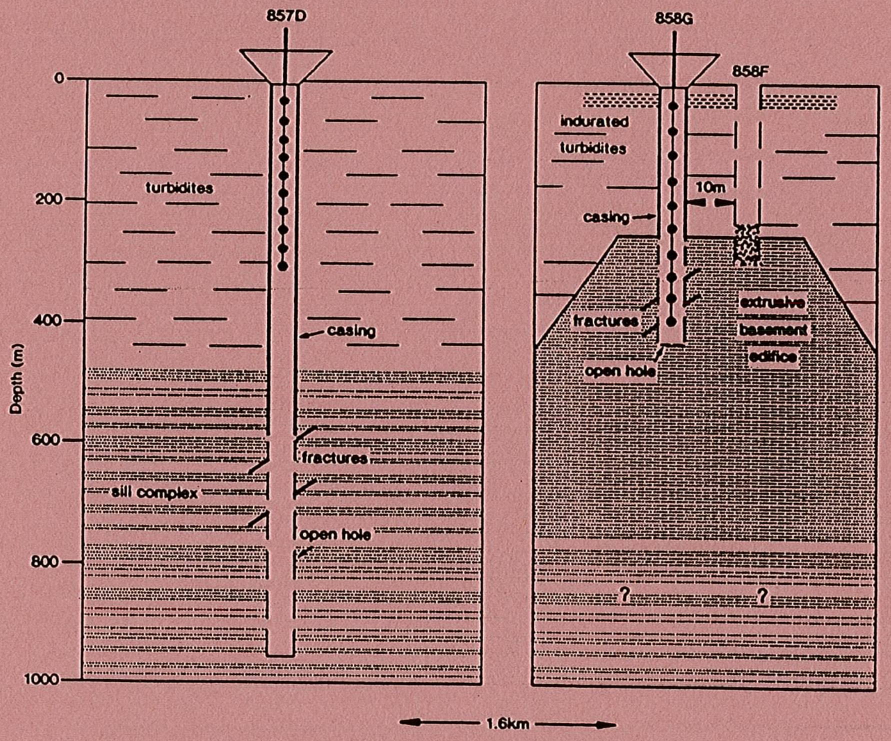
SEDIMENT COVERED OCEAN RIDGE EXPERIMENTS (SCORE)

Report of a workshop sponsored by RIDGE/USSAC

July 29-30, Portland, Oregon



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INTRODUCTION

The Sediment Covered Ocean Ridge Experiments (SCORE) workshop was held July 29-30 in Portland, OR. The purpose of the workshop was to determine and prioritize the pre- and post-drilling observations and experiments that would maximize the scientific return from oceanic drilling on sedimented ridges. The proposal for a second leg of ODP drilling to address hydrothermal circulation and massive sulfide mineralization at the Middle Valley and Escanaba Trough sedimented ridges (SR II) has been highly ranked by LITHP and SGPP, and has been included in the 1996 prospectus. The scientific community represented by RIDGE in the U.S. and by InterRidge internationally is also interested in the scientific drilling and the associated research opportunities presented by SR II. This drilling provides an excellent opportunity to extend the function of the drill ship beyond observation to active experimentation. Drilling in the active hydrothermal field in Middle Valley on Leg 139 (SR I) demonstrated that drilling-induced disturbances could provide important information on properties controlling hydrothermal circulation, including pore pressure and permeability. Pre- and post-drilling monitoring and sampling in the active hydrothermal fields will document hydrologic, geochemical, and biological changes induced by drilling, allowing new insights on processes controlling hydrothermal circulation.

These new opportunities extend beyond the experience the Ocean Drilling Program and require careful planning to maximize the scientific return from the drilling. Consequently, a small workshop was planned to determine the observations, experiments and equipment needed to take advantage of this opportunity. The workshop brought together a multidisciplinary group (Appendix 1) drawing primarily on the expertise within the RIDGE and the ODP communities. The agenda for the meeting included one day of overview presentations and group discussions to provide the participants with a common working knowledge of the geology, geophysics, geochemistry, and biology of the proposed drill sites. The second day of the meeting was dedicated to group discussion focused on the planning and prioritization of pre- and post-drilling research opportunities.

Leg 139 was designed to investigate the large scale hydrothermal circulation in Middle Valley, a sediment-covered abandoned spreading center at the northern end of the Juan de Fuca Ridge. The leg also made important contributions to our understanding of the nature of oceanic crust formed at sediment-covered spreading centers, the nature of hydrothermal alteration of both igneous and sedimentary protoliths, and the deposition and alteration of massive sulfide deposits. SR II will focus more specifically on the formation of massive sulfide deposits and the tectonic controls on fluid flow in hydrothermal upflow zones.

BACKGROUND

Middle Valley

Middle Valley lies at the northern end of the Juan de Fuca spreading system forming one leg of a RTT unstable triple junction with the Solvanco fracture zone and the Nootka fault (Fig. 1). The tectonic setting of Middle Valley is described by Davis and Villinger (1992). Middle Valley is a medium rate spreading center (58 mm/yr), but the proximity to the cold Explorer plate results in a reduced magma supply and a slow-spreading-ridge morphology with a deep and wide axial trough. A ridge jump is in progress and current magmatic activity is shifting to the West Valley spreading center. Proximity of the Middle Valley spreading center to an abundant supply of terrigenous sediment during the Pleistocene low stand of sea level has resulted in burial of the spreading center by 200 to >1000 m of turbiditic and hemipelagic sediment with sediment thickness increasing towards the north. Two main areas are targeted for drilling (Fig. 1), the Dead Dog vent field in the Area of Active Venting (Site 858) and the Bent Hill area (Site 856).

Dead Dog Vent Field

The principal center of hydrothermal activity in Middle Valley is the Dead Dog vent field (Fig. 2). Contoured heat flow values show a concentric high which is coincident with a side scan acoustic anomaly that outlines the vent field. The vent field contains at least 20 active vents with temperatures ranging up to 276°C (Ames et al., 1993). Active vents occur predominantly on top of 5-18 m high, sediment covered mounds a few tens of meters in diameter. The vent fluid composition indicates interaction of hydrothermal fluid with both basaltic and sedimentary rock. Hydrothermal chimneys are predominantly composed of anhydrite with only minor amounts Mg-rich phyllosilicates and sulfide minerals. Seismic profiles across the vent field show it is located about 2 km east of a prominent basement fault (858 fault of Rohr and Schmidt, 1994). Sediment cover on the fault block in the area surrounding the vent field is approximately 450 m which overlies a sill-sediment complex that forms the transition to oceanic crust (Davis et al., 1992). However, hard acoustic reflectors that occur only immediately beneath the vent field were confirmed by drilling to be the top of a volcanic edifice at only 250 m depth. The presence of more permeable volcanic basement penetrating up into the sediment cover acts as a chimney to focus the flow of hydrothermal fluid to the sea floor (Davis and Fisher, 1994).

Vent specific fauna are not particularly abundant and are restricted to small areas throughout the vent field. Despite the fact that vent organisms are rather inconspicuous relative to most vent sites, the Dead Dog vent field is the most specious vent site known (Juniper et al., 1992). A minimum of 25 new endemic species have been described even though the total number of organisms collected is only a fraction of those from more extensively studied sites, such as the southern Juan de Fuca Ridge.

Bent Hill

Bent Hill is one of a string of small topographic highs that run parallel to the eastern rift bounding normal fault scarp (Fig. 1). These bathymetric highs include volcanic cones to the south, where sediment cover thins, and uplifted sediment hills to the north. These features lie close to a normal fault that offsets basement reflectors, but near surface sediment layering appears to be continuous across this fault. The transition from essentially non-magnetic oceanic crust that typifies the center of Middle Valley to crust with normal levels of magnetization passes through this area and probably marks the boundary between normal extrusive basalt and the sill-sediment complex that forms the upper oceanic crust in the center of Middle Valley (Currie and Davis, 1994). Bent Hill is a roughly circular feature 400 m in diameter that has been recently uplifted by approximately 50 m (Fig. 3). It is bounded on the west by a steep scarp that parallels the rift-bounding faults and exposes semi-consolidated turbiditic sediment. A very primitive olivine-rich sill, which is petrogenetically distinct from the diabases and basalts recovered by drilling elsewhere in Middle Valley, was recovered at the base of the two drill holes that penetrate Bent Hill (Fig. 3).

A ridge of massive sulfide that rises 35 m above the surrounding turbidite fill of the valley is located approximate 100 m south of the southern edge of Bent Hill and is referred to as the Bent Hill deposit (Fig. 3). The massive sulfide mound is highly weathered to iron oxyhydroxides and partially sediment buried. Massive sulfide extends a minimum distance of 60 m N-S and 90 m E-W. Hole 856H penetrated 94 m of massive sulfide (Fig. 3) before the hole had to be abandoned due to inflow of heavy sulfide sand from the upper weathered section of the deposit. A strong near-bottom magnetic anomaly over this mound is related to late stage hydrothermal alteration of pyrrhotite to pyrite plus magnetite and has been modeled to suggest that mineralization continues at least another 30 m below the level drilled and possibly much deeper (Tivey, 1994).

A second mound of massive sulfide occurs approximately 300 m further south and is referred to as the Sunnyside Up deposit (Fig 3). The morphology, degree of oxidation, and sediment cover indicate that this deposit is younger than the Bent Hill deposit. A single 264°C hydrothermal vent is present on the north flank of this deposit. Contoured heat flow values for the Bent Hill area show high values centered around this active vent. The composition of the vent fluids is distinguished from those at the Dead Dog vent field by having a chloride content significantly below that of seawater as opposed to the slightly elevated chloride contents that characterize the main vent field.

Escanaba Trough

The Gorda Ridge spreading center is located offshore of Oregon and northern California and is bounded by the Mendocino Fracture Zone on the south and the Blanco Fracture Zone on the north (Fig. 1). A small offset in the spreading axis at 41° 40' N latitude marks the northern boundary of Escanaba Trough, which forms the southernmost part of Gorda Ridge. Escanaba Trough is opening at a total rate of approximately 24 mm/yr and has a morphology consistent with the slow spreading rate. The axial valley, which is at a depth of 3,300 m, increases in width from about 5 km at the north end to more than 15 km near the intersection with the Mendocino Fracture Zone.

South of 41° 17′ N latitude, the axial valley of Escanaba Trough is filled with several hundred meters of turbiditic sediment. The sedimentary cover thickens southward and is a kilometer or more in thickness near the Mendocino Fracture Zone. Turbiditic sediment enters the trough at the southern end and is channeled northward by the axial valley walls (Vallier et al., 1973; Normark et al., 1994). Sedimentation was relatively rapid (up to 25 mm yr^{-1}) during low stands of sea level in the Pleistocene, and the entire sediment fill of the trough probably was deposited within the last 100,000 years (Normark et al., 1994; Davis and Becker, 1994a).

Seismic reflection surveys show that the floor of Escanaba Trough is generally a smooth, flat plain underlain by continuous and relatively undisturbed turbidites (Davis and Becker; 1994a; Morton and Fox, 1994). However, local areas along the axis of spreading have irregular sea floor topography characterized by circular hills 0.5 to 1.2 km in diameter that are uplifted 50 to 120 m above the surrounding sea floor. The sediment cover in these areas is described as moderately to highly disturbed based on the discontinuity or absence of seismic reflectors (Morton and Fox, 1994). Morton et al. (1994) mapped the distribution of the topographically rough, seismically disturbed zones, which typically are 3 to 6 km wide, oval-shaped areas aligned along the spreading axis. The strongly disturbed zones are also areas of high heat flow (Davis and Becker, 1994a).

The areas of sediment disruption are sites of recent axial-rift igneous activity. The geologic and geophysical evidence suggests that axial-rift igneous activity at these sites is manifested by intrusion of dikes, sills, and laccoliths into the sediment with less abundant volcanic flows (Morton and Fox, 1994; Zierenberg et al, 1993, 1994). Sulfide mineralization has been sampled by dredging, sediment coring, or submersible at four igneous centers within the sediment-covered part of Escanaba Trough. The NESCA area (Fig. 4) contains several large massive sulfide deposits including an area of active hydrothermal venting.

The massive sulfide deposits on the western and southeastern flanks of the Central Hill in the NESCA area are actively venting hydrothermal fluid, and the area on the northern flank shows indications of very recent hydrothermal activity, suggesting that these deposits are all part of the same hydrothermal system. An extensive area of massive sulfide is exposed on the north slope of the Central Hill. Massive sulfide extends more than 270 m from north to south and more than 100 m from east to west, but the western edge has not been determined. An adjacent area is characterized by abundant, closely spaced sulfide mounds typically 20 to 60 m in diameter and 5 to 10 m high. Two mounds were observed to actively discharge high-temperature hydrothermal fluid; one near the eastern margin of the sulfide area was venting 217°C fluid, and one on the western edge of the explored area was venting 108°C fluid. Even though these mounds are 275 m apart, the major-element composition of the end-member fluid at each vent is identical (Campbell and others, 1994), a result that is consistent with the hypothesis that this large mineralized area is a single hydrothermal system hydrologically interconnected at depth.

Several areas of low temperature venting have been observed which support extensive communities of tube worms and clams. Vent faunal distributions have not been systematically mapped. Preliminary observations on the faunal assemblage present in Escanaba Trough are presented in Van Dover et al. (1990).

RECOMMENDATIONS FOR MIDDLE VALLEY

The extensive existing data set available for Middle Valley provide most of the necessary information to plan and execute the pre- and post-drilling observations recommended for this area. The drilling transects in both the Dead Dog vent field and the Bent Hill area require some holes to be positioned to within a few tens of meters to meet the scientific objectives. Existing submersible and ROV mapping allow identification of drill targets at this scale. However, previous work was performed in acoustic transponder networks that have not been maintained. Easily locatable land marks, including drill holes and hydrothermal vents, will allow correlation of earlier maps to future work. A transponder grid is also required for production of a map of hydrothermal vent fauna that can be co-registered with physical features of the vent field in a Geographic Information System (GIS). Without such a map, it will not be possible to quantify biological response to drilling induced changes in hydrothermal flow. In order to minimize the time-consumptive use of the drill ship camera system to locate drilling targets, a net of seafloor transponders needs to be emplaced and maintained for the period covering the pre- and post-drilling observations. ODP positioning beacons should be placed within the transponder net at both the Dead Dog vent field and the Bent Hill sulfide deposit prior to drilling to allow precise location of the drill targets, relative to the beacon, by submersible or ROV.

A high resolution heat flow, piston coring, and pore pressure experiment in the Dead Dog vent field proposed by Fisher, Langseth, and Baker has been funded. The grid of measurements proposed in this study will be controlled by transponder navigation. Cruise plans include placing of ODP beacons within this transponder net. The results of this study will provide an important constraint on the detailed location of an Advanced Piston Core (APC) transect across the Dead Dog mound that is designed to investigate the small scale hydrology of the vent field and the formation of the mounds that host the active hydrothermal vents.

Vent fluids were sampled in the Dead Dog vent field in 1990 using the Alvin submersible. Vent fluids were collected in 1991 and 1992, but these samples were too highly diluted with seawater to provide useful information on temporal changes in fluid composition. It will not be possible to evaluate any drilling-induced changes in the hydrothermal fluid compositions unless a time series of samples can be obtained prior to the next drilling leg. Vent fluid compositions of samples collected from several vents within the Dead Dog vent field are similar, but are substantially different from fluids collected from the single vent located south of Bent Hill. This isolated vent has a salinity that is 24% lower than ambient seawater, whereas the Dead Dog vents have chloride values that are elevated by about 7% relative to sea water (Butterfield et al., 1994). Vent temperatures are near 265° C at both sites and are well below the phase separation boundary. The nature and persistence of this salinity difference is unknown. The role of phase separation in forming these fluids can be best tested by the abundance and isotopic composition of dissolved gasses in the hydrothermal fluid. Unfortunately, gas-tight sample bottles were not available at the time of the previous dives. The Middle Valley vent fluids are clearly gas rich, as indicated by the low volumes of fluid recovered in the

Ti syringe major element samplers. Sampling of hydrothermal fluids prior to drilling to establish a time series baseline for evaluation of drilling-induced changes is clearly a high priority goal for evaluating the effects of drilling on hydrothermal fluid flow. Gas-tight samplers are needed to determine the volatile contents and compositions of the fluids. Post-drilling sampling of vent fluids will obviously be required to delineate drilling-induced changes in the hydrothermal field.

Fluid sampling will also provide the opportunity to install monitoring devices for recording, at minimum, fluid temperature and flux prior to drilling to evaluate drilling-induced changes in hydrothermal fluid flow. Knowledge of these first order variables is essential if we hope to quantify any changes in hydrothermal circulation that may result from drilling. Several appropriate systems have been developed for monitoring and recording changes in the hydrothermal flow. If drilling is scheduled for 1996, many of the instruments designed for monitoring the TAG hydrothermal field may be available for redeployment in Middle Valley. Instruments can be recovered during the post-drilling sampling of vent fluids.

In addition to the pre- and post-drilling observations needed to characterize changes in the vent field, the workshop discussed some direct experimentation that could be incorporated into the drilling plan. Measurements from the CORKed holes in Middle Valley indicate that introduction of cold seawater into the hot formation at Middle Valley will lead to an approximately 1MPa overpressure relative to *in situ* pore pressure. This pressure change is comparable to the change caused by deep man-made lakes which are known to induce earthquakes. If we assume that the rocks near the ridge axis are in a tensional state near failure by normal faulting, then the increased pore pressure should induce localized failure detectable by OBS. This presents a fascinating opportunity to investigate the geometry and mechanism of faulting in a hydrothermally active ridge environment. An OBS array should be deployed prior to drilling to assess natural seismicity and should continue recording during and after drilling to monitor drilling induced seismicity.

One of the most exciting results of the workshop was the realization that a hole-to-hole hydrologic experiment to assess the lateral permeability at the km-scale was technically feasible. Calculations based on measured pore pressure and permeability in the two CORKed and instrumented holes in Middle Valley indicate the overpressure induced by introduction of cold seawater into Hole 857D during drilling to deepen this hole should be observable as a perturbation that can be monitored in Hole 858G. Prior to sealing hole 857D with the CORK, the formation was accepting surface sea water at a rate in excess of 10,000 l/min (Davis et al., 1992). This flow will be restimulated for the few days interval when Hole 857D is unCORKed prior to deepening and logging. This hole will then be reCORKed ending a brief transient pressure pulse that should be of sufficient amplitude to be observable in the pressures recorded at the reCORKed Hole 858G 1.6 km away. If successful, the results of this experiment would provide the first determination of the lateral permeability in a seafloor hydrothermal system at the scale of a hydrothermal convection cell. Conducting this experiment requires a change in the drilling plan outlined in the SR II proposal. Hole 858G will need to be reinstrumented and resealed prior to other drilling near the vent field. Hole 858G should be equipped with an acoustic data link so that the pressure field within this hole can be monitored in real time to determine the optimum timing of other drilling in the area. The experiment outlined in the current SR II proposal, which would leave Hole 858G unCORKed for use as a point source vent that is cased directly to basement bypassing the flow path through the sediment section taken by natural vent fluids, should be postponed until after the batteries in the data logger have expired, at which point the hole will be unCORKed by submersible or ROV.

RECOMMENDATIONS FOR ESCANABA TROUGH

High resolution spatial-temporal characterization of active seafloor hydrothermal systems is an essential component of optimizing the effectiveness of drilling such a system. Drilling should be considered as a highly controlled perturbation experiment with the potential to substantially improve our understanding of the controls on fluid flow. Pre- and post-drilling characterization of the hydrothermal system are required if we are to utilize drilling induced perturbations as an experimental tool. The geologic data base for Escanaba Trough is not as extensive as that for Middle Valley. A notable gap in the Escanaba data is the lack of side scan sonar data other than the low resolution GLORIA map.

The highest priority need for maximizing the scientific return from drilling at Escanaba Trough is to obtain better mapping to determine the extent of hydrothermal activity and to understand the local tectonic controls on hydrothermal activity. The seafloor mapping in the immediate area of the drilling targets is sufficient to both ensure that drilling is technically feasible and that there is high probability of successfully achieving the objectives for drilling stated in the SR II proposal. However, knowledge of the geological and structural setting of the area outside the immediate drill area is limited. In particular the boundaries of the hydrothermal areas have not been defined and the distribution of vent fauna is not known outside of the vent area.

Deep-towed seafloor swath mapping capabilities are now available that can collect simultaneous bathymetry/sidescan back scatter data at meter-scale resolution. The entire area of the NESCA igneous center could be mapped in approximately four days. Subsequent photographic surveys focused on known and newly discovered hydrothermal vent fields should be conducted by either a towed system or ROV, necessitating deployment of a seafloor transponder net and use of a dynamically positioned ship. A single cruise would be sufficient to map the surface extent of hydrothermal deposits and vent fauna as well as provide information on the geological and structural setting of the area surrounding the drill site. Because sufficient detailed mapping exists to site drilling within the main hydrothermal field, mapping of the NESCA area could be delayed until after drilling if required by the realities of ship schedules and availability of research funds. However, it would obviously be advantageous to conduct this work prior to drilling so that the locations of drill sites could be fine tuned to maximize their effectiveness. Furthermore, it is essential to carry out this type of survey prior to drilling if we are to effectively monitor drilling-induced changes in the venting or biological communities on a scale larger than a few tens of meters.

Smaller scale mapping of the Escanaba Trough is also highly desirable to place the NESCA site into regional context. The U.S. Geological Survey has a strong interest in producing a 30 kHz side scan sonar map of the Escanaba Trough. There are plans to fund a cruise to this area in the summer of 1995 using a newly developed side-scan sonar system. Because this system has not completed deep water testing, the cruise plans remain preliminary at the time this workshop report was produced. Limited funding for this program may require the U.S.G.S. to seek additional support in terms of shared ship and(or) instrument time to ensure that the cruise is scheduled and that there are adequate time and resources for successfully mapping Escanaba Trough.

Vent fluids were sampled at Escanaba Trough in 1988 (Campbell et al., 1994). No gas-tight samplers were used, so the content and composition of dissolved gas in the vent fluids is poorly constrained. Samples collected with the major element Ti syringes were very gas-rich and clearly leaked on the ascent to the surface. Nevertheless, the isotopic ratios of both He (Campbell et al., 1994) and CO_2 (B. Taylor, pers. comm.) indicated a primarily magmatic source for the gases, in distinct contrast to Middle Valley where CO_2 and CH_4 are derived from organic carbon sources (Taylor, 1990). The two highest priorities for fluid sampling at Escanaba Trough are to collect vent fluids for major and minor element compositions in order to establish a base line time series against which post-drilling fluid samples can be compared to evaluate drilling-induced changes, and to collect samples for analysis of dissolved gas in the hydrothermal fluid.

One re-entry hole is planned for the area of the hydrothermal vents. This hole is intended to penetrate into igneous basement rocks. The present drilling plan does not call for instrumenting this hole due to the high cost, both in terms of drill time and ODP operational funds, necessary to install a CORK. Regardless of whether this hole is left open or sealed, it represents a hydrologic experiment and a potential perturbation of the hydrothermal field. Therefore, if opportunities arise for sampling vent fluids and biota prior to drilling, it would be highly desirable to install instrumentation to monitor vent temperature and flux before, during and after drilling. Instrument recovery in the period after drilling will be coordinated with resampling of hydrothermal fluids and remapping of faunal distribution to quantify any drilling-induced changes.

Several other pre-drilling observations are highly desirable, although of a lower priority, for characterizing the Escanaba Trough drilling site. A more detailed grid of high resolution seismic lines over the drill site would help constrain the location and orientation of near-surface faulting that is interpreted to control fluid flow in the shallow subsurface. Furthermore, the nature, depth, and extent of high amplitude seismic reflectors interpreted to be basaltic sills are poorly constrained by the present seismic data and could be potentially useful in refining the position of drill holes to achieve maximum penetration beneath the massive sulfide deposit. A grid of heat flow measurements across the drill site would provide information on the present configuration of hydrothermal discharge. On-bottom gravity measurements at Middle Valley both localize and constrain the subsurface extent of massive sulfide mineralization. A transect of on-bottom gravity measurements at Escanaba Trough might similarly help to define the areas of thickest subsurface accumulation of massive sulfide. Near-bottom magnetic profiles across the area of massive sulfide in Middle Valley show strong anomalies in response to alteration of pyrrhotite to pyrite plus magnetite in the core of the system. Massive sulfide samples collected from outcrops at Escanaba Trough have a primary mineralogy dominated by non-magnetic hexagonal pyrrhotite; therefore a magnetic survey is unlikely to outline areas of sulfide mineralization unless there has been significant alteration to monoclinic pyrrhotite or magnetite. However, no near-bottom magnetic data presently exist for Escanaba Trough.

A final recommendation for the Escanaba Trough site is that a net of seafloor transponders be emplaced and maintained through out the pre- and post-drilling period. A transponder network would be required for the production of an accurate map of hydrothermal vent fauna that can be co-registrared with physical features of the vent field in a GIS based map. An ODP beacon should be installed and located within this net to ensure that a minimum amount of drill ship time is utilized in camera surveys searching for appropriate drill sites. The working group considers this to be a very high priority.

BIOLOGICAL CONSIDERATIONS OF SR II DRILLING

The SCORE workshop provided an important opportunity for hydrothermal vent biologists to interact with scientists involved in ocean drilling in a workshop setting. It became quickly evident that biologists could benefit from involvement in the Sedimented Ridges drilling program. Firstly, even without direct participation in drilling legs, biologists could expand their approach and understanding of hydrothermal ecosystems by studying drill sites and incorporating drilling results into their analyses. Secondly, a number of unique experimental and sampling opportunities are available to biologists through active participation in the drilling legs and associated monitoring. Finally, since vent organisms are the most immediate expression of the full range of surficial venting, interpretation of their distribution patterns should contribute to subsurface interpretations.

Data on the sub-seafloor constraints on hydrothermal circulation obtained by drilling will provide important information on the fundamental control of vent organism distribution. At present, we have only a two-dimensional view of community patterning.

It will be an exciting challenge to scale up ecological questions to match this expanded understanding of vent field hydrothermal processes. Characterization of the distribution of zones of high sub-floor permeability and location of hydrothermally sealed zones that obstruct fluid flow will provide information on the controls of biological colonization and their likely longevity. It will be useful to explore and predict links between long-term changes in hydrology and the stability of vent fauna populations and vent community structure.

Longevity and continuity of hydrothermal activity have been proposed as important factors controlling biodiversity in vent communities. Sustained hydrothermal activity at sites such as Middle Valley permits, on one level, colonization of the site by a large suite of organisms adapted to vent habitats, and on another level, the development *in situ* of new vent species. Drilling results such as recovery of paleo vent communities within drill cores (Davis et al., 1992) and dating of major active and inactive sulfide deposits will therefore be of great interest to biologists.

Opportunities for direct participation in drilling legs

Recent observations of the ejection of large quantities of microbe-rich particulates following dike injection events raise the question of the extent of subsurface microbial production. The depth of a subsurface biosphere remains to be determined. A letter of intent outlining the rationale and strategies for a drilling leg dedicated to investigating this frontier area has been submitted to the JOIDES office (Delaney et al., 1994). A systematic study of the vertical extent of subseafloor growth will likely require some tool and procedural development, and eventually dedicated drilling legs. Sedimented Ridges drilling will provide an opportunity to develop and test a sampling protocol in advance of a leg dedicated to investigation of the base of the biosphere. Some progress in tool and procedural development could be made through participation of microbiologists in the Middle Valley and Escanaba drilling programs. Additionally, the retrieval of the thermistor strings and sampling tubes from the two CORKed holes in Middle Valley presents a unique opportunity to sample any thermophilic bacteria that might have colonized these surfaces because the temperature and pressure conditions have been measured and the ambient fluid will be directly sampled.

More traditional opportunities for microbiologists to study the impact of hydrothermal activity on biogeochemical processes within the sediment blanket that covers ridge crest basalt will also be presented by the proposed drilling. Shallow holes and piston coring will provide samples for study of microbial biomass and activity within the first few tens of meters of sediment. This can be complemented by sampling of sediments outside the vent fields. The indurated capping layer observed at 20-30 m depth within the active vent field at Middle Valley may be a result of methane oxidation and carbonate deposition (Baker et al., 1994). Since drilling strategy includes attempts to specifically sample this layer, there is an interest in examining the possible role of microorganisms in its formation. Planned sampling of fluids in the bore hole at 858G, and future uncapping of the hole, provide opportunities to sample fluids unaffected by passage through the sediment blanket and transformation by microbial processes. Comparison with samples from nearby chimneys and diffuse flow sights could provide some insight into the importance of sediment microbial processes in modifying fluid chemistry.

There is an opportunity to establish a sedimented ridges biological observatory at Middle Valley, in the active vent field. The CORKs at Holes 858G and 857D, when refitted with new thermistor strings, pressure transducers and acoustic modems will permit long-term monitoring of hydrothermal fluid supply to the vent field. Coupled with periodic re-mapping of organism distribution and heat flow, this monitoring system is a potentially powerful tool for studying the influence of variability in hydrothermal activity on vent communities. The proposed two-hole experiment involving Holes 857D and 858G effectively represents the controlled manipulation of an entire hydrothermal system. This offers an excellent opportunity to study the effects of sub-surface hydrological variations on fluid supply to vent communities such as bivalve beds, and the consequences for vent organisms, including behavioral and biochemical responses.

By comparison to Middle Valley, data on the distribution and faunal composition of Escanaba Trough vent organisms is sparse. Dense clumps of tube worms with associated anemones, paralvinellid and ampharetid polychaetes, lepetodrilid limpets, coiled gastropods, pycnogonids, copepods, and tanaid crustaceans were observed at several sites (Van Dover et al., 1990). Clusters of large bivalves were observed associated with some areas of low temperature venting. Grab samples of vent biota were collected during Alvin and Sea Cliff dive programs in 1988. However, the vent fauna have not been systematically collected or mapped at Escanaba Trough. It will therefore be impossible to quantitatively monitor any changes in the hydrothermal communities in response to drilling from the present state of knowledge at this site. Any future mapping and sampling efforts in this area must include a serious effort to quantify the species distribution and habitat requirements of the hydrothermal assemblages if we hope to detect drilling-induced changes. Ideally, these maps would be controlled within a transponder net and should be part of a GIS-based data set that includes the physical features of the sea floor and the distribution of hydrothermal venting. The availability of suitable research platforms and appropriate scientific personnel make adequate characterization of this vent field unlikely in the time available before drilling, but any additional information will improve our understanding of this site.

The possible environmental impact of drilling activities on vent specific fauna was extensively discussed at the workshop. Initial concerns were mostly based on the observation of at least 25 new species of vent endemic animals in a highly restricted area at the Middle Valley site. It is not known if any other populations exist to repopulate a colony annihilated by drilling. The 1991 MV drilling avoided sensitive areas and did not use drilling mud; subsequent biological impact appeared to be minimal. Drilling of massive sulfide at the Bent Hill site in Middle Valley and in Escanaba Trough may require the use of drilling mud to clear high density sulfide cutting from the drill holes. It is not presently possible to predict the effects of drilling mud on what may be an endemic faunal community, but filter feeding organisms are likely to be impacted. Estimates of the amount of sediment deposited in the vicinity of the drill holes are needed and can best be provided by deployment of sediment traps and post-drilling sea floor observations in the Bent Hill area, which is not known to contain endemic species. Pending an evaluation of the results from this site, it is recommended that the use of drilling mud be kept to a minimum in areas of active hydrothermal venting that may contain endemic species.

SUMMARY OF HIGH PRIORITY RECOMMENDATIONS

Middle Valley

- A net of seafloor transponders needs to be emplaced and maintained for the period covering the pre- and post-drilling observations. ODP positioning beacons should be placed within the transponder net at both the Dead Dog vent field and the Bent Hill sulfide deposit prior to drilling.
- Hydrothermal fluids need to be sampled prior to drilling to establish a time series baseline for evaluation of drilling induced changes. Gas-tight samplers are needed to determine the volatile contents and compositions of the fluids.
- Monitoring devices for recording, at minimum, fluid temperature and flux should be emplaced in the vent field prior to drilling to evaluate drilling-induced changes in hydrothermal fluid flow.
- An OBS array should be deployed prior to drilling to assess natural seismicity and should continue recording during and after drilling to monitor drilling-induced seismicity.
- A hole-to-hole hydrologic experiment should be conducted using the overpressure induced by introduction of cold seawater into Hole 857D during drilling as a perturbation

that can be monitored in Hole 858G. This requires the drilling plan proposed in SR II be changed to reinstrument and reseal Hole 858G prior to drilling near the vent field. Hole 858G should be equipped with an acoustic data link so that the pressure field within this hole can be monitored in real time to determine the optimum timing of other drilling in the area.

Escanaba Trough

- High-resolution deep towed swath mapping using a system capable of collecting co-registered bathymetry and sidescan backscatter imagery should cover the extended area of the Escanaba Trough drill sites.
- Photomosaic coverage of the immediate area of the drill sites is needed to establish the extent of hydrothermally discharge, the distribution of vent-specific fauna, and to facilitate exact placement of the drill holes to both maximize scientific return and minimize drilling difficulties.
- A net of seafloor transponders needs to be emplaced and maintained for the period covering the pre- and post-drilling observations. ODP positioning beacons should be placed within the transponder net prior to drilling.
- Hydrothermal fluids need to be sampled prior to drilling to establish a time series baseline for evaluation of drilling-induced changes. Gas-tight samplers are needed to determine the volatile contents and compositions of the fluids.
- Monitoring devices for recording, at minimum, fluid temperature and flux should be emplaced in the vent field prior to drilling to evaluate drilling-induced changes in hydrothermal fluid flow.
- Insufficient data are available at present to locate and identify endemic vent fauna at Escanaba Trough that could be adversely affected by drilling. Detecting drilling-induced changes in faunal assemblages or populations at this site will require an extensive effort to map and sample vent fauna prior to drilling. Use of drilling mud

should be minimized in the vicinity of sensitive vent communities because of possible adverse effects on filter-feeding organisms.

The working group also discussed the potential availability of research vessels and equipment for the period that precedes drilling. There is serious concern that the UNOLS ships with dynamic positioning capabilities necessary for high resolution photomosaicing of the hydrothermal field will be unavailable prior to drilling due to commitments in the Indian Ocean. A scheduled maintenance period for the Alvin submersible in 1996 could also have a serious impact on proposals to sample hydrothermal fluids and to map and sample vent fauna. The cooperation of the international scientific community will be needed to successfully complete the pre-drilling sampling and mapping that will best enhance the results of drilling. The working group recommends that the InterRidge and ODP programs encourage and coordinate research cruises in these areas so that scientific return from drilling can be maximized. If the second leg of Sedimented Ridges drilling is scheduled, it will present an unparalleled opportunity for a multinational, multidisciplinary research effort that embodies the spirit of ODP and InterRidge programs which seek increased understanding of our world through examination of the interrelated processes that do not recognize our national or disciplinary boundaries.

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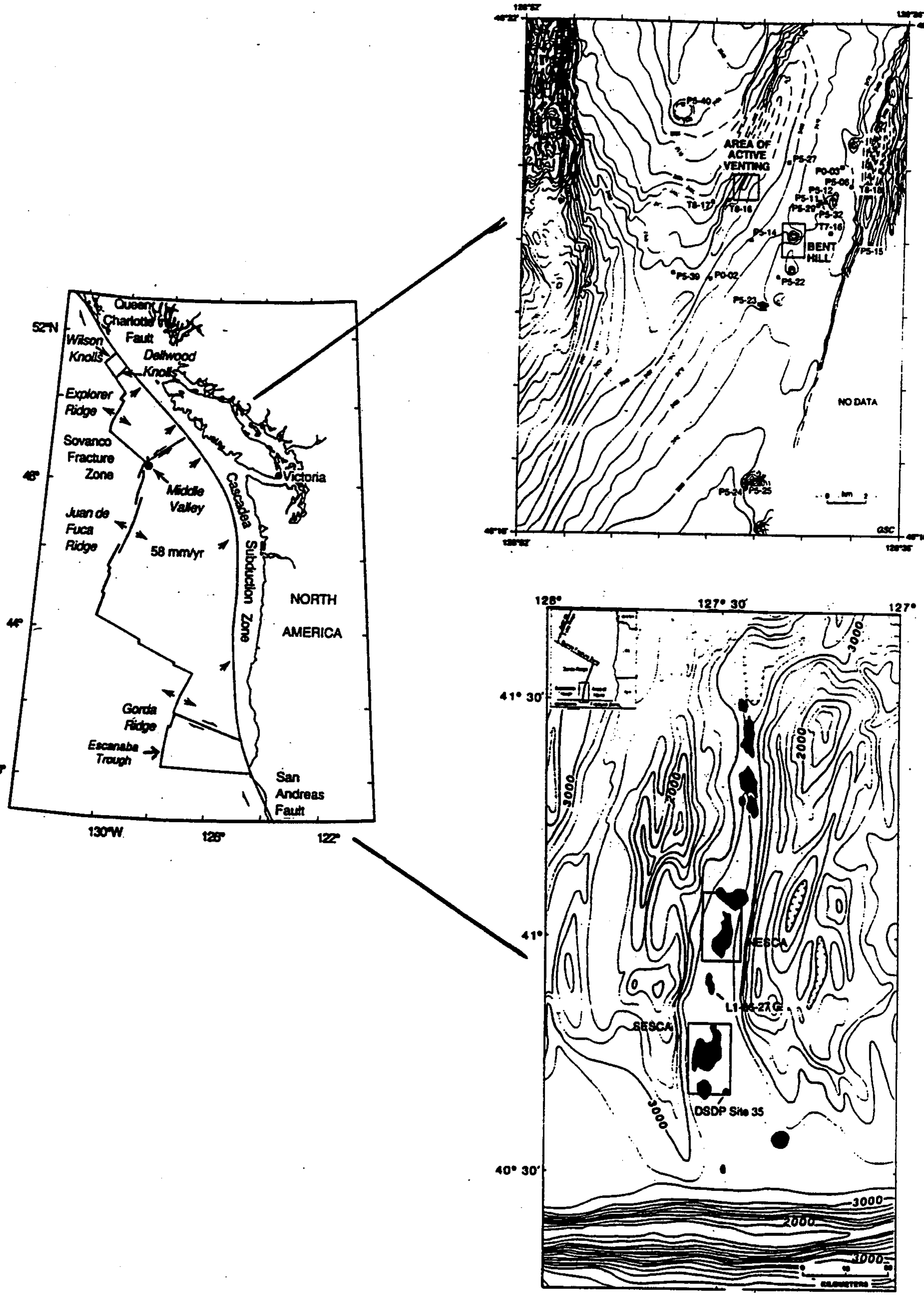

Fig. 1 Location map showing the tectonic setting of the sediment-covered spreading centers at Middle Valley and Escanaba Trough on the Juan de Fuca-Gorda Spreading system. Bathymetry of Middle Valley shown as contours drawn at 50-m intervals. Areas of proposed drilling are the Dead Dog vent field (Site 858) in the Area of Active Venting and Bent Hill (Site 856). Bathymetry of Escanaba Trough shown at 200-m intervals. Black areas are the igneous centers. Proposed drill sites are within the NESCA area. Location of DSDP Site 35 is shown.

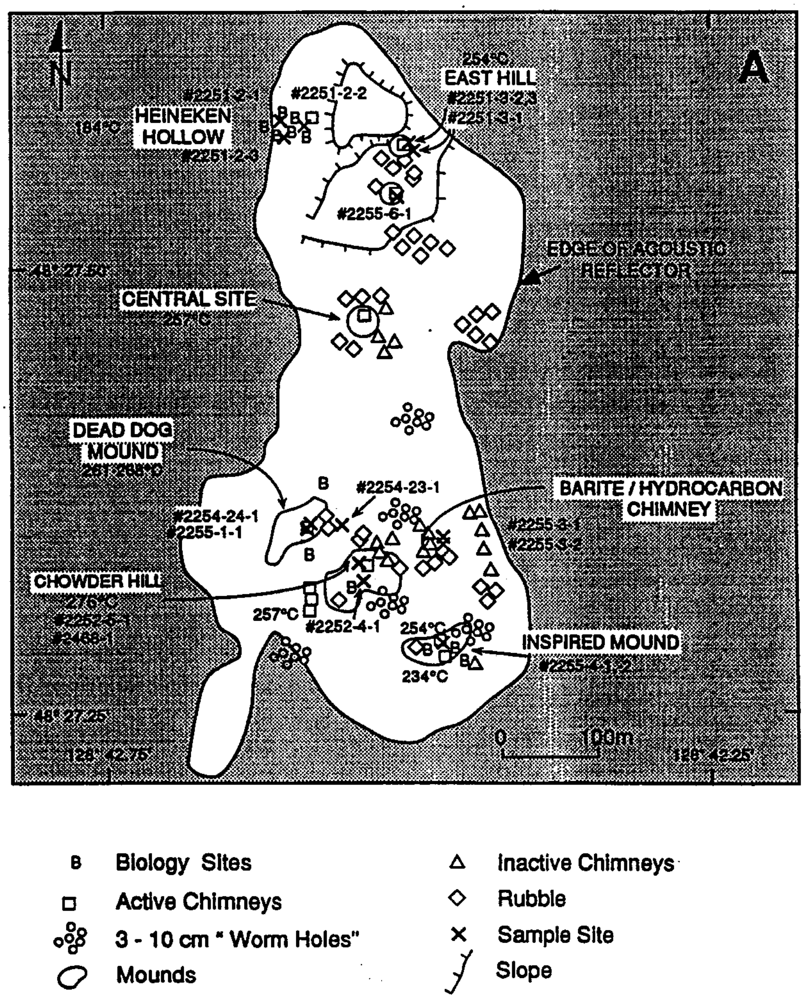

Fig. 2 Bottom-Map of Dead Dog vent field showing the location of the major vent sites, which are confined to an area with high reflectivity mapped by side scan sonar. Individual vents within the Dead Dog vent field typically sit on conical mounds of hydrothermally altered sediment (i.e. Dead Dog Mound and Chowder Hill). (From Ames et al., 1993).

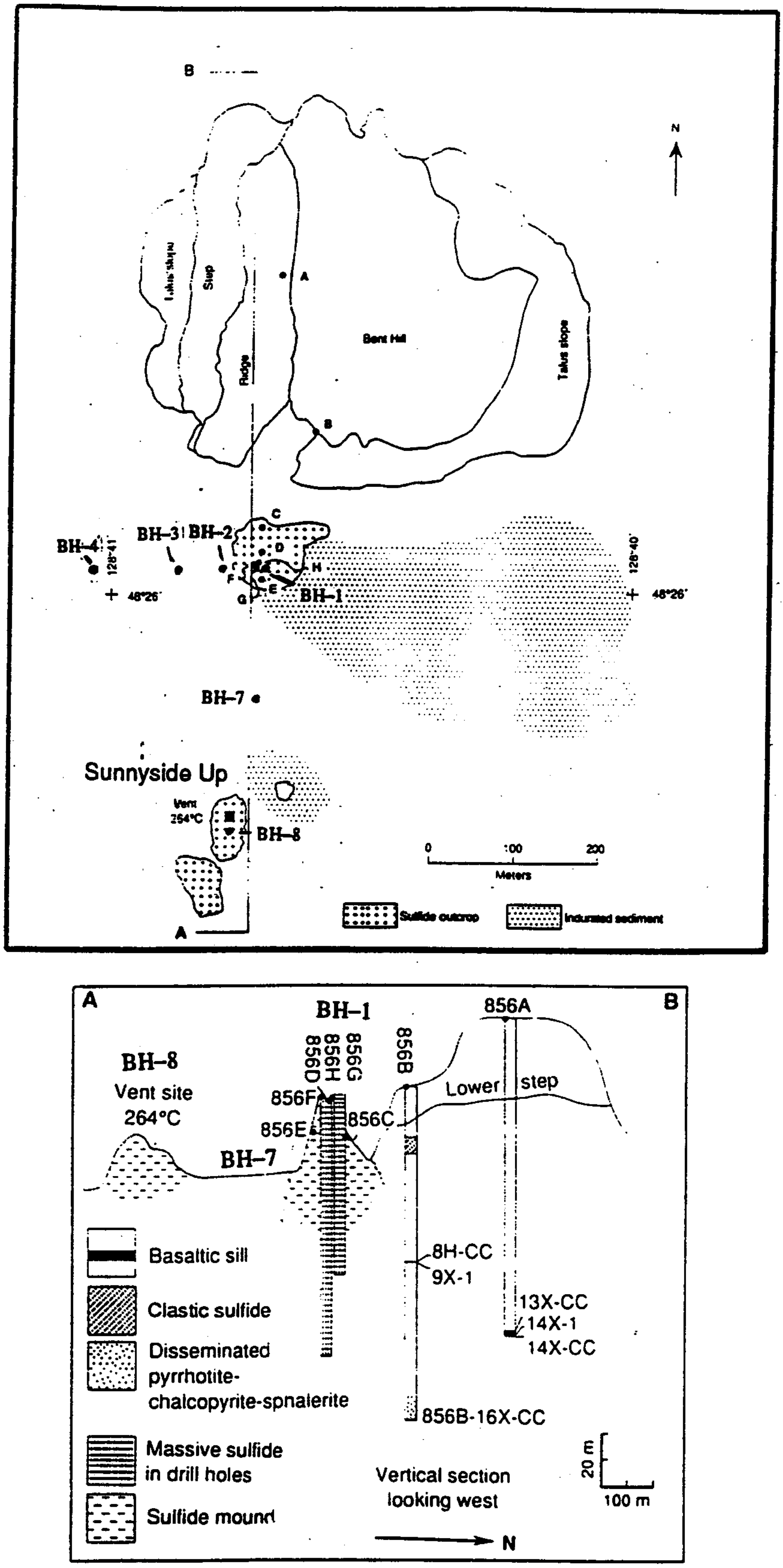

Fig. 3. Top-Map of 856 area showing the location of Bent Hill and the two sulfide mounds to the south. A ridge parallel normal fault (not shown) bounds the west side of the sulfide deposits, Bent Hill, and similar uplifted sediment hill that occur south of the map area. Proposed sites BH 1-4 are shown.

Bottom-North-south cross-section (5 × vertical exaggeration) of 856 area showing the extent of penetration of the massive sulfide deposit south of Bent Hill and the location of basaltic sills beneath Bent Hill.

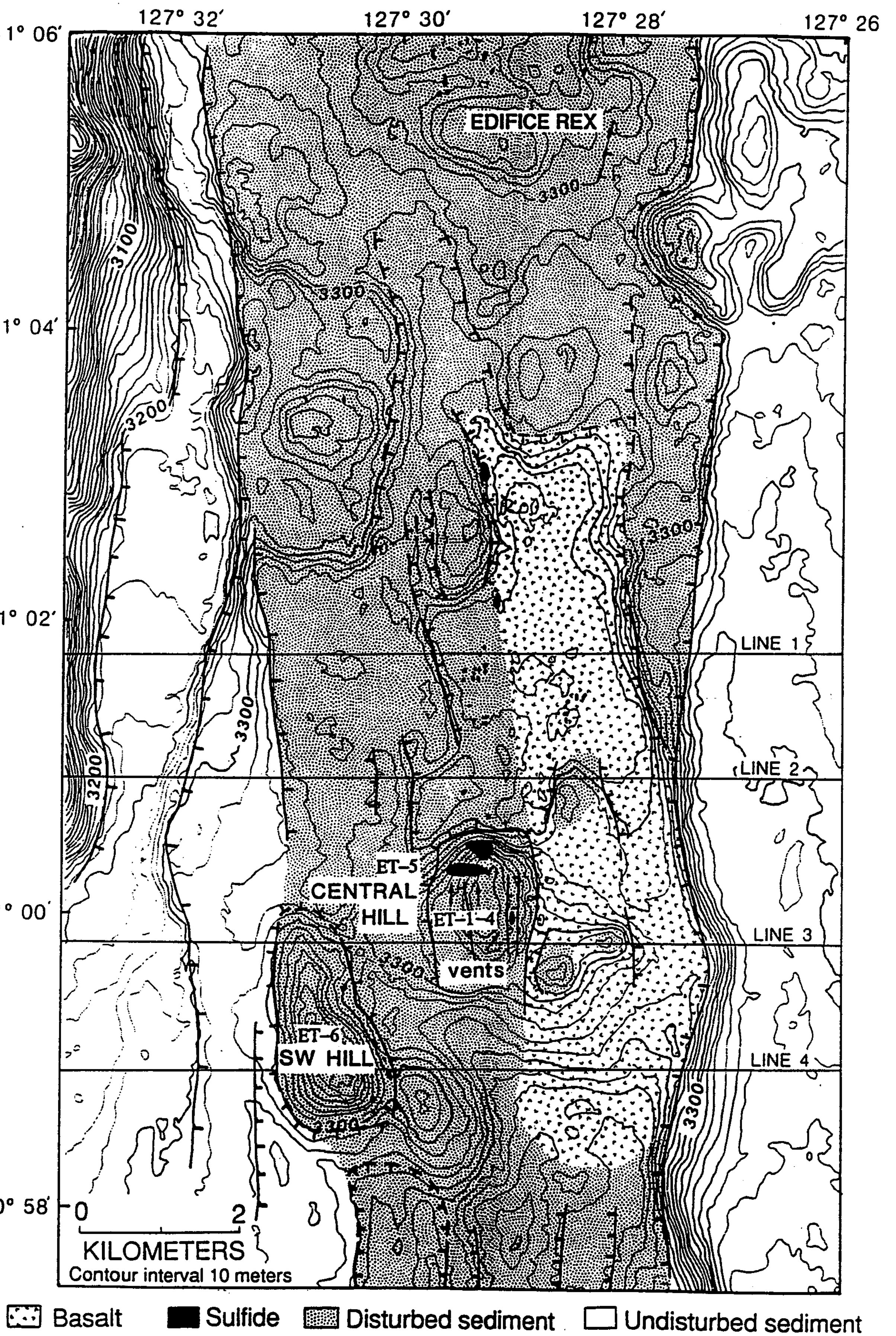

Fig. 4. Map of the NESCA area of Escanaba Trough showing the location of the SW Hill, Central Hill, on-axis volcanic rocks, sulfide deposits (black), and active vent sites. Location of proposed sites ET-1-6 are shown. The location of faults is constrained by the seismic profiles and camera and submersible mapping of scarps.

APPENDIX I

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