CRUISE REPORT
VENTS LEG II
NOAA SHIP DISCOVERER
JUNE 22-JULY 16, 1992

A JOINT CANADIAN/U.S. EXPEDITION WITH A REMOTELY OPERATED VEHICLE TO THE JUAN DE FUCA RIDGE

COMPILED BY MEMBERS OF THE SCIENTIFIC PARTY

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OVERVIEW

The purpose of this cruise was to conduct deep-water operations at hydrothermal vent sites along the Juan de Fuca Ridge with a HYSUB Remotely Operated Vehicle (ROV) operated by the Institute of Ocean Sciences in Sidney, British Columbia. Although designed for water depths of up to 5000 meters, the ROV (now officially named ROPOS for Remotely Operated Platform for Ocean Science) had not previously been used in water depths below a few hundred meters. NOAA (through the NOAA VENTS Program of PMEL) and, IOS, the Department of Energy and Mines Canada and the Natural Sciences Resoures Canada jointly contributed facility and personnel expenses for the expedition. Twenty-four scientists and engineers participated in the project. The main goals of the expedition were: (1) to test the handling capabilities of the ROPOS in the confined and hazardous environment of hydrothermal vents; (2) to perform delicate chemical, biological and geological sampling and well-navigated mapping; and (3) to test the limits of operations on an existing oceanographic vessel not equipped with dynamic postioning capability. Two well-mapped sites were chosen for the initial cruise; the Middle Valley site at the northern end of the Juan de Fuca ridge and the "megaplume" site at the southern end of the ridge. In addition to ROV operations, Sea Beam mapping and deployment of seafloor instruments designed to measure seafloor deformation and detect seafloor volcanic activity were also scheduled.

SCIENCE PROGRAM

General:

Both the Middle Valley and Cleft sites are well mapped with camera tows, Alvin dives and various gophysical measurements. Extensive drilling by ODP had been done in 1991 at the Middle Valley site. For each site, a number of scientific objectives were defined before the cruise. For Middle Valley, the primary objectives were to: (1) obtain additional water samples from the high-temperature vents of the Dead Dog and Bent Hill vents; (2) obtain biological specimens, in particular a range of clams and sulfide worms; (3) take selected geological specimens from new sites; (4) obtain temperatures and push cores at clam beds to determine chemistry of pore fluids; (5) map in detail several new areas, including northern portion of Dead Dog vent field and Bent Hill area. For the Cleft site, the primary objectives were to: (1) continue time series of vent-fluid sampling; (2) obtain additional biological samples from high temperature chimneys; (3) map in detail and sample large extinct chimney fields north of monolith; and (4) examine southern lava mounds for active or recently active vents.

Results of Chemical Sampling:

The goal of the chemical sampling portion of this cruise was to demonstrate that the HYSUB 5000 ROV (ROPOS) is capable of the precise positioning and manipulator control necessary to take a fluid sample from a hydrothermal vent. Vent fluid sampling (using titanium syringes called major samplers) is one of the most exacting and difficult tasks associated with mid-ocean ridge hydrothermal research. Fluid sampling requires positioning an inlet tube directly in a small (< 5 cm diameter) orifice and maintaining position for more than five minutes while the samplers are flushed, filled, and allowed to equilibrate. Because the submersible must maintain a stable position and avoid direct contact with hot corrosive fluids, it is essential that the surface ship hold station to within a radius of < 100 m to avoid dragging the ROV away from the vent.

For vent fluid sampling, ROPOS was outfitted with a pair of titanium major samplers (triggered simultaneously) and a temperature probe, with the tip of the temperature probe located near the ends of the sampler inlet tubes. On two occasions, dive 199 at Dead Dog vent at the Middle Valley site and dive 202 at Monolith vent at North Cleft, we were able to successfully sample vent fluids with ROPOS. The pilots were able to maintain position by driving the ROV laterally and downward against the vent structure and monitor the position of the sampler inlet tips on two video camera monitors. The temperature probe readout was also monitored at the surface and used to optimize position of the samplers.

Shipboard analyses of the fluids for pH, alkalinity, hydrogen sulfide, ammonia, chloride; and silica were carried out and confirmed that vent fluid was successfully recovered. In addition to demonstrating the ability of ROPOS to sample hydrothermal vent fluids, we achieved the scientific goal of making the first measurement of ammonia and taking sub-samples for the first gas analysis on the fluids from Middle Valley. Based on the silica content of the fluids, the sample taken at Middle Valley contained 1.6% hydrothermal fluid, while the sample taken at Monolith vent contained 7.5% hydrothermal fluid. The relatively low percentage of hydrothermal fluid in the samples indicates that extensive entrainment of seawater took place during sampling, which is not unusual. Vent fluid sampling is a skill which takes considerable practice to perfect, and these were the first samples ever taken by an ROV. We had an excellent group of pilots, who are to be commended for their efforts. It is clear that ROPOS has what it takes to be a good fluid sampling tool, and experience will improve the quality of samples over time. ROPOS dove with the major samplers on three other dives, but was unable to complete vent fluid sampling before the dives were terminated due to mechanical problems. On those occasions, we triggered the samplers in near-bottom seawater.

In addition to the titanium major samples, we took a small push core (~7 cm diameter) in a clam bed at Middle Valley and analyzed the pore fluids for pH, ammonia, hydrogen sulfide and silica. The temperature probe, which proved to be extremely robust, was used to measure the temperature in the sediment, and indicated 15°C at a depth of approximately 20 cm. The pore fluids were enriched in silica, hydrogen sulfide and ammonia, and showed a clear increase with depth in the core.

The sampling configuration we used to prove that the ROV could take fluid samples permitted only one sample in the course of a dive, and the sampler could not be put down because the temperature probe was fixed onto the inlet tubes and wired to the ROV. We envision two possible solutions to this problem. The first and most economical solution would be to develop an elevator that could safely transport several major samplers and other tools to the working area on the seafloor, where the ROV could pick them up, use them, and bring them back to the elevator, where they could be secured and sent to the surface. Provided the elevator could be placed within 100 m of the sampling site, this would not significantly slow down operations. The elevator is very much needed for collection of biological and geological samples as well. Development of a working elevator is a high priority for ROV operations in the near future.

The second and more difficult solution would be to design a compact, light-weight manifold sampler capable of holding up to four major samplers and two gas-tight samplers. This is quite a challenge, since ROPOS has a very limited payload (~25 lbs water weight), and very little protected space to house instruments. Since each major sampler weighs nearly 10 pounds in water, pursuit of this option would require either increasing the payload of ROPOS by adding more syntactic foam, or designing a new, smaller, lighter sampler with the same non-contaminating features as the titanium major samplers. This option requires more study, but may be a possibility for the long term.

During this expedition, we used 4 titanium samplers belonging to the University of Victoria and the Geological Survey of Canada. We also rented 4 samplers from the ALVIN group as backup. PMEL should consider buying or making 4 titanium major samplers for use with the manifold sampler and for ROV work. This would allow us to make minor modifications which would improve the performance of the bottles on the manifold sampler, and we would avoid the inevitable problem of needing to borrow samplers for use on the ROV at the same time as ALVIN operations are taking place. ROPOS is potentially an ideal platform for the PMEL Scanner, which could be configured to perform low-level measurements in the buoyant or non-buoyant plume, or to measure higher levels of hydrothermal constituents in diffuse vents. In addition to its ability to compliment water column CTD studies with chemical data to evaluate the strength of hydrothermal plumes, the scanner would be useful as a reconnaissance tool to locate and partially characterize hydrothermal sources prior to taking discrete, high-temperature vent fluid samples.

Results of Biological and Geological Sampling:

The success of the biological and geological sampling program is manifested in Tables I and II. Twenty-three biological and geological samples were taken in eight dives from ten different vent fields. Several "tools" were used in obtaining samples. The ROPOS has operable five and seven function arms, both of which performed well. A "Pacman" attachment can be used on either arm for clenching and holding biological samples and friable geologcal samples; it performed very well. Successful tube coring was also performed, and in the future it should be possible to take several tube cores on one dive. The seven-function arm was superior for delicate manipulations. A multi-function suction sampler can also be attached to ROPOS, although it was not used during the 1992 cruise. All in all, sampling was performed with almost the same ease as with a submersible, although the potential size and weight of samples is reduced. The ability of the scientific party to interact with the pilots in sample selection and to more clearly document the microenvironment from which the sample compensates for this, however.

As with the chemical sampling, an elevator mooring is a clear advantage for future biological and geological sampling with the ROV and should be developed further.

Imaging:

The primary imaging tools on ROPOS are: (1) a SIT camera, (2) an Osprey color CCD video camera, (3) a Photo-sea 250-frame 35mm still camera, (3) and a Mesotech scanning sonar (see appendix IV for description. The video and sonar were continuously recorded on super-VHS and (for the color camera) 8mm format VCRs. All of these systems performed well; the video systems gave excellent, noise-free images superior to many submersible systems that the scientific party had experience with. For the future, the addition of a ultra-low light level

CCD still camera (in particular the one developed at the University of Washington and co-funded by NOAA/PMEL) and a state-of-art CCD color video camera would greatly enhance the ROPOS's imaging capabilities. Also, an analog to digital recording capability for the sonar would greatly enhance the scientific usefulness of the Mesotech system (see Appendix IV for further discussion of sonar).

Data Logging:

A clear need for a scientific data logger exists. At present, the data stream originates from Eproms built into the existing telemetry system. After reviewing the science experience on the 1992 expedition, it was concluded that a separate science telemetry system is probably the best alternative. A relatively inexpensive system is available and should be purchased if possible. The alternative is to have separate RS232 links for various sensors (such as was the case for the temperature probe and ODP data logger in 1992), but this will severely limit the number of science sensors on any given dive.

DIVE SUMMARIES

HYS-192 Dead Dog Mound area - JD180-181(6/27-6/28); 2136 in water; 0058-0504 on bottom; 0725 on surface

Objectives: (1) Locate the well-positioned platform and "cork" at ODP Hole 139-858-G, (2) Reconnoiter the Dead Dog and Chowder Hill areas

Achievements:

ROPOS proved to be an excellent mapping vehicle during this dive. The scanning sonar, SIT and color video images are vastly superior to ALVIN, with 10-m views commonplace. Without the power restrictions common to manned submersibles, the scanning sonar could be operated continuously, and is an important navigational and mapping tool.

This dive was restricted to the southern part of the acoustic anomaly known as the Dead Dog Vent Field (ODP Initial Reports, Leg 139, in press). Hole 858G was located after about 0.75 hours of traversing. These traverses covered the flat muddy surface that typifies the non-vent areas of Middle Valley. The muddy areas have many burrows. These burrows are absent from the actively venting areas. Hole 858G is an excellent sonar target, as it stands about 2 m off the seafloor, with two sonar reflector "ears" and has a conical base and 3-m-wide platform. The drill stem was quite rusted, revealing the need for cleaning prior to attaching the data logger (dive HYS200).

Dead Dog chimney sits on a mound about 20 m in diameter, which itself is on a less prominently elevated area, about 50 m in diameter. The anhydrite chimney that sits on top of Dead Dog Hill is a single prominent spire, about 7 m high, on top of about 2 m of anhydrite rubble. The chimney is much higher than previously observed (1990), when it was only about 2 m high. Venting is profuse from the upper 4 m. A small discreet vent spouts from its base.

A sample composed of anhydrite and rusted sediment was scooped here (HYS-192-0233). This sample yielded a collection of sulfide worms.

Sample HYS 192-024 was taken from the base of Dead Dog Chimney. It consists of anhydrite plus minor organic material (A maximum temperature of 168°C was measured by ALVIN at this site). Blocky, yellow-stained talus blocks, probably containing anhydrite and Fesaponite in highly altered, indurated sediment, surround the mound area.

From Dead Dog Hill, ROPOS traversed about 65 m southeast to Chowder Hill. An excursion to the north reached ODP Hole 858F, which contains a cone, emplaced after drilling to block downward flow that was initiated during drilling. This hole is about 15 m north of Hole 858G.

Chowder Hill is the highest hill in the vent field, and has a steep north side. At the base of this steep slope, a distinctive clam field was discovered. Sample HYS192-0416 contained the mollusc Calyptogena, and a gravelly, anhydrite-indurated substrate. The latter is pyritiferous and carbonaceous, and emitted a distinctive order of H_2S on recovery. The dive ended after 4 hours when the SIT camera was dislodged from its mounting and the hydraulic oil reservoir became critically low due to filling of the tether with hydralic fluid (as expected).

HYS 193 Chowder Hill Area JD181 (6/29); in water 0304; d0604-0850 on bottom; 1405 on surface

Objectives: Traverse and map Chowder Hill area; test acoustic navigation system; Locate Hole 858 B on the southeastern slope of Chowder Hill

Achievements:

Navigation problems limited activities with the absence of transponder navigation. The base of Chowder Hill was found using the Mesotech sonar. The dive was initiated on the clam bed located on the previous dive. The north slope was traversed to reach Chowder Hill spire. This slope has several small active vent sites, each about 50 cm high ("chimlets"). This spire is about 2 m high, and sits on a small anhydrite mound, about 3m in diameter. Other small vents are visible to the east, and appear to aligned east-west. The top of the hill is at 2415 m. The area surrounding the chimney is composed of white, blocky anhydrite, formed through chimney collapse.

The dive ended after 6 hours, when cage hydraulics failed. At surface, it was discovered that the tether was severely damaged when it was dragged through the chimlet field; the outer covering was completely melted in a few spots, and it was heavily scored along about 20 m.

HYS-194: Aborted-ground fault

HYS-195: Aborted- telemetry failure

HYS 196: Chowder Hill Area -JD182-183 (7/1/92-7/2/92); 0535 in water; 1042-0028 on bottom; 0319 on surface

Objectives: To traverse and map the southeastern part of the Dead Dog Vent Field, including the Dead Dog, Chowder Hill and Inspired Mounds areas. To re-locate the 858G and other ODP drill holes, and continue to verify the acoustic navigation system.

Achievements:

The cage was positioned over the Chowder Hill clam bed (Dive 192). The acoustic navigation of both the cage and ROV worked almost continually during this dive, although were best when the cage motor was turned off.

Hole 858G was a good sonar target, and was reached after mapping for about 45 minutes, and passing holes 858E and F. The clam bed and the Chowder Hill vent were re-visited, and a course set for the Inspired Mounds area to the southeast. Sonar targets were easily established, and the ROV driven directly to the Inspired Mound area.

The sides of Inspired Mound are composed of blocky altered sediment and anhydrite talus; the valleys and flat areas between the mounds are heavily burrowed mud. A sample (HYS 196-1459) was scraped into the tray, and represents the typical hemipelagic ooze found away from the vent sites.

Inspired vent is composed of anhydrite, about 4 m high, above a basal mound of anhydrite talus. Palm worms were sampled from a warm water vent (Marker 19) along with a slab of indurated sediment. After completing the mapping of the Inspired Mound area, we traversed northward over heavily bioturbated mud, back to Chowder Hill. The next traverse was east from Chowder Hill over bioturbated mud. Sample HYS 196-1641 was taken of these muds. We traversed over 100 m east of Chowder Hill, passing several new clam beds, small vents, and worm beds. This area of vents seemed to form an E-W valley (Brown Glen), flanked by parallel ridges. We returned to Chowder hill, and again traversed east on a parallel course along which a parallel trend of small vents was mapped. New clam beds were located 120 m east of Chowder Hill. Indurated sediment was sampled (HYS196-2208). From this new clam bed, ROPOS was turned southeast to a target near the eastern edge of the acoustic anomaly. It traversed baked and fissured sediment, over a series of low mounds, to a broad hill of indurated and blocky, slabby sediment, named Ascidea Hill after the prominent biota located there. This dive ended after 14 hours.

<u>HYS 197:</u> Dead Dog Mound and Chowder Clam Bed - JD184-185 (7/2/92-7/3/92); 1526 in water; 2025-0005 on bottom; 0330 on deck

<u>Objectives:</u> (1)Continue detailed mapping Dead Dog Vent area, and the clam bed on the north side of Chowder Hill, (2) Attempt at sampling high temperature vents with the titanium syringe samplers.

<u>Achievements:</u>

The cage was positioned immediately north of the ODP Hole 858G, and was immediately found with the ROV. With good navigation its position was well fixed. Sonar navigation indicated that Dead Dog vent is 45 m southwest. ROPOS was then driven toward Dead Dog Vent, passing initially over sediments with a few scattered blocks of indurated material. Burrowed hemipelagic mud gradually gives way to indurated sediment. Talus of indurated mud is prominent at the base of Dead Dog Mound. At the top of the mound, the chimney was surveyed using the video system by circling it and traversing up its length. Worms are abundant at the chimney base, in 8°C water. The top of Dead Dog Chimney was knocked down. The lower part is quite hard, and composed of crystalline anhydrite. A sample of the chimney (HYS 197-2117) was collected about 4 m from the base. Water sampling of a small vent at the base was unsuccessful due to failure of the 24 volt power supply.

A traverse was made east (40 m) and south(60 m) to the Chowder Hill clam bed and it was mapped in some detail. It is an elliptical area, about 11x7 m and oriented NW along a break in the lower slope of Chowder Hill. It is about 1 m above the level of the hemipelagic mud flats to the north, and slopes very slightly to the southeast. The main vent at

Chowder Hill is about 25 m to the south. A series of temperature measurements were made in the gravelly substrate. Immediately below the clams, the temperature was 7.5° C, and 7 cm below, it was 12.2° C. We were pulled back to the cage, then re-occupied the clam bed for further biological observations. The dive ended after 4 hours.

HYS 198: Bent Hill Area - JD185-186 (7/3/92/7/4/92); 1730 in water; 2130-0025 on bottom; 0239 on surface

Objectives: (1) Sample water at Bent Hill, (2) Map the geology of the vent site and along the south flank of the main hill.

Achievements:

Acoustic navigation at this site was very poor, and insufficient for locating traverses and samples. The cage was positioned northwest of Bent Vent. Depth is 2650 m, and consists of moderately bioturbated greenish hemipelagic mud, with a thin layer of reddish mud on top. The latter was easily disturbed as the ROPOS passed over it.

The traverse south continued south for about 40 m towards a sonar target (the Bent Vent site) over this hemipelagic mud. The base of the mound is marked by blocks of talus on the mud. The talus blocks are yellow, indurated sediment away from the mound (elevation 2443 m), with more sulfide debris at the edge of the mound (elevation 2442 m).

The main vent stack is 2 m high, and a subsidiary stack is 1 m high. Worms appear to be absent. A yellowish matte covers the lower parts of the chimneys and the basal mound (Fe-oxidizing bacteria ?). The chimneys are soft and very friable, and could not be sampled.

After the ROPOS returned to the cage, the hill was again approached (40m at 210°) over heavily bioturbated mud (2457 m). Hydraulic problems continued, with periodic electrical failures. At the base of the hill a packman sample (HYS 198-2319) was taken. This sample consists of pelagic mud and collapsed chimney detritus.

This dive lasted just under three hours, almost entirely without navigation. Most of its objectives were not met.

HYS 199 Dead Dog Vent Field, Chowder Hill and the Central and North parts of the Acoustic Anomaly - JD186-187 (7/4/92-7/5/92) 1700 in water; 2008-0612 on bottom; 0928 on surface

Objectives: (1) Complete the mapping of Dead Dog Hill, Chowder Hill clam bed, (2) traverse northwards to East Hill and Heineken Hollow.

Achievements:

The first hour or so of this dive had no acoustic navigation, and the dive starting point was difficult to establish. Sonar targets took the ROV towards Chowder Vent, over flat bioturbated hemipelagic mud , and nearer the hill, talus blocks and indurated sediment. The vent is at 2410 m. Dead Dog Vent was revisited (about 50 m bearing 320°), and then the ROPOS was returned to the cage with no navigation, and the sonar again ranged on Hole 858G. Hole 858G was approached a few minutes later. Transponder navigation returned, and Dead Dog Vent was revisited, again traversing over hemipelagic mud, then indurated crust with no worm holes.

At Dead Dog Vent, the water sampler was deployed at a basal vent (2409 m) near marker 12. The maximum temperature reached was 242° C and one bottle filled (HYS199-2314). From here for the remainder of the dive, there was good acoustic navigation.

The ROPOS then moved to Chowder Hill clam bed, and mapped the area in great detail for the next 40 minutes. A composite push core was collected by penetrating the sediment in the clam bed twice. Clam shells, sediment and pore waters were recovered from this sample (HYS 199-
2410). Following this mapping, a field of small "chimlet" vents was discovered about 15 m south of the clam bed on the slope of Chowder Hill. These are each about 50 cm high, weakly active, and composed of anhydrite.

Following the Chowder Hill mapping, a northward traverse was initiated, with the objective of re-locating the ALVIN targets at Central Site, East Hill and Heineken Hollow. On the northward traverse, numerous sonar targets were located; in some areas, these were too numerous to be completely checked.

The first 180 m from Chowder Hill chimlets crossed pelagic, weakly bioturbated mud at 2423 m depth. Many targets were visible on the sonar; most consisted of low (2-5 m) mounds in a hummocky terrain. We first encountered (and temporarily caught) an ODP transponder. From it a traverse was made to the first good sonar target.

In the general area of the Central Site vent field and those to the north of it were like those to the south. Weakly bioturbated pelagic mud (2419 m) changes northward to gently undulating hummocks (2417 m) that are more strongly burrowed. Nearer the vent site, the surface changes to non-bioturbated, indurated mud, which is increasingly desiccated. Each hill typically has a vent on its top, with most of the hills at elevations of 2410 to 2412 m.

The Central Site vent occurs near the mid-point of the acoustically anomalous area. It consists of three high temperature vents, and additional grey to black anhydrite chimneys, each 1 to 2 m high. Surrounding these active vents are several smaller chimneys, each 10 to 30 cm high. These are thought to be barite (based on ALVIN sampling), and are growing from a "plate" of indurated mud, in a zone 20 to 30 m in diameter around the hot vents (called the Noodles Vent here).

To the NNE of the Noodles area, about 40m, another low, black multi-spired chimney structure (Pin Vent) occurs on indurated sediments, but without a prominent rise. This vent appears to be composed of anhydrite, with no associated barite-type spires. Between the Pin and Noodles sites, the sediment is flat and bioturbated.

Moving 60 m NNE from Pin vent, ROPOS moved over bioturbated mud (2417 m) to an apron of brecciated indurated sediment that surrounds a snow-white anhydrite chimney, emitting 227°C water. Only clear water is discharging from this vent. A sample of crystalline anhydrite with pyrite (HYS 199-2703) was collected from its basal apron. A sample of well indurated hemipelagic crust was collected between the basal apron to the vent site (HYS 199-2708). This area is referred to as Pincushion Flats, because of the large number and unusual nature of these vents. All of these are included in the Central Site area.

ROPOS then moved 80 m further north to a much larger vent complex that is part of the East Hill zone of vents. This distinctive vent site is called the ROPOS vent. Overall, the vent complex is about 80m in diameter. At the center of this vent complex is a very large dual-spired vent composed of anhydrite. It is about 10 m in width at its base, and 3-4 m high. The top of this mound is at 2409 m. Another part of this vent complex, about 20 m south of the main vent, is a secondary mound, about 5 m in diameter, with its top at 2412 m, the base at 2415 m. A sample of indurated sediment was collected here (HYS 199-2726).

A 90-m traverse was made to the NE of the ROPOS site, but encountered only pelagic mud. After passing SW of the ROPOS area, a 100 m^2 area of very low-relief indurated pelagic mud was traversed. At least two sag pits are present; these are areas of local collapse of the indurated mud. They have low-temperature diffuse venting, with worm colonies locally abundant. The worms have an unusual appearance, occurring as twisted, intertwined and ropy clusters.

The ROPOS then proceeded SW to about 120 m due south of the Heineken Hollow feature and turned north into a broad area of desiccated and indurated sediment with many patches of ropy worms and scattered clam beds. Shimmering warm water is venting from fractures in the indurated mud. A temperature of 3.3° C was measured in one of these. The spiral snail *Buccinum* is widespread around the margins of these areas of diffuse, fracture-controlled venting. These snails may be the "golf balls" recorded in the towed camera work in this area. The worm beds are extensive, and sample HYS 199-2917 was taken where the clusters are thick and tangled.

A wide loop was made to the west and north, passing over the margin of the acoustic reflector. After traversing bioturbated pelagic mud Heineken Hollow was approached from the west over an apron of indurated mud. Heineken Hollow is formed of a central area of collapsed indurated mud, with profuse diffuse venting throughout the collapsed area. The collapse is about 20 m wide. One hot vent was measured at 114° C. Clams and snails are abundant on the apron of the Hollow.

The dive ended here after 11 hours on the bottom.

<u>HYS 200:</u> Hole 858G - JD187 (7/5/92); 1301 in water;1619-1916 on bottom

<u>Objectives:</u> The purpose of this dive was to retrieve the data from the two corked ODP holes, 858G and 857D.

<u>Achievements:</u>

The data were to be collected by placing an conical "top hat", made of aluminum rods, over the top of the bore hole. In the center of the top hat is a connector that, when aligned, connects to the data port on the cork. After landing on the platform of the cork at site 858G, the ROV was stabilized by using the five-function arm to hold the lip of the casing surrounding the cork. The top hat slid over the hole with minor difficulty, and made a good connection to the recording device in the hole. The data were successfully retrieved and stored.

Problems with the hydraulic arm caused the dive to be terminated. On retrieval, it was discovered that the continuous current supplied to the connector caused it to quickly corrode so the data could not have been retrieved from Hole 857D even if the ROV had been functioning well.

<u>HYS-201</u> North Cleft/Monolith Vent JD 189-190 (7/7/92-7/8/92); 2146 in water; 0057-1130 on bottom; 1609 on surface

<u>Objectives</u>: (1) Locate Monolith Vent, (2) obtain accurate position tied to dGPS, (3) obtain vent fluid sample, (4) photograph chimney structure and active vents to obtain comparison to previous years and conduct geological traverses to the west and north of the Monolith Vent.

<u>Achievements</u>:

No navigation was functioning on the ROV or the cage during this dive. Navigation was by dead reckoning, sonar and prior knowledge of the area. The site was identified on the sonar by the sudden narrowing of the fissure at the vent site previously known by Sea MARC I side-scan sonar and ALVIN observations from 1990. A set of ALVIN weights were observed just east of the main fissure, and these proved to be good markers for subsequent approaches. Good quality video traverses were made of older sheet flows to the east of the main fissure and Monolith was found after 4 hours of searching. The water sampler was damaged during manouvering and was inoperative during the dive. A small active vent (probably found on dive 226 in 1990 and named New Vent) was reached and sampled for sulfide (sphalerite sample taken on HYS201-0608), worms and limpets in 60 C water. For the purposes of the cruse, the vent is recorded as Table II vent. A sample of altered sheet flow (HYS201-0719) was also collected near its base. A traverse was made to the west of Monolith up the eastern side of Cracked Hill. On this section, some alteration was recorded on videotape and a basalt sample (HYS 201-907) was collected. After returning to Table II Vent, the dive was ended after 11 hours.

Operational Notes:

The RM661 failed completely during the beginning of this dive and was not operative in the deep mode the remainder of the cruise. It worked on deck but would not work at depth. One of the plug-in boards was found to have an obvious temperature sensitivity, but the problem could not be localized further. Also during this dive, an overload in the surface transformer caused a power loss in the ROV and cage but was fixed and the dive continued.

HYS-202 North Cleft/Monolith Vent JD192-193 (7/10-7/11); 2147 in water; 0141-0833 on bottom;1248 on surface

Objectives: (1) Obtain dGPS position of Monolith Vent, (2) obtain water sample, (3) obtain biological and geological samples, (4) conduct structural mapping of area around Monolith using sonar and video systms, and (5) deploy markers to aid relocating sites.

Achievements:

Despite major efforts to repair the naviagation system, no navigation was obtained on this dive. Because of increasing winds throughout the dive, some difficulty was experienced in holding position east of Monolith. After four hours, ship positioning improved and Table II Vent was reached and an east-facing marker (W8) was deployed. Another marker (S4) was placed immediately below the Monolith Vent soon after. During this time, excellent color video was recorded. On subsequent approaches, the markers proved easy to relocate. The relationship between Table II Vent, Monolith and a small vent lying within several meters north of Monolith (Table Vent of 1990 dives) was confirmed and continuous diffuse venting was seen from Table II Vent to Monolith along the eastern lip of the main fissure. Detailed and extensive color video (~45 min) and still-camera coverage was obtained over Monolith. Two full-water bottle samples (TMax=260°C; HYS 202-0617) and a small sulfide sample (HYS 202-0617A) were obtained. The success of this sampling and observation period was made possible by excellent station-keeping over a 3-hour period in 15-20-knot winds in a watch circle of 100 m diameter. Tube worms and sulfide substrata (HYS 202-655) were also obtained during the latter stages of the dive. A basalt sample (HYS 202-0550) was inadvertently collected by the

ROV from the wall to the west of the vent at the base of Monolith in the fissure.

Operational Notes: The dive was curtailed after 11 hours after failure of the Tether Management System. Because of inability to spool in tether, a two-part recovery was necessary.

HYS-203 North Cleft/ Monolith Vent JD194 (7/12); 0915 in water; 1429-1732 on bottom; 2115 surface

Objectives: Relocate Monolith Vent, obtain dGPS position, map structural geology (examine for cross structures), move to north, find, fix and sample Fountain Vent, and map and sample large sulfide structures north of Fountain Vent.

Achievements: To obtain basic navigation, relay transponders were placed on both the ROV and the cage and the Oceano RM661 unit was kept on the ship. Without consistent acoustic navigation, ship-positioning problems plagued the first few hours of the dive. Marker W8 was located and shortly thereafter, Monolith was reached. The new higher-resolution video camera was first tested on this dive and obtained excellent footage of the Monolith Vent. While the ROV was held at Monolith, acoustic positions of the cage were obtained and by using the sonar for bearing and range on the cage from the ROV, positions of Monolith were obtained. These positions (10-20 m rms) plotted about 60 m southwest of the predicted Monolith site. After 5 hours of bottom time, the tether reel-in system failed and the dive was terminated. No samples were obtained during the dive.

Operational Notes:

After failure of the tether management reel-in system, the ROV and the cage were again recovered separately. After review of the damage, it was decided to terminate ROV operations because: (1)it was not clearly understood how the failure was initiated and and there was a chance of major damage or even loss of the system if a hasty repair was again attempted, and (2) the two part recovery was difficult and potentially hazardous to personnel and equipment in even moderate weather conditions as presently configured.

OPERATIONAL ASPECTS OF THE CRUISE: Problems and Recommendations

Motion Compensation: The most critical need for future ROV operations is some method of heave compensation to reduce snap-loading and other problems involved with excessive ship motion. Experience in 1992 showed that snap-loading can be a significant problem even in light to moderate seas for certain swell periods and amplitudes. Although it can be mitigated to some degree by separating the ROV from the cage at shallow depth and powering the ROV to depth, snap-loading and excessive ship motion are likely to be a significant problem in typical seas in the Northeast Pacific summer (15-20 knots of wind and variable swells) and will curtail operations in otherwise operable conditions. Excessive ship motion also has deletrious effects on handling (see below) and in mating and unmating the cage and ROV during dives. During the 1992 cruise, an accelerometer (supplied by the Atlantic Geoscience Center, Canada) and a specially written software package was used to monitor the ship motion. This was a useful tool and should be developed further.

Launch and Recovery Handling: Several areas of concern were raised after the 1992 experience. First, the small vertical and lateral clearances between the A-frame and the cage, although generally not a major problem in the unusually light seas of the 1992 field season, pose a major potential problem in the future. In the longer term, the existing A-frame could be replaced with a larger (higher ,wider and stronger) version. For 1993, any improvement in clearance is desirable. Second, a better recovery system is highly desirable, particularly a system for minimizing the swing of the package as it comes off the water surface. The most difficult type of situation is the two-part recovery. In this situation, which occurred several times during the 1992 cruise, the ROV is unable to mate with the cage and has to be recovered separately. In 1992, a small boat attached a line to the ROV and it was craned aboard. The aft crane is not ideal for this type of service; for example, using the crane at full extension created a very severe pendulum effect. If possible, it would be best to eliminate the use of the small boat entirely and assess how to better use the crane (knuckling it down more?) for this type of operation.

Navigation: Accurate and continuous tracking of the ship and vehicle position is an essential component of any successful ROV operation. Shallow-water ROVs typically use ultra-short base-line navigation systems which are commercially available but have limited ranges. The depth and ranges encountered on this project necessitated developing a long-baseline (LBL) navigation system specifically designed for ROV operations using a caged tether management system and a nondynamically-positioned vessel. Custom PC-based software, a submersible transceiver, and a responder were purchased from Oceano/MOORS. The navigation concept used an array of bottom-moored transponders with a ranging receiver on the cage. A responder (wire activated transponder) was installed on the ROV so all acoustic transmissions were nearly horizontal, with no acoustically derived ship positions required. Differential GPS, using a base station in Newport, Oregon and an open Inmarsat link was used for ship navigation. The master computer controlled the transceiver and displayed all navigation. A remote computer on the bridge provided a continuous display of ship, cage and ROV positions and a watch circle for ship positioning. The concept was proven to be sound and provided all necessary information when operating correctly. However, the transceiver had several severe problems which caused significant loss of navigation data. The problems were apparently a combination of firmware errors, low receiver sensitivity, and low-temperature faults. This was one of the first models of a new piece of hardware from the company, and due to late delivery before the cruise, little time was available to run performance tests in Seattle before the cruise. It will be returned to the factory for repairs. However, the navigation software performed well under the guidance of a contract software engineer who had been involved in the program development. The bridge display proved to be essential for vessel station-keeping, where ROV operations often required positioning and maintaining the vessel within 50 meters of target positions. Assuming the hardware problems are corrected, further improvement of the system could involve noise reduction on the cage and ROV, acoustic isolation of the acoustic modules, and better selection of transponder reply frequencies. Alternatives to the high priced satellite-linked differential GPS system should also be explored (for example, the use of an HF radio link and the potential for access to a military-precision receiver).

ROV and Cage: Although there were a number of minor problems with the system (electronic problems etc.), most were easily correctable. Several general observations can be made, however. First, the lack of electronic spares is a serious concern and should be corrected by the next expedition. Second, the tether management reel-in system experienced major structural failures at the end of the cruise and caused curtailment of operation and forced two-vehicle recoveries. The reasons for this problem should be identified and corrected. The third major area of concern is the tether. Although the tether is buoyant at the surface, it is not at depth and creates a major operational constraint, particularly in areas of hot water and/or rough terrain. A buoyant tether is a high priority concern for future operations.

OTHER CRUISE ACCOMPLISHMENTS

In addition to the ROV operations, two extensive Sea Beam surveys of the eastern flank of Middle Valley and the flanks of the Cleft segment were accomplished. Also, one Bottom Pressure Reccorder and a Rumbleometer was deployed at Axial Volcano and two Rumbleometers were deployed at the North Cleft site. Eight transponder deployments (four at each site) and seven recoveries were made. One PMEL Benthos-type transponder was lost at the latter site. It apparently surfaced but was not sighted. A SUS charge calibration experiment using 24 SUS charges along a predetermined line was completed on the last day of the cruise.

SUMMARY

First and foremost the expedition was an unqualified success. The ROPOS accrued about 60 hours of bottom time at ten vent sites, during which 25 geological, biological and chemical samples were taken, continuous video was recorded and 545 35 mm frames taken. This expedition marks the first time that such samples, which require delicate manipulation, were obtained from the Mid-Ocean Ridge by a remote vehicle. In addition, the ROPOS achieved a successful coupling to the drillstring instrument package and 10 months of data were recovered from it. The use of differential GPS coupled with the new LBL10 software made it possible for the bridge watch to hold the ship in position within a 100-m watch circle in winds up to 15 knots and seas of 6 to 8 feet. However, in order to achieve expanded bottom time and increased scientific payback, improvements (as outlined above) are necessary in motion compensation, launch and recovery handling, tether management navigation, instrumentation, and science telemetry. The ROPOS has a high potential for future VENTS research.

SCIENTIFIC PERSONNEL

NAME	ROLE	AFFILIATION
Robert W. Embley	Co-Chief Scientist/Geologist	NOAA/PMEL, Newport, OR
James M. Franklin	Co-Chief Scientis/Geologist	Geol. Survey of Canada, Ottawa
Ian R. Jonasson	Geologist	" " " "
Verena Tunnicliffe	Biologist	Univ. Victoria, Victoria, B.C.
Barry Milligan	Biologist (Grad. Student)	" " " "
Kim Juniper	Biologist	Univ. du Quebec
Pascal Martineau	Biologist (Grad. Student)	" " "
Glenn Brown	Geologist	Univ. Toronto, Toronto
Rob Leitch	Engineer	" " " "
William W. Chadwick	Geologist	CIMRS, Oregon St. Un., Newport, OR.
Dave Butterfield	Chemist	NOAA/PMEL, Seattle, WA
Andra Bobbitt	Acoustic Navigation	" " "
Brian Wichner	Technician	" " "
Hugh Milburn	Engineer	NOAA/PMEL, Seattle, WA
Chris Meinig	Engineer	" " "
Andy Campbell	Technician	" " "
Mike Stapp	Engineer	" " "
Robert McDonald	Engineer	Pacific Geoscience Center, Sidney, B.C.
Keith Shepherd	Party Chief for ROV	Institute of Ocean Sciences, Sidney, B.C.
Robert Holland	ROV Pilot	" " "
Keith Tambouri	ROV Pilot	DTEC, Vancouver, B.C
Robert Rhodes	ROV Pilot	Consultant, Vancouver, B.C.
Jame Illman	Navigation software	Software Engineering Associates, Seattle, WA
Steve Etchemendy	ROV Engineer/pilot	Monterey Bay Aquarium Research Inst.

APPENDICES

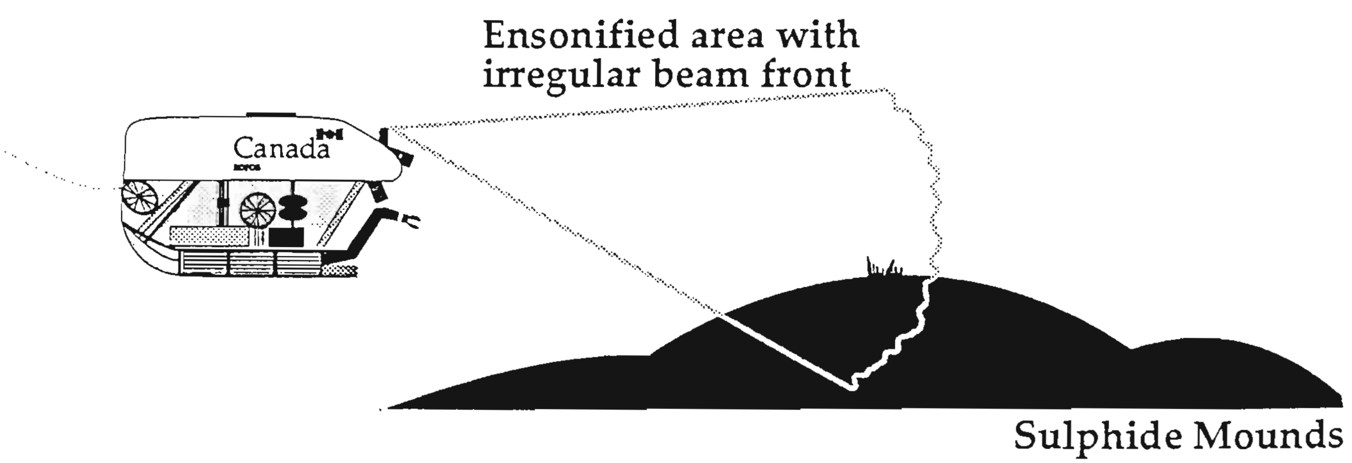
VENTS Sonar Imagery

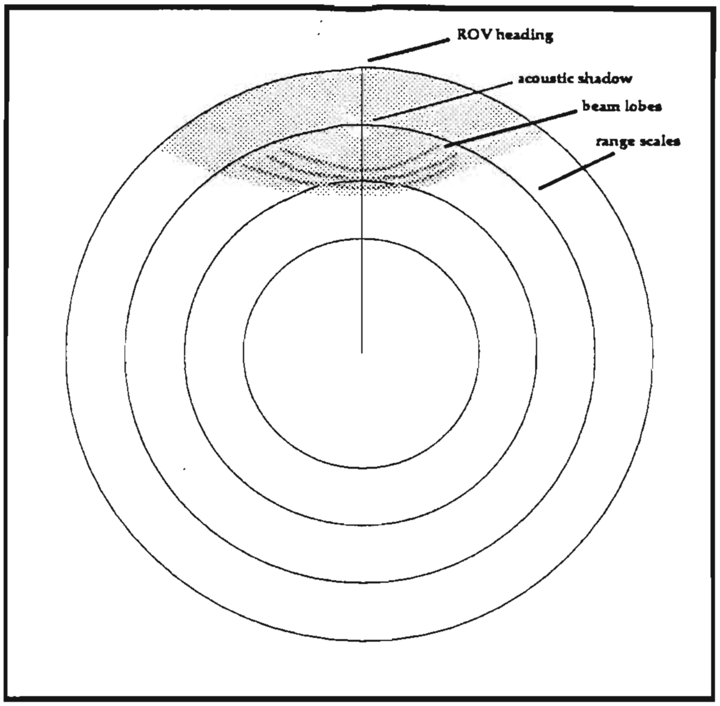
The HYSUB ROV is equipped with a Mesotech 971 Colour Imaging Sonar. The 330 kHz system is vertically mounted at the front of the ROV (see Figure). During the VENTS cruise we recorded the sonar imagery data on standard VHS tapes with a signal from the NTSC port on the control box. A VCR settings problem sometime after the start of Dive 199 led to no data being recorded until the start of Dive 202. Half way through Dive 201 the sonar was crippled during a return to the cage. The protecting bumper bar was compressed into the sonar head. This was repaired for the following dive.

The Mesotech 971 has five scanning modes. The table below summarizes these modes. A polar scanning mode was used for most of our operation. This was popular with the pilots, because they could keep track of the relative cage position. On two occasions we ran the system in sidescan mode. A sidescan mode survey of the ridge crest was planned but never completed. To reduce distortions from varying vehicle position it is recommended that such surveys be conducted over a defined grid and with the vehicle traveling with a constant ground speed and depth.

polar	one direction 360°, data plotted as function of range and angle
sector	similar to polar but scan is over a narrow sector centred about an angleset by the heading switch.
linear	scan over area but plot is in a rectangular form
perspective	mode positions returns in a perspective display using rectangular coordinates
sidescan	transducer is fixed by angle set by Heading switch, relies on movement of the vehicle. As the horizontal axis is time, if vehicle's ground speed varies, the image will be distorted.

The positioning of returning echoes is based on their arrival time. During flight it is common for the vehicle to change heading and altitude which distorts the images. The data quality is greatly improved when the ROV is stationary on the bottom. At Middle Valley there was an early tendency to set the vehicle on high points to scan the surroundings. This worked only if the neighbouring mounds reached the same level as the survey site. The best data from fixed points came when the vehicle was parked in lower areas, either on the flank of mounds or in the saddles between mounds.





Mesotech Image

The mounds of the sulphides at Middle Valley appeared on the sonar to be terraced. This is an artifact produced by irregularities in the sonar beam. The banded imagery resembles the concentric ring phenomena described by the manufacturer. The outgoing sonar beam has varying intensity lobes that produce artificial bands in the images from inclined areas. If the bottom slope is constant, a polar scan will produce bands concentric around the display origin. At Middle Valley, because we were scanning distant mounds with slopes leading away from the vehicle, the high amplitude returns bend around the summit of the mound (see Figure).

While this sonar system is suitable for navigating the vehicle and searching the bottom, it is a poor system for mapping and image analysis. With a digital system, quality navigation, and altitude information, the ROV could be a powerful tool to map bottom geology. A higher frequency system could be used to map water column anomalies and detailed features around hydrothermal vents. Glenn Brown and associates at the University of Toronto will research the possibility of converting the existing system or mounting another system on the ROV for such high-resolution mapping of the deep sea floor.

DIVE SAMPLE SUMMARY

SOURCE	DATE	SAMPLE #	TYPE	TIME	POSITION	DEPTH (m)	TEMP (ºC)	REMARKS
MIDDLE VALLEY	27/06	192-0230	grab	02:30	1463X/7031Y	2417.00		Dead Dog - small pinnacle at base of chimney - 3D #13
		192-0249	grab	02:49	1463X/7031Y	2414.00		Dead Dog - fauna & sediment anhydrite/hydrocarbon
		192-0410	grab	04:10	1507X/6988Y	2415.00		Clam Bed @ Chowder Hill - clams, associate fauna & sediments
		192-0437	biology	04:37	1514X/6991Y	2415.00		1 single clam Calytogena with 7 functions
	28/06	193-0930	sea water	09:30		2370.00		
	01/07	196-1405	bulldozed mud	14:05	1593X/6912Y	2417.00		Inspired Mounds - Mixture
		196-1511	biogeo-grab	15:11	1586X/6872Y	2415.00		Inspired Mounds - Palm worm oasis - 3D #19
		196-1641	bulldozed mud	16:41	1527X/6933Y	2419.00		Inspired Mounds - sediment mixture - grey muds
		196-2207	Geo.	22:07	1567X/6956Y	2417.00		Inspired Mounds - 7 functions
	02/07	197-2117	grab	21:17	1464X/7032Y	2408.00		Dead Dog - chimney - anhydrite crust - geo. sample
		197-2140	temp	21:40	1471X/7011Y		246.00	Dead Dog - Water sample aborted
	03/07	198-2319	grab	23:19	3513X/4291Y	2455.00		Bent Vent - mud
	04/07	199-2314	water bottle	23:14	1463X/7031Y	2409.00	242.00	Dead Dog - water sample at 3D marker #13
		199-2325	temp	23:25	1463X/7031Y	2409.00	246.00	Dead Dog - small orifice on base of the main active vent - T º over 17min
		199-2419	core	00:19	1510X/6961Y	2416.00		Club Clam Bed
		199-2655	temp	02:55	1590X/7322Y	2411.00	227.00	Orange mat -temp gradient
		199-2708	metamud block	03:38	1590X/7322Y			Snowball vent
		199-2738	temp	03:38	1584X/7391Y	2411.00	258.80	Ropos Vent
		199-2846	temp	04:46	1480X/7349Y	2412.00		Clam Bed - Temps among clams
		199-2917	Bio.	05:17	1481X/7381Y	2417.00		vestimentifera with 7 functions
CLEFT SEGMENT	08/07	201-0608	BioGeo	06:08	no navigation	2245.00		Monolith - Sulfide chimney with sulfide worms
		201-0719	Basalt	07:19	no navigation	2246.00		small vent near Monolith Vent - fresh Lava
		201-0907	Basalt	09:07	no navigation	2231.00		west of Monolith - Lava
	10/07	202-0605	water bottle	06:05	no navigation			Monolith - sonar died
		202-0639	worms grab	06:39	no navigation			Monolith

TABLE : GEOLOGICAL/GEOCHEMICAL SAMPLES

SAMPLE NO.	JD #	SAMPLE TIME (Z)	DEPTH	LOCATION	TYPE	COMMENTS	X (UTM)	Y(UTM)
HYS 192-0232	180	0217-0232	2417	Dead Dog Vent	Anhydrite Crust	Base of Chimney	521463	5367031
HYS 192-0249	180	0233-0249	2414	Dead Dog Vent	Anhydrite Crust	Small vent at base	1463	7031
HYS 192-0416	180	0416-0448	2415	Chowder Hill	Sulfidic sediments	Clam bed	1514	6991
HYS 196-1405	184	1405-1407	2417	Inspired Mounds	Brown mud + crust	Valley between Chowder H. + Inspired Mounds	1593	6912
HYS 196-1459	184	1448-1507	2415	Inspired mounds	Indurated sediment	At palm worm site	1586	6897
HYS 196-1641	184	1641-1653	2419	Inspired mounds	Hemipelagic mud	Base of mounds	1529	6933
HYS 196-2208	184	2202-2215	2418	Inspired Mounds	Indurated sediment	Crust on low mound	1567	6956
HYS 197-2117	184	2117-2119	2412	Dead Dog Vent	Chimney Crust	2 m up from base	1404	7032
HYS 198-2319	185	2319-2320	2455	North of Bent Hill	Pelagic mud	Base of mound	3513	4316
HYS 199-2314	186	2314-	2414	Dead Dog Vent	Water at 246 C	Small vent at base	1463	7031
HYS 199-2410	187	0010-	2416	Chowder Hill	Push core	Clam bed	1510	6986
HYS 199-2703	187	0303-	2411	Snowball Vent	Chimney basal crus	Anhydrite	1590	7347
HYS 199-2708	187	0308-	2411	Snowball Vent	Indurated Sediment	Edge of vent apron	1590	7346
HYS199-2726	187	0326-	2412	Central Mounds	Indurated Sediment	Expired Vent	1570	7397
HYS 201-608	190	0530-0608	2246	Table II Vent	Sulfide beehive	Sphalerite/marcasite	12 m N. Monolith	
HYS 201-719	190	719	2248	Table II Vent	Basalt	Footwall sheet flow	12 m N. Monolith	
HYS 201-0907	190	0907	2231	Cracked Hill	Altered Basalt	Small lobe		
HYS 202-0550	193	~0550	2249	Base of Monolith in fissure	Altered basalt	Lobate flow		
HYS 202-0617	193	0603-0617	2246	Top Monolith Ven	Vent Fluid	Up to 260 C		
HYS 202-0617A	193	0603-0617	2246	" "	Smoke and mud	In Titanium bottle		
HYS 202-0655	193	0634-0655	2246	" "	Chimney crust	Sphalerite, marcasite and worms		

VIDEO TAPE LOG

SOURCE	DIVE/TAPE ID	DATE	START	END	SUBJECT	REMARKS
MIDDLE VALLEY	HYS192-1	27/06	*00:45*	02:37	ODP drill pipe/Dead Dog/Pacman sample	
	HYS192-2		02:40	04:38	Dead Dog(DD)/Clam Bed(CB)/DD sulphide sample/CB sample	
	HYS192-3		04:40	05:55	Clam Bed: Clams sample/knocked sit camera/Off bottom	
MIDDLE VALLEY	HYS193-1	28/06	05:57	07:54	transecting to Sucker Hole/ Clam Bed	
	HYS193-2		07:55	09:26	Near top of Chowder Hill/Off Bottom/Sea water sample	
MIDDLE VALLEY	HYS196-1	01/07	09:36	11:32	ODP drill Hole	
	HYS196-2		11:32	13:25	Clam Bed/Inspired Mounds	
	HYS196-3		13:25	15:29	Inspired Mounds/Palm worm oasis/Biogeo-sample	
	HYS196-4		15:29	17:13	Inspired Mounds/PhotoTransect	
	HYS196-5		17:13	19:22	West of Inspired Mounds/ Solemys Bed	
	HYS196-6		19:22	23:13	Midwater/Inspired Mounds/Geo-sample/ Clam Bed	tape stopped during mid-water
MIDDLE VALLEY	HYS197-1	02/07 MESO	19:56	20:58	sonar dive	
	HYS197-1	COL/SIL	20:25	22:25	Dead Dog- Biogeosample & Water sample	
	HYS197-2	COL/SIL	22:26	23:54	Clam Bed - Temperature sample	
MIDDLE VALLEY	HYS198-1	03/07	21:23	23:22	Bent Hill site	
	HYS198-2		23:22	00:25	on bottom for fix	
MIDDLE VALLEY	HYS199-1	04/07	20:27	22:25	Deag Dog/Chowder Hill/Platform G	
	HYS199-2		22:26	00:21	Dead Dog/Water sample/Clam Bed	
	HYS199-3		00:22	02:15	Chowder Hill/Big Burrows/Shrimp Vent	
	HYS199-4		02:15	04:12	Orange bacterial mattes-Temp/ Ropos Vent	
	HYS199-5		04:12	06:13	Mounds/Burrows - Temps among clams	
MIDDLE VALLEY	HYS200-1	05/07	16:07	18:05	Hole G: stored data	
	HYS200-2		18:05	19:35	Hole G	
MEGA PLUME	HYS201-1	08/07 SIT			Dive without Navigation II	tape started and stopped
	HYS201-1	COL/MESO	00:41		on bottom	tape started and stopped
	HYS201-1		03:59	04:50	Monolith	tapes started again
	HYS201-2		04:50	07:06	Table Vent/ Biogeo-sample	tapes stopped 06:28/started 06:46
	HYS201-3		07:07	09:06	Table periphery/ Geosample	Table Vent/Monolith
	HYS201-4		09:07	11:05	Unknown Vent on E-W Table Vent	
	HYS201-5		11:05	11:54		
MEGA PLUME	HYS202-1	10/07	01:27	03:23	looking for Monolith	No navigation / new colour camera
	HYS202-2		03:23	05:37	Table Vent/marker W8/Monolith/marker S4	all tapes stopped by electrical glith- sonar died
	HYS202-3		05:37	07:35	Monolith/ water sample/ Bio-sample	No Sonar
	HYS202-4		07:35	08:37	Monolith	Dive aborted
MEGA PLUME	HYS203-1	12/07	14:29	16:21	Monolith / cage	
	HYS203-2		16:27	17:32	Monolith	

PHOTO LOG

DIVE	#	SUBJECT	TIME	DATE	LOCATION	DEPTH	COMMENTS
HYS192	1	Rusty can	01:04	27-06-92	Middle Valley		
	2	Cucumber	01:05				
	3	Cucumber	01:05				
	4	Psychrotus	01:07				
	5	Rattal	01:10				attrobe double firing
	6	Diadem anemone	01:13				
	7	Drill pipe	01:20				
	8	Drill cuttings	01:24				white layer
	9	Drill Hole	01:26				clouds - cracks in mid.
	10	Drill Hole	01:34				snow fllds
	11	Drill Hole	01:36				Cork on Drill Hole 858G
	12		01:48				moving off drill platform
	13	sulphide mud	01:50				
	14	sulphide mud	01:53				
	15	fish	01:54				
	16	white stuff at base of hill	01:55				
	17	white stuff at base of hill	01:55				
	18-22	Dead Dog chimney	01:56				
	23	Dead Dog	02:04				
	24	Dead Dog	04:14				
	25	Dead Dog marker	02:17				
	26	small chimney next to D.D.	02:23				
	27	new marker at D.D.	02:46				
	28	Pacman next to chimney	02:47				
	29	Dead Dog chimney	02:56				
	30	Base of Dead Dog	03:16				
	31	Crinoids	03:30				en route to Chowder Hill
	32	dredge track	03:33				en route to Chowder Hill
	33	dredge track	03:35				en route to Chowder Hill
	34	Clam Bed	03:36				
	35	Vents	03:46				above Clam Bed or Chowder Hill
	36	Nontronite	04:07				at base of Chowder Hill
	37	Clam Bed	04:09				
	38	Clam Bed - black mud	04:37				
	39	Clam Bed after sampling	04:39				
	40	Clam Bed	04:42				
HYS 193	1	Landing site	06:13	28-06-92	Middle Valley		
	2	bacterial mats					
	3	Chowder Hill					
	4-7	base of the chimney					
	8	chowder Hill					
	9	chimlets	06:22				diffuse field on mound lip
	10	side of Chowder Hill					
	11	anhydrite mud	06:46				"south of Chowder Hill, 10m down slope"
	12	tin can	06:50				south of Chowder Hill
	13	Chowder Hill	06:56				south of C.H.
	14	Clam Bed					
	15	Chowder Hill	07:15				south of C.H. on flat bottom
	16	Chowder Hill	07:16				climbing north on C.H.
	17	top of Chowder Hill	07:50				
HYS 196	1	Drill Hole	10:50	01-07-92	Middle Valley		
	2	Drill Hole					
	3	Drill Hole F	10:54				plug
	4	Drill Hole G	10:55				
	5	Platform at 858 G	11:01				close up
	6-7	run south to Chowder Hill	12:07				
	8	Clam Bed	12:13				
	9	Clam Bed	12:25				leaving C.B. to climb hill
	10	chimneys	12:32				top of Chowder Hill
	11	ChowderHill top	13:02				looking downslope 15° heading on C.H. top
	12	burrow	13:14				SE of C.H.
	13	tether on sea bed	13:24				en route to Inspired Mounds
	14	bacteria mats	13:33				
	15	chimneys					Inspired Mounds area
	16	Inspired Mounds	14:06				approaching I.M. Head 207°
	17	Inspired Mounds	14:08				edge of I.M. hydrothermal area
	18	Inspired Mounds	14:43				constant fix for 15 min
	19	Inspired Mounds	14:46				transect to west into I.M.

	20	Inspired Mounds	14:53				
	21	palm worm	15:04				base of I.M.
	22	BioGeo sample #1	15:22				3D marker #19
	23	red mud/burrows	16:06				transect from position NW I.M. to SE
	24-36	photo transect					
	37	worm tube/burrows	16:11				into Mounds
	38	anhydrite sample	16:23				attempted anhydrite sample sit
	39	base of I.M.	16:22				settled to get fix
	40-51	photo transect	16:37				Inspired Mounds: W->S->E
	52	single clam shell	16:51				
	53	clam shell					being badly pulled
	54	cage	17:10				mid-water
	55	photo transect	18:45				210° from north to I.M. but then pulled by ship
	56-67	Solamys field	19:15				attempted failed sample
	68-69	piston core hole	20:33				
	70-71	burrowed terrain					east of I.M.
	72-94	photo transect	20:45				to chimlets on north side of Chowder Hill
	95-97	photo transect	20:52				Chowder Hill to valley
	98	sample site	21:42				
	99-101	side of I.M.?	21:52				Lost!
	102	anemone	22:23				
	103	photo transect	22:57				"south from position area, east of know area"
HYS 197	1-5	bore hole 858G	20:30	02-07-92	Middle Valley		
	6-7		20:37				30m north of Dead Dog
	8-13		20:44				run 220°
	14-17		20:54				run 120° to Dead Dog
	18-20		21:00				run 110° to Dead Dog
	19-43	Dead Dog	21:09				run up Dead Dog to base of chimney
	43-58	BioGeo sample/ Dead Dog	21:13				up & down Dead Dog spire
	59-81	water sample /Dead Dog	21:49				end of Dead Dog sequence
	82-99	photo transect	22:25				Dead Dog to Clam Bed
							#95: close up of white precipitate on sediment surface
	100	clams	22:31				"sitting at edge of clams, heading 110°C"
HYS 198	115	Bent Hill area	21:28	03-07-92	Middle Valley		
	116	transit to sonar target	21:40				
		sulfides on mounds	21:43				
	140	bacteria mats & chimney	21:57				
			22:35				run up target hill
HYS 201	1	low temp vent along fissure	04:15	08-07-92	Middle Valley		north of Monolith? No navigation!!
	2	old sheet flows	04:20				north of Monolith - broken &buckled
	3	collapse column	04:26				on edge of fissure
	4-5	contact of young/old lava	04:29				
	6-9	Monolith vent	04:34				looking NW
	10-17	Monolith vent	04:35				looking W
	18-21	Monolith vent	04:37				looking W
	22-25	Monolith vent					looking NW-W
	26-30	Monolith vent					looking SW
	31-35	Monolith vent	04:42				looking NE
	36-40	Monolith vent	04:43				
	41-44	Monolith vent	04:45				looking NW
	45-48	Monolith vent	04:51				"sampling, looking WNW"
	49-53		05:02				"looking S, SE"
	54-	old lavas	05:18				push-up structure in old lavas
		old vent	05:20				"old lava ""Table vent"""
	-73	sulfides & worms	05:30				tried to sample
	74	tether on old sheet flow	05:33				
	75	rattal	05:37				
	76-86	Table Vent	05:40				back at Table Vent
	87-91	temp sample	05:59				
	92-93	Table Vent	06:47				
	100	midwater	06:53				
	101	Table Vent periphery	07:02				
	102	Table Vent periphery	07:20				sample #2 - basalt
	103	basalt	07:58				
	104-105	altered basalt	08:53				
	106	anhydrite on basalt	08:57				
		Monolith	10:33				facing 224°
HYS 202	1	sheet flows	01:31	10-07-92	Monolith	2250	No Navigation!! east of wall
	2	older pillows/large fissure	01:33			2247	
	3	edge of fissure	01:39			2239	west of target?

	4	lether color	01:45				adjusting colour for colour contrast
	5	yellow floc	02:11				on compression ridge- west?
	6	wall & fissure	02:18			2253	2ºC - main cleft
	7-9	sponge	02:40			2254	talus
	10-13	blocky sheet flow	02:49			2253	2ºC - looking north
	14	large fracture	03:24				east of cleft
	15	sheet flows	03:25			2250	
	16	pushed up sheet flows	03:39			2256	
	17	animals	03:40			2256	
	18	edge of cleft	03:43			2248	small buds in old lava
	19	edge of new flows	03:48			2241	"some problems control: sometimes 2 flashes, sometimes none"
	20	white thing on rock; fissure	04:14			2229	wallwest
	21	push up sheets	04:15				on west wall high
	22-23	pillow lava	05:26			2250	near edge of piece rubble
	24	bucket lid	05:28			2248	
	25	Table 2 vent	05:30			2246	Monolith new vent
	26-33	Monolith & marker	05:31			2248	
	34-36	Monolith	05:35			2248	some double flashes
							try to use conuter number from here
	53	small vent 2m NE	05:41				Butterfield say "original Table vent- other is Table 2(or new)"
	54	Monolith top	05:42				
	55	Monolith base					facing east in fissure
	56-57	basal vent areas					
	58-59	south end of base of Monolith					
	60-62	smoker vents - top of stack	06:00			2246	
	63-77	top of Monolith					long series of close ups of mid-upper biota- variously facing
							north to west while positioning for water sample
	78	"water sample, top of vent"					rock wrenching
	79	sheet flows					
	80-81	sheet flows -> blocks					
	82-84	sheet flows					
	85	copy flows	07:29			2254	
	86	crab	07:46				
	87	pillow lavas	07:47				
	88	Pillow lavas	07:48				
	89	pillow lavas	07:49				
	90	sheet flows	08:14				2 flashes - problems with lights again
HYS 203	1	sheet flows	14:32	12-07-92	Monolith	2251	drop point 40m east of Monolith
	2	collapse pit in sheets	14:33				
	3	brittle stars	14:33				close up abobe
	4	shrimp on flow	14:34			2246	east of Monolith
	5	sheet flows	14:36			2246	no flash
	6	sedimented sheet flow- brittle stars	14:42			2249	on edge of cleft (NE) Ropes (EW)
	7	rubbly sheet flows	15:55			2251	
	8	pillows					edge of cleft - block
	9-10	blank - upwelling pillow lava	15:58			2251	
	11	sheet flows - brittle stars	16:12			2251	edge of cleft
	12	sheet flows	16:14			2252	
	13-15	marker #10					no flash
	16	base of marker flag #10	16:35			2248	
	17-19	base of marker #10	16:37			2248	sponges on rocks around warm water seeps- flag
	20	warm water vents in talus & pushed up	16:44			2248	sheet flows (base of wall) - rocks altered
	21-23	smokers	16:48			2248	near top of Monolith Vent
	24						looking 248° gyro
	25-28	various views of spigots	16:50				looking 249° gyro
	29-35	left->right scan of spigots	16:51			2246	top of Monolith - 249° gyro
	36-37	chimney tops	17:02			2246	looking 260°
	38	chimney	17:05			2246	looking west 260°
	39	view of middle spill in old chimney	17:06			2246	stack flanked by new growth bearing spigots at top- looking 265°
	40	view as above	17:07			2246	looking 265°
	41-42	top of middle vents	17:07			2246	looking 257°
	43	base of Monolith	17:11			2248	looking 231°
	44	Table I vent - 2m N of Monolith	17:12			2246	looking 304°- at base of main stack- small live of vents N
	45	Table II vent	17:13			2247	looking 339° - approx. 10-12m N of Monolith on same vent line
	46-47	base of Table II vent	17:14			2248	looking 200° - Rocky lava looks pushed up- abundant spongesin low T
	48-49	marker W8	17:18			2247	positioned about 5m east of Table II - fish - looking 310°

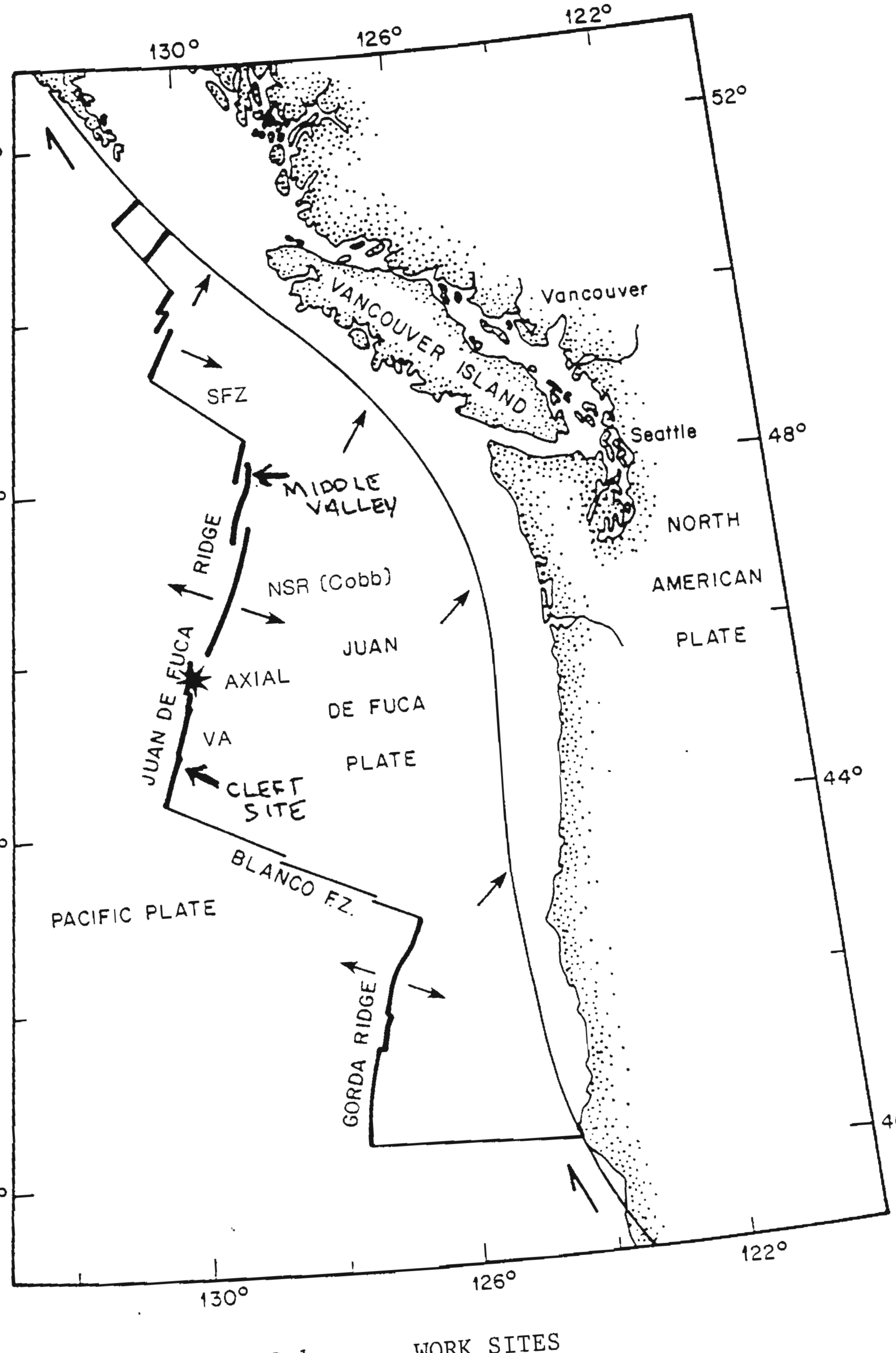


FIG 1 WORK SITES

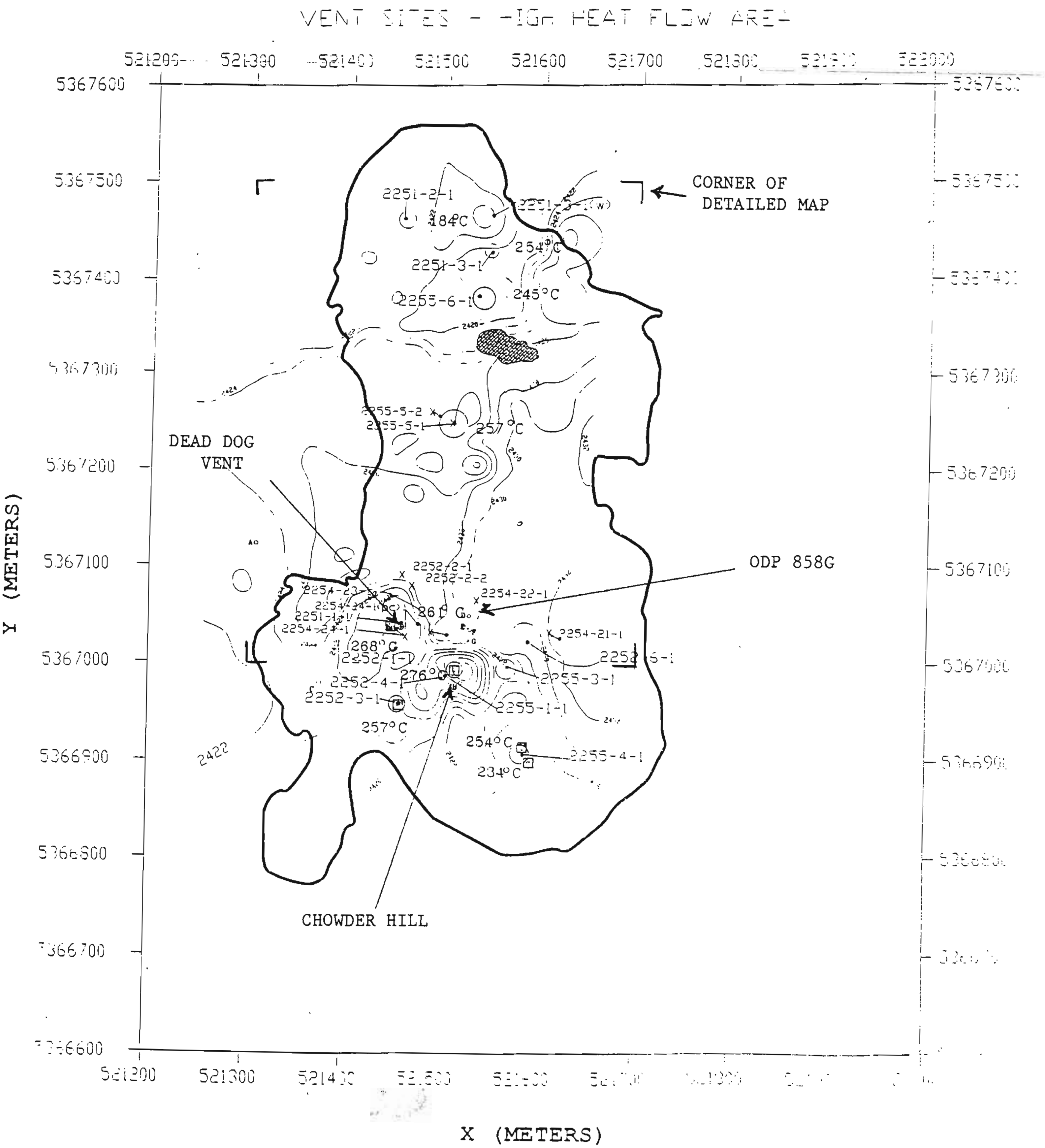


FIG. 2 LOCATION MAP FOR MIDDLE VALLEY SITES

ROPOS TRACK--DIVE 199

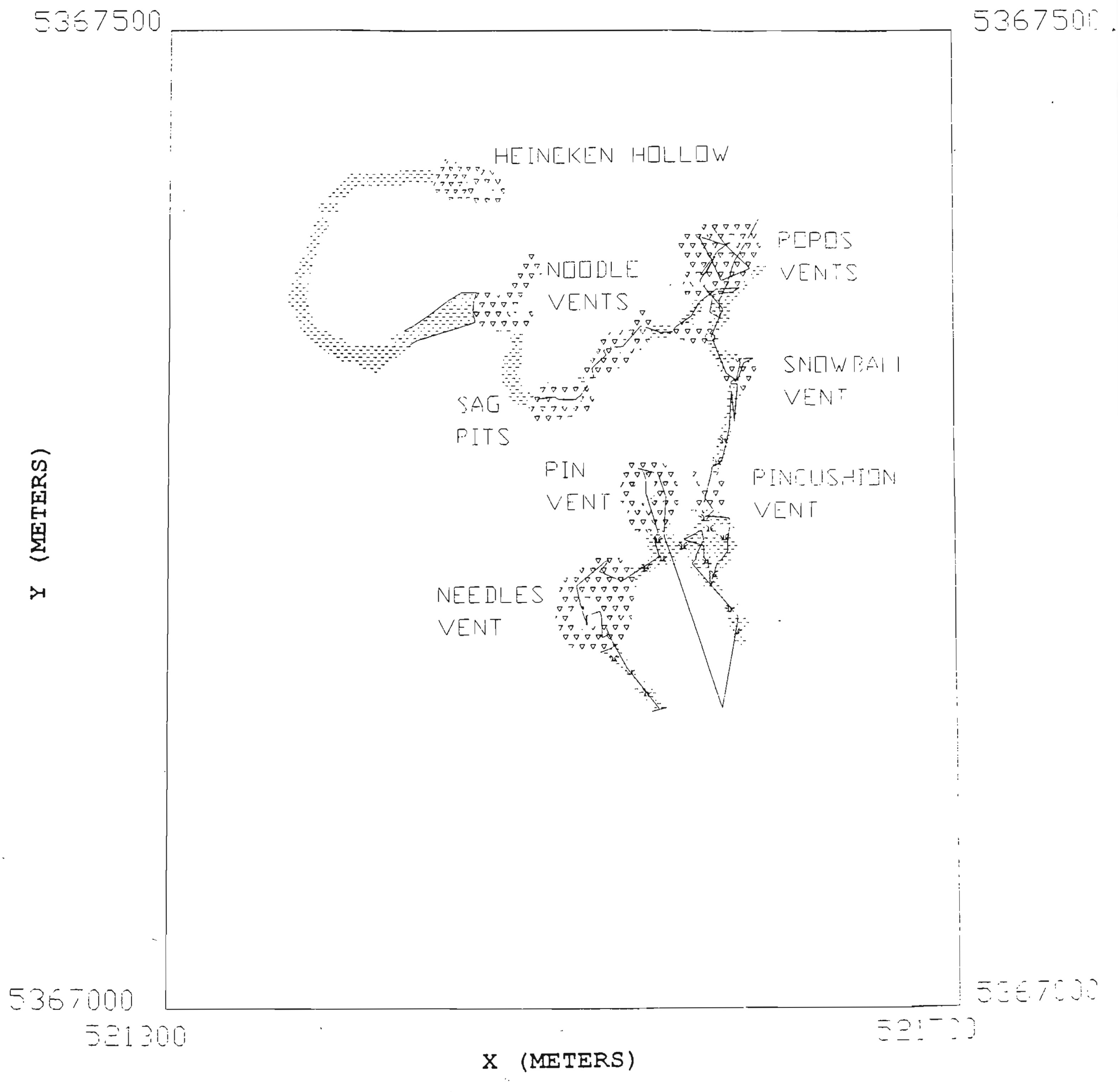
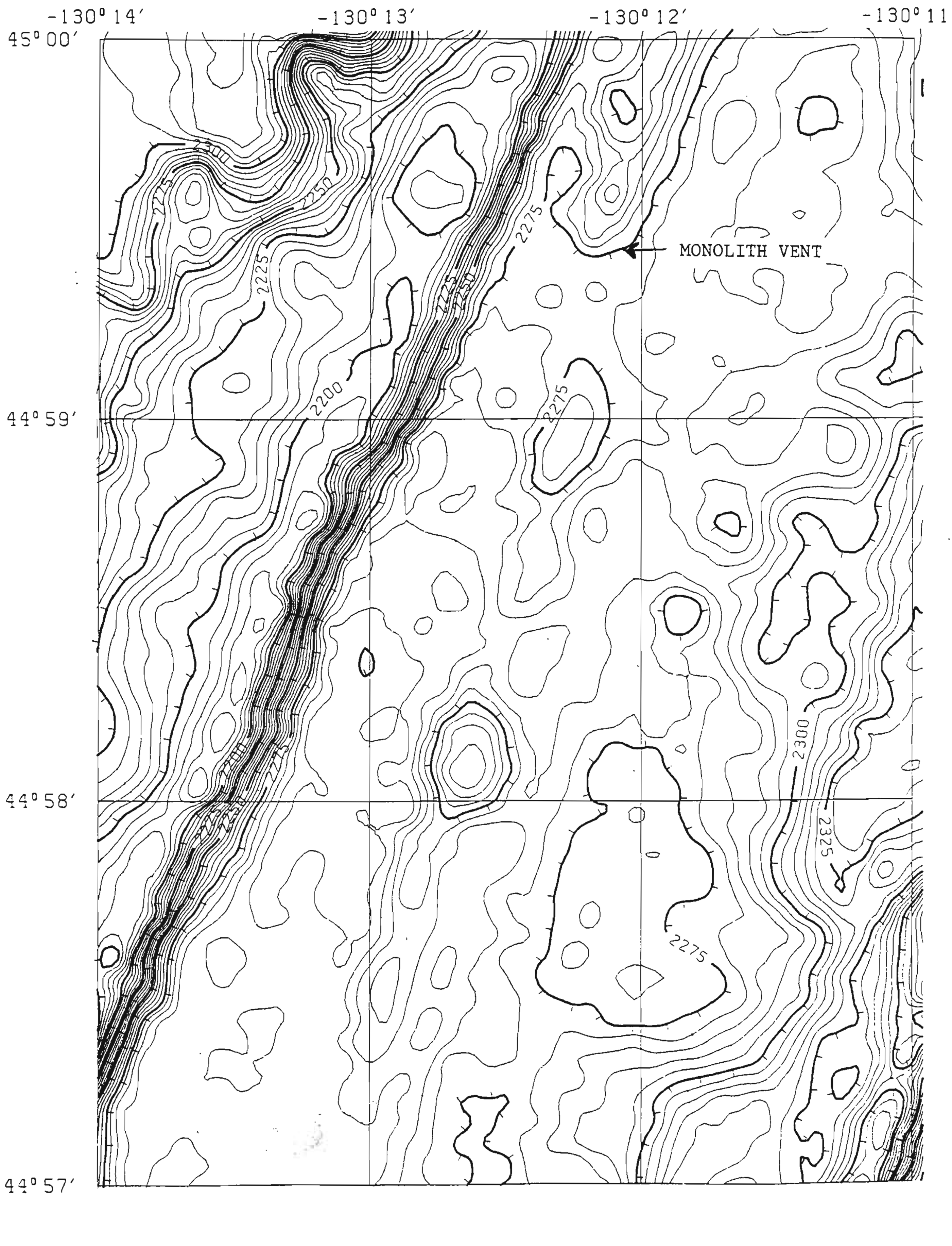


FIG 3



-130° 14′
-130° 13′
-130° 12′
-130° 11′
45° 00′
44° 59′
44° 58′
44° 57′
MONOLITH VENT
2300
2275
2250
2225
2200
2325