 243
LOBS27	244-248	ltr	4,13	17		
LW1251	249-250	ltr	4,13	17		
LW1250	251-252	rtl	4,13	17		
LOBS9	253-256	ltr	4,13	17,18		
LOBS15	257-260	rtl	4,13	18		
LOBS11	261-264	ltr	4,13	18		
LOBS17	265-268	rtl	4,13	18		
LOBS13	269-272	ltr	4,13	18,19		
LOBS19	273-276	rtl	4,13	19		
HR108	277-283	ltr	4,13	19		
HR13	284-292	rtl	4,13	19,20		
HR14	293-295	ltr	4,13	20		