UNIVERSITY - NATIONAL OCEANOGRAPHIC LABORATORY SYSTEM

UNOLS

DEep Submergence Science Committee

Annual Planning Meeting

Summary Report

Sunday, December 12, 1999

Moscone Center, Room 220
San Francisco, CA

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Introduction - DESSC Chair's report:
Patty Fryer, DESSC Chair, opened the meeting at 8:30 am by welcoming the meeting participants. Newly appointed DESSC members – Joris Geiskes and David Mindell were introduced. Patty reviewed the agenda. One of the tasks facing the DESSC in the coming year will be revising their terms of reference to bring them up to date and to also reflect the expanded role of the committee. These minutes reflect the order in which the meeting agenda was addressed. The agenda is included as ***Appendix I*** and a list of meeting participants is included in ***Appendix II***.

Some highlights of the year included the DESCEND workshop which was well attended by the submergence community of scientists and engineers. Deep submergence activities included 12 science cruises aboard ATLANTIS with an additional four flyaway ROV programs aboard other ships. Patty encouraged the community to think about deep submergence science directions for the out years. She presented maps showing a summary of ALVIN and ROV days on station for funded and pending programs for 2001 and beyond, see ***Appendix III***.

1999 Science Reports - Presentations by Principal Investigators:
Brief reports from Science PIs who had used ALVIN and/or the ROVs over the past year were presented. Viewgraphs and other material from the science reports are included as ***Appendix IV***.

Bob Vrijenhoek – Information from Bob Vrijenhoek's report is contained in ***Appendix IV-A***. Bob began by reviewing the overall objectives of his work with hydrothermal vents. He reviewed the questions addressed by his studies on evolutionary systematics,

phylogeography, and metapopolation processes. Over the years, they have sampled from vent sites around the world including the East Pacific, West Pacific and Atlantic, see map. In January 1999, an ALVIN dive program was conducted on the Southern East Pacific Rise. Bob showed a map of the sites sampled on the cruise. Many new species were discovered. Bob reported that there were some technical difficulties on the cruise. Fuel consumption was a concern, and as a result, Bob in his role as chief scientist had to work with the Captain and crew in conserving fuel. SeaBeam problems were experienced on the cruise, but the science party was able to make do. The system problems need attention. Even with the problems, Bob reported that the cruise was very successful.

John Lupton – John Lupton was on the same cruise ATLANTIS cruise as Bob Vrijenhoek in January 1999. He conducted a ten-dive program. His viewgraphs are included in ***Appendix IV-B***. The cruise had a very full schedule with night operations and a busy biology and chemistry element. John showed a site map of the research area along the Southern East Pacific Rise. New sampling sites were shown in red and black indicated revisited sites. John showed a few sampling results for the 31.1S site. They worked with Dick Hey at this site who had surveyed the area extensively in 1998. Plume studies were examined. A vent field was discovered and found to be similar in nature to the ones found at Axial Seamount. The vents were rich in magmatic gases and which may indicate a magma system near the surface. Although there were only two pilots throughout the cruise, crew support was very good.

John Sinton – John Sinton's ATLANTIS program, the STOWA Cruise began in late January and continued until early March. His viewgraphs are included as ***Appendix IV-C***. The cruise involved three elements, volcanology, mussels, and ABE. John's program was involved with the volcanology portion of the cruise. DSL 120 was used first and approximately 160 km^2 of seafloor was imaged in four days. This was followed by ALVIN 23 ALVIN dives (three dives were funded by Cindy Van Dover's program). 24 ALVIN dives had been planned, but one day was lost to weather. John reported that this was a very successful program. Five pilots supported the operations. ALVIN bottom time per dive was approximately 5.5 hrs. There were 92 wax core and dredge stations and 232 rock samples were collected. The real time data collected from DSL-120 was a good source for dive planning. John reported that the final processed data was not available at the end of the cruise, but expected that WHOI now has it. The only problem that could be reported was with the number of external 35m cameras available. John wished to convey the message that this was a successful program.

Cindy Van Dover – Cindy Van Dover conducted a three-dive ALVIN program on the same cruise as John Sinton. Her program focused on diversity at mussel beds. Mussel pots were used for sampling and worked very well. Cindy reported that they were able to get five good samples from the six collected.

Cindy continued her report by discussing her cruise to the Northern EPR at 9-degrees N in November 1999. Three ALVIN dives were made, also to study mussel beds. Six mussel pot samples were successful collected. She reported that they are also interested in

recruitment, i.e. what draws animals to sites? They are investigating the possibility that sulfide might be the attraction. Cindy reported that they have developed a sulfide generator, AKA, "stink pots." The sulfide generator was tested and left at the 9N site.

Cindy reported on a few problems experienced with her cruise. The ship's laboratory sinks were in poor condition and as a result she was required to carry out work on deck, sometimes in the rain. Also, Cindy reported that her dive series was taxed with a pilot training dive.

Dana Yoerger – Dana Yoerger also participated in the same cruise as John Sinton and Cindy Van Dover. He was involved in the ABE portion of the cruise. Dana showed the vehicle track lines. Imagenex was used successfully for imaging the sea floor. Dana showed examples of images obtained from Maria Cormier's data. Video was also obtained using ABE. They were able to do some mosaicing. ABE's hill climbing capability was successfully demonstrated. At the request of Rodey Batiza, bottom sampling was tried using ABE. Wax coring was successful. By the end of the cruise, ABE was being deployed over the ship's side and operated all night. There are still a few glitches with the system. Battery problems were experienced with ABE and it cost some bottom time. The bow thruster also experienced failure problems. Dana noted that if there were a fatal problem with the vehicle, the system would drop its weights and surface.

Jeff Karson – In March/April, Jeff Karson had an ATLANTIS cruise to the Hess Deep. His viewgraphs include maps of the study area and are provided as ***Appendix IV-D***. The program conducted a nested survey using DSL-120, Argo II and ALVIN. The Hess Deep has very steep walls and offered a challenging terrain for the systems to operate. Excellent data was obtained using DSL-120 and they were able to adequately plan for follow-on dives. Over 200 samples were collected during operations using ALVIN. Argo II was used at night for surveying steep slopes. Jeff reported that the support provided by the pilots was excellent. They were able to examine crustal structures and spectacular outcrops. From images, they were able to mosaic and study dikes. Pre-cruise planning efforts lead to a very successful cruise. Dan Fornari and Andy Bowen provided very helpful information on the operational feasibilities. The at-sea crew support was terrific. The only problem he encountered was that he had expected to be able to perform more night-time work than possible under existing crew over-time limits.

Marta Torres – Marta Torres reported on her program, TECFLUX 99, aboard ATLANTIS in June/July. Twelve ALVIN dives were carried out. Marta's viewgraphs are included as ***Appendix IV-E*** and show the study area. GEOMAR collaborated on the program and conducted night camera tows from F/S SONNE. The study area was Hydrate Ridge, Cascadia. Marta reported that this is a complicated system to study since it is very dynamic. Additionally, North Hydrate Ridge is very different from the South. Coring is very challenging in the North. Bubbling occurs at the summit of North Ridge and there seems to be tidal, [temporal] effects on this system. The South was thought to be a more diffusive site, but is more dynamic than originally suspected. There are soft mounds, that if poked produce bubbles. Marta showed a graph which illustrates the highly

heterogeneous distribution of methane flux. These data were collected simultaneous by benthic landers deployed over bacterial mats, clam field, and background sediment. Marta noted that the only way to examine this system is to use many tools. Marta showed a viewgraph of the tools used. A variety of instruments were used to sample benthic fluxes, temperature changes and gas composition. She made a plea for the development of pressurized corers so that gas hydrate samples can be recovered intact.

Miriam Kastner – Mariam Kastner reported on her September 1999 cruise on ATLANTIS. Her viewgraphs are included as ***Appendix IV-F***. The title of her program is "Active C Flux on the Cascadia Accretionary Prism: In-situ Measurement of Hydrocarbon Sequestration as Gas Hydrates and Authigenic Carbonate Deposits." Co-PIs on the cruise were Bobb Carson, Miriam Kastner, and Doug Bartlett (Hans Jannasch). They attempted to quantify the amount of gas moving through the water column into the atmosphere. Borehole site 892 was studied and the evidence of flow is convincing. They designed and engineered a carbonate chamber to be placed over the borehole. It was deployed during their cruise and will remain on the borehole for a year before retrieval. Miriam experienced battery problems with ALVIN on this cruise (the worst she has ever encountered) and expressed hope that the problem will be addressed.

Geoff Wheat – Geoff Wheat reported on his September ATLANTIS cruise, CORKs 99. His viewgraphs are included as ***Appendix IV-G***. At sea goals included downloading temperature and pressure data, retrieving data loggers, thermister strings and Osmosamplers, conducting in situ calibration, logging boreholes for temperature, collecting fluids in boreholes and plugging boreholes. ALVIN was used during the day and the control vehicle was used at night. They weren't able to get everything accomplished, but additional dives have been awarded. Operational challenges included coordination between two research groups (in terms of bunks and baskets). Bunk space is always going to be at a premium on multi-program cruises. They noted that the pull strength of the wire used was less than the pull of the wire on retrieval of the instruments in the depth of water they were working in (2600m water depth) and that this may be a general problem for future operations. There were temperature effects on the wireline tools. Operational successes included the joint operations of the control vehicle and ALVIN. The vehicle was very good at reentering the 3.5" borehole with a 2" instrument at a water depth of 2600 m. Heavy gear was handled with ALVIN. Geoff showed graphs of the Osmosampler's data. They will continue to analyze the fluids.

Dana Yoerger – Dana Yoerger reported on Bob Ballard's cruise in the Mediterranean and Black Sea aboard R/V NORTHERN HORIZON. Biblical archaeologists from Harvard University also collaborated on the project. During NR-1 operations to examine the wreck of Dakar off Israel, Phoenician shipwrecks were discovered. In this 1999 cruise, Jason and DSL-120 were used on the expedition to examine these wrecks. Jason's imaging was mosaiced and Dana showed the image of one of the wrecks. A closed loop system was used in the operations. Automated mosaicing software development is in progress.

Bill Seyfried – Bill Seyfried reported on his ATLANTIS cruise in September at Juan de Fuca. The title of his program is "In-Situ Measurement and Monitoring of Dissolved H2, H2S, and pH in Mid-Ocean Ridge Hydrothermal Fluids." Bill's viewgraphs are included in ***Appendix IV-H***. Four ALVIN dives were carried out. PIs for the program were Bill, Kang Ding and Meg Tivey. They field-tested an array of electrochemical sensors at the Endeavor site for measurement of dissolved gases and high temperature vent fluids. Bill reviewed their testing strategy. The Bradley ICL was used as a sensor interface with the submersible. The cruise participants and their responsibilities during the cruise are included in the appendix. Kong Ding discussed the sensor and reviewed the results of in-situ measurement of vent fluid chemistry. He showed the comparison of dissolved H_2S concentrations measured by using different methods and noted that they are fairly similar. They are able to see the real time relationship between dissolved gases and temperature from a single vent site.

Marv Lilley –Marv Lilley discussed his work with seismicity and magma chambers. He discussed He^3 and CO_2 measurements at Endeavor Main Field before and after the June 1999 earthquakes. With the exception of the Dante site, He^3 was significantly higher in 1999 than in previous years. In all cases, CO_2 was higher in 1999 at all sites. Marv's CO_2 chart and John Lupton's He^3 chart are included in ***Appendix IV-I***.

Jim Cowen – Jim Cowen reported on his THOMPSON cruise in August/September. His viewgraphs are included as ***Appendix IV-J***. The main objective of the program is to extract proxies of biological data. Last year they used ALVIN to deploy systems to collect particulates. This year they used Jason for retrieval of the systems. There were four work sites with 9.5 days on station and nine Jason lowerings. Two Jason lowerings were aborted. Total Jason bottom time was 74 hours. One of the concerns in planning the cruise program was the awkwardness of the particulate collector systems in terms of handling; they are large and heavy. They worried that the elevator would not be able to support their needs. With patience and skill the Jason pilots were able to recover their systems. Early manipulator/connector failures were fixed. Jim praised Jason and the tireless/creative/skilled crew in their support of the program. Jim reviewed the Jason dive summary very briefly (see Appendix IV-J). He noted that they were able to get many experimental deployments that would not have been possible using ALVIN. Temperature could be measured within the diffuse sites without influence from the ambient temperature.

A question was asked about the comparison between ALVIN and Jason operations. Paul Johnson commented that Jason worked very well this year. The project could have been carried out using ALVIN very effectively, but would have required repeated operations and large bottom time. They are two very different vehicles.

Bob Embley – Bob Embley reported on the NeMO Net project and his Jason cruise in September on THOMPSON. His viewgraphs are included in ***Appendix IV-K***. The goal was to deploy a seafloor unit that could talk to the surface moored buoy and then signal to the GOES satellite. The sea floor unit was located at a site that had recently been surveyed by ROPOS. The camera system was quite large and a bit difficult for Jason to

handle, but it worked fine. An image came back about every five days. Temperature data was sent back every day. The pictures can be viewed on the NeMO website. They now have the ability to get real time data back to the shore.

Bob continued by reporting on the Acoustic Extensometer Project. The plan was to deploy twelve instruments across the valley floor at south Cleft to monitor horizontal strain. The instruments were not ready to be deployed during the September cruise, but they are committed to getting them in place this year, perhaps using R/V RON BROWN.

Bob reviewed the accomplishments in 1999 using Jason. Imagenex high-resolution bathymetry of the deployment site was obtained. They have deployed 12 benchmarks and made pressure measurements at each for vertical deformation monitoring. Three HOBO high-temperature probes have been deployed at south Cleft vent sites. Instrument acoustic modems are being field-tested. The results from prototype extensometer instruments have been published in December 1999 GRL.

Dana Yoerger – Dana Yoerger reported on Alan Chave's H_2O cruise on THOMPSON. The goal of the cruise was to recover and redeploy the H_2O junction box and IRIS seismometer using Jason. To recover the box, a lift line was dropped from Medea and connected by Jason. They were able to put the junction box down exactly where it had been and reinstall it. The junction box is roughly 1500 lbs. and 2.5m long. It was in 5000m of water. A lot was learned about deployment environments during this operation. Pre-cruise planning is essential.

National Deep Submergence Facility Operator's Report – Dick Pittenger provided WHOI's operator's report and began with a recap of ALVIN dive statistics from 1964 to 1999, see ***Appendix V***. There have been 3,502 total dives with a cumulative total depth of 7,191,806 meters. WHOI has been trying to raise the awareness of the importance of deep submergence science in the political world. They provided Congressman Jerry Lewis with a first hand look at ATLANTIS and ALVIN. WHOI gave Rita Caldwell a dive on ALVIN. She will use some of the images from this dive in her presentation at AGU.

NDSF Vehicle Operations Summary - Rick Chandler continued the WHOI report with a review of 1999 operations, see ***Appendix VI***. Annual operating costs in 1999 was $4,057,650 for the facility. Use of the facilities in 1998 and 1999 was high. Rick presented a chart showing the ALVIN dives lost vs. completed since 1985. In 1999 there were 335 ATLANTIS operating days and 175 ALVIN dives. The average dive depth was 2,386 m with average dive duration of 8.1 hours. Average bottom time was 5.3 hours. Fifteen science programs were carried out. Some of the highlights of the year included 38 dives on the Southern East Pacific Rise. The first dives north of 50-degree latitude were conducted in Gulf of Alaska. 1999 saw the first use of an IMAX camera in ALVIN.

In 1999, there were six ROV programs for a total of 48 vehicle lowerings. A total of 834.6 bottom hours were achieved and 371.8 miles were covered. Highlights of the year included successful use of the SM2000 multibeam sonar, 57,324 electronic still camera

photos were taken, 45 transponders were launched, nine elevators were used and there were two EXACT deployments.

Dick Pittenger continued with a report on ATLANTIS projects completed in 1999 and the funded projects to be completed. Some of the major items completed in 1999 included replacement of the anchors, installation of an ozonator in the potable water system, overhaul of the engines, and replacement of all fuel injectors. The complete list of ATLANTIS items is contained in ***Appendix VII***. Close to 100 ATLANTIS improvement items have been completed in the summer and fall. Dick reviewed the projects still to be completed. Bow thruster noise, lab power distribution and drains are still issues. Dick invited the community to provide any additional comments to WHOI. Dick addressed the fuel consumption issue. The work on the southern East Pacific Rise in 1999 represented the ship's most remote journey and there was no fuel usage history to rely on. WHOI wanted to avoid buying fuel at Easter Island since the last time they purchased fuel from the island salt water was in the fuel. As a result, WHOI tried to implement fuel conservation measures.

The other issue addressed by Dick was overtime. On Jeff Karson's cruise the science party expected to do 24 hour operations. Dick reported that this is a budgetary issue. WHOI tries to provide quality service at a reasonable price. In the future, Jon Alberts will address ship support and overtime with PIs during their pre-proposal stage as well as during pre-cruise planning. Some of the problems can be solved by better communication. More information provided at the pre-cruise stage would be helpful.

ALVIN Upgrades – Barrie Walden reviewed ALVIN upgrade projects, see ***Appendix VIII***. Current projects include addition of an in-hull digital camera. An SM2000 multibeam sonar has been tried (on loan) and is working very well. A new one is on order. The video route upgrade has a lot of capabilities and community feedback is needed. WHOI is experimenting with ring laser gyros and they expect to be ready to purchase one within the next six months. Development of the virtual ALVIN software package that WHOI had hoped would allow pre-cruise power consumption scenarios has been slow going. The software company is working on the final version which is due soon. Prototype development of a steerable elevator is expected soon and they hope to have positive results by June. Pressure proofing to the inductively coupled link (ICL) is underway. Barrie provided additional details on the video route upgrade (see appendix). ALVIN planned projects include a Doppler/Ring laser gyro navigation system, in hull digital cameras, and replacement of the quartz viewer port lights with HMI lights. The HMI lights require less power.

Barrie reviewed the projects being considered for ALVIN's overhaul. He indicated that ideas and priorities are welcome from the community. The overhaul list under WHOI consideration includes:

- Hard mount observer video controls
- Modify interior floor space arrangement
- Science basket modifications

- Lateral thruster with DP system
- Battery monitoring
- Manipulator upgrades
- Acoustic modem to allow ALVIN information to be sent to ship while submerged.
- External still camera changes

Barrie explained that the external still camera images are the ones used for publications. He has examples of high grab images taken from video and asks that the community look at these images to determine if they are adequate to replace the external 35 mm camera images. Mounting of these cameras is difficult and they take up science space.

Barrie continued by discussing the magnetic media. WHOI would like to shift to digital tapes. The Hi-8 tapes need to be transferred to another media as soon as possible to avoid degradation. There is a significant difference in cost between Hi8 and digital. The Hi8 video tape costs $8.29 while the digital video tape costs $30.90. For 175 dives/year for ALVIN the estimated Hi8 cost is $17,409 vs. $64,890 for digital. WHOI would like to shift over the ALVIN to digital because they feel that it would provide a better product. They will wait to convert the Jason media until further evaluation. On the support ship, there will be a capability to convert media for the science party before they leave the ship.

Lunch Break

NDSF Tethered Vehicle Upgrades - Andy Bowen provided a report on the NDSF Tethered Vehicles upgrades in 1999 and plans for 2000 and beyond, see ***Appendix IX***. The 1999 upgrades included overhaul of the hiab crane, overhaul of the traction winch, and purchase and testing of the Deep Simrad SM2000 sonar. The full list of items is included in the Appendix. Plans in 2000 include replacement of the tool van, specification and purchase of a neutrally buoyant umbilical, evaluation of digital video recording media, and completing the first year of the ROV upgrade effort.

Andy reviewed the DSL-120 status. Dock trials of DSL 120 vehicle tow dynamics have been conducted. Further evaluation and improvement is ongoing. They hope to improve slow speed dynamics. EDREX97 data processing has been completed and the sidescan and bathymetry has been reprocessed. Andy gave the full list of data reprocessed or in process. They should soon be completed with the reprocessing backlog. Generation of new DSL-120 intermediate data has been completed. Bathymetry re-processing with new flat bottom tables is undergoing evaluation and testing.

Andy reviewed the upgrades planned for the NDSF ROVs Jason II, ARGO II and DSL-120. Jason II upgrades are intended to improve manipulative capabilities, increase sample and equipment payload capability, increase speed and thrust, increase depth rating to 6500 meters and include tether management. The full list of upgrades is included in the appendix.

Andy reviewed the schedule for the upgrade implementations for DSL 120, Argo II, and Jason II. System specification/development began in 1999. Sonar electronics has gone out to bid and results are expected by October. There is a possibility that the system could be tried during Donna Blackman's ATLANTIS cruise as night operations. A six-month conversion to Jason II is expected during 2001 with a three month standdown. Andy provided a Jason II design overview. The design includes swing arms, a sample drawer, six thrusters, six video cameras, and high speed data transmission. There is a hydraulic system for powering the arms as well as some payloads. It was commented that the vehicle design appear to have everything in a forward-looking mode, why not look at the sides? Andy replied that the swing arms will somewhat address this. It was also questioned on why the multibeam sonar is located on the top of system. Andy replied that it is forward looking with a 400 m range. A tilt mechanism will be added. The sample drawer configuration was also a concern since it implements a height restriction. Andy said that for tall items you need to use the arms and put a basket on the arms. The drawer does offer freeing up area in front of the vehicle for other work. The drawer can be removed depending on the mission.

SEA CLIFF – ALVIN Engineering Study - Bob Brown reported on the SEA CLIFF engineering study, see ***Appendix X***. Although they had hoped to be completed with the study, one of the subcontractors is running behind. SEA CLIFF has been moved from Otis Airforce base to WHOI. The TURTLE and SEA CLIFF spare parts will be transferred over to WHOI in early 2000. There is still the issue of whether WHOI will have to pay an unshelving cost for removal of the parts from the Navy. These specifics are being worked out. A couple of SEA CLIFF components are being used on the NDSF vehicles. The sonar system was being used prior to transfer. The batteries had to be removed from SEA CLIFF for safety reasons. Everything else on SEA CLIFF is intact.

The SEA CLIFF study will study the following options:

- Improvements to the 4500 m ALVIN
- Use of SEA CLIFF as it is
- Basic conversion of ALVIN to 6000 meters using SEA CLIFF components
- Frame up new design of 6000 meter vehicle.

As part of the study, a survey of ALVIN users has been completed and received excellent comments. A study of all other 6000 m HOVs has been completed. Specifications for improving ALVIN have been developed. The outstanding items of the study are in costing out of options and completing the final report.

NDSF Outyear Planning of Funded, Unscheduled Programs – Jon Alberts provided a report on cruise planning and stated that the Web form is working well. Shozo Tashiro, a JAMSTEC deep submergence pilot, visited WHOI for six months to learn about their operations. Jon presented the 1999 schedule, see ***Appendix XI***. The schedule is busy in 2000. ALVIN will return to Woods Hole in December to begin its overhaul. There are four ROV programs that will be carried out on other ships.

Next Jon showed a summary of the 2001 ship requests for ALVIN & ROV operations. Programs are requested for times throughout the year. Then he showed the proposed upgrade period for the facilities along with the corresponding weather windows. There are two options being considered for the DSL upgrades; Plan A would implement the upgrades in mid-year and Plan B implements the upgrades at the end of the year. WHOI would like the DESSC to advise on this situation and recommend the preferred option. With ALVIN's overhaul period in the first six months of the year, approximately 80 dives could be scheduled in 2001.

Agency Reports:

National Science Foundation (NSF) – Don Heinrichs gave the report for NSF. Although NSF's final budget has not been approved, they anticipate a 2% increase for facilities. The total NSF budget will likely see a major increase. The Biocomplexity RFP has been advertised and might be of interest to the deep submergence community. A major portion of the budget increases will go to these programs. The final decisions on how funds will be distributed with in the Ocean Sciences section are unclear. Last year NSF spent approximately $30M on facility support. This year the fleet operations proposals are up to approximately $40M. This increase was not anticipated and as a result, cost efficiencies as well as perhaps deferring some programs are being considered. It is likely that more than $30M will be spent, but not as much as $40M. The research section is looking at level funding and no major shifts are expected.

Don continued by reporting that NSF has completed a year-long review of the Academic Research fleet. The review found that fleet operations and management are in a good state. The primary initiative for NSF and UNOLS should be support to science – service to science. The UNOLS Office will be moving to Moss Landing Marine Laboratories on 1 May. Hosting the Office was competitively bid to the UNOLS operator institutions. The MLML proposal is under agency review at this time. The Academic Fleet Review recommended that the new UNOLS Office operate under a cooperative agreement. The agreement is being drafted by the agencies. NSF has asked that the UNOLS Council review the recommendations of the fleet review and examine their taskings.

Don closed his report by noting that the science of deep submergence is very healthy. Don will retire at the end of the year. Mike Reeves will be his replacement. The meeting participants applauded Don Heinrichs' many years of service to their community.

National Undersea Research Program (NURP) – Barbara Moore gave the NURP report. NOAA/NURP will continue to honor their commitment to the National Deep Submergence Facilities of $500K. These funds are awarded on a competitive basis within NURP. In 2000, funding went to support Alaska operations. In 2001, there are two competing proposals one of which is in the Gulf of Mexico. Barbara reported that the other method of NURP facility funding is by individual centers supporting programs with their own center funding.

Office of Naval Research - There was no ONR report; however, Dan Roland who will be involved with ONR's deep submergence facility programs was introduced.

Report on the DESCEND Workshop – Patty Fryer gave a brief summary of the DESCEND workshop for the people who were not present. The goal of the workshop was to define future submergence science directions and identify the facilities needed to meet these directions. The process of how to obtain the needed facilities still needs to be addressed. We also need to determine how to help the agencies get the addition funds needed to increase the capabilities of the submergence assets. The steering committee has suggested that in addition to a final report, a glossy foldout brochure be produced summarizing the workshop findings and recommendations. This would be in addition to the full report. The brochure could be useful in convincing colleagues and congressmen of the importance of submergence science.

Patty presented the major science issues that were identified in the workshop. These included:

- Biological diversity, complexity and dynamics.
- Lithosphere formation, evolution and destruction.
- Fluids and material and energy fluxes.
- Etc

Next, Patty reviewed technology needs identified in the workshop:

- An appropriate increase in the level of submergence science and facility funding
- Dedicated vehicles for observatory science
- Chemical and biological sensors with direct read-out in real time
- General use instrumentation with compatibility across vehicle platforms
- Low-cost modular vehicles capable of multidisciplinary applications
- UNOLS-type coordination and funding model
- Proposal pressure
- Metadata coordination

Patty reviewed the draft DESCEND report outline which includes the following sections:

- Executive summary
- Introduction
- Results of the science breakout sessions
- Results of the technology breakout sessions
- Recommendations
- Follow-up
- Appendices

Patty reported that during the wrap-up session of DESCEND there was a strawman vote of the participants to answer a couple of questions: (1) Do we need increased accessibility to existing facilities? and (2) Do we need additional assets? The participants answered yes to both questions. Consequently, additional funds are needed.

There are a few areas that will require follow-up to the meeting. A technology follow-up meeting has been suggested. A community based submergence science steering group to perform the function of a coordinating committee has been recommended. It has been suggested that DESSC or an expanded DESSC could serve in this capacity.

Patty went on to suggest that the workshop report needs an overall theme that catches the reader's attention, a real "motherhood" theme. With tongue firmly in cheek, Patty presented a suggestion for a report title. Because submergence science provides the means by which to study critical problems in marine and biological science throughout the world oceans, a logical title could be: World, Ocean, Marine and Biological Science or "WOMB" Science.

When the laughter subsided, Patty encouraging suggestions and comments from the audience. A lively discussion followed and it basically became a brainstorming session. The focus of the discussion was on the major submergence science issues. The comments, questions, and suggestions from the meeting participants are listed below:

- The question was asked of whether the report should be a focussed program vs. a list of science objectives?

- Titles for the report were suggested:
  - "Mission to the deep ocean floor."
  - Biosystematics of Inner Space "BS"
  - H2O Earth as a Living Planet "HELP"

- It was commented that we need to capitalize on the tools needed and maintain a focus on the diversity of deep submergence.

– There has been a lot of effort been put into the NEPTUNE program. Their report is coming together. There is also the RIDGE 2000 workshop. The results of these workshops should be applied to DESCEND.

- We need to convince not only the funding agencies of the science and technology needs, but also the political world.

- The report must focus on both the technology needs as well as the science directions.

- Knowing all of the good science that needs to be done, we need to be assured that we will have the facilities needed for the next 5 to 10 years. How do we effectively package this message?

- We need to make the use of deep submergence vehicles as self evident as the need to have ships. A theme is needed that brings forward the science objectives.

- It was suggested to stress the exploratory needs of the ocean. We spent the 20th century exploring the continents, now it is time to explore the deep ocean. The discovery aspect should be pursued.

- It was also commented that although discovery is a good path to take, the scientific element needs to remain to make the report viable within the community.

- It was suggested that the community be able to look over the draft, this would stimulate the community and help them make suggestions. The draft report can be posted on the web.

- It was recommended the we look at successful programs and explore the techniques they used to promote their program.

- To increase submergence science visibility and funding potential, broaden the umbrella. Expand DESSC.

As the discussion period ended, the meeting was adjourned to executive session. Patty asked that the DESSC stay to discuss the recommendations of the meeting participants and strategies for follow-on activities to DESCEND. She thanked the participants for their input and asked them to stay tuned for further DESCEND activities.

The meeting was adjourned at 3:00 pm

Appendix I

UNOLS DEep Submergence Science Committee
Planning Meeting
Moscone Center, Room 220
San Francisco, CA
Sunday, December 12, 1999

08:00 **Coffee, Distribution of Meeting Material (Written Reports)**

08:15 **Introduction - DESSC Chair's Report**

08:25 **1999 Science Reports - Presentations by Principal Investigators**
- ALVIN users
- ROV/AUV users

10:15 - 10:30 **Break**

10:30 **1999 Science Reports - Presentations by Principal Investigators (cont.)**
- ALVIN users
- ROV/AUV users

10:45 **National Deep Submergence Facility Operator's Report (WHOI)**
- NDSF Vehicle Operations Summary
- Ship and Vehicle Upgrades/Overhauls & Synchronization
  - ⇒ ATLANTIS
  - ⇒ ALVIN
  - ⇒ Jason, Argo II, DSL-120
- SEA CLIFF Engineering Study

12:00 - 13:00 **Break for Lunch** (Lunches will be available at the meeting in Moscone Room 232 for a cost of $10.00)

13:00 **Wrap-Up NDSF Report and Outyear Planning of Funded, Unscheduled Programs**

13:15 **Agency and UNOLS reports**

13:30 **Report on the UNOLS DESCEND Workshop**

14:30 - 14:45 **Break**

14:45 **Discussion of follow-up for DESCEND Workshop recommendations**
- Technology workshop
- DESSC's role

16:30 **Adjourn**

Appendix II

DESSC - Dec. 12, 1999

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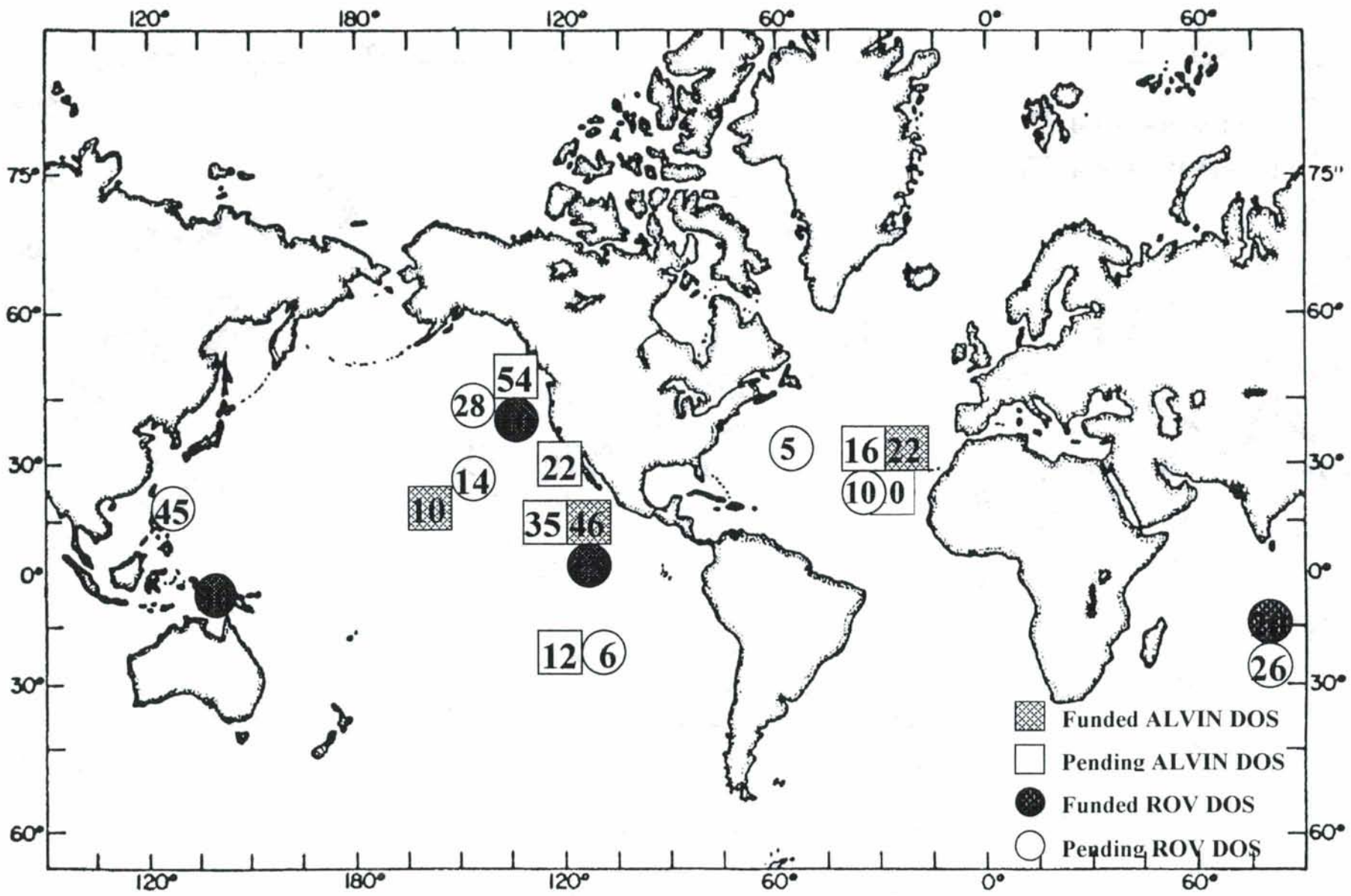
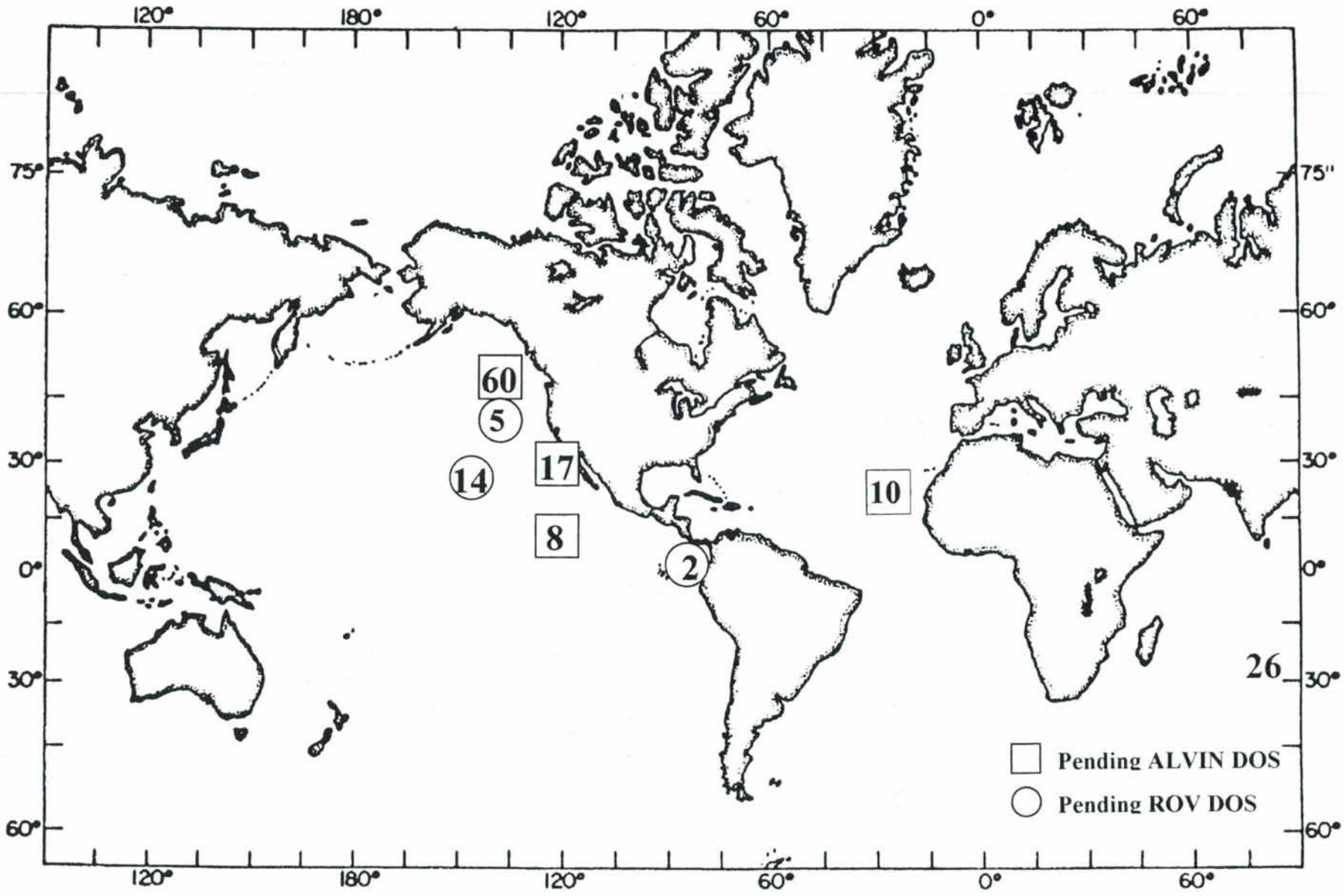
Appendix III

SUMMARY OF ALVIN & ROV DAYS ON STATION: 2001



SUMMARY OF ALVIN & ROV DAYS ON STATION: 2002 & 2003



ALVIN/ROV Requests: 2001 and Beyond

Year	Name	Inst	Op. Area	dos	ALVIN	Jason	ARGO-II	DSL-120	Agency	Fund/Pend
Bermuda										
2001	Collins, John	WHOI	Bermuda- 30N 62W	5		5			NSF	P
			Total Pending:	**5**		**5**				
Mid Atlantic Ridge										
2001	Chave, Alan	WHOI	MAR -23N, 45W	7	6				NSF	P
2001	Michael, Peter	U.Tulsa	MAR -30N or 30S	28	10	10			NSF	P
2001	VanDover, Cindy	W&M	MAR	12	12				NSf	F
2001	Vrijenhoek, Bob	Rutgets	MAR	10	10				NSF	F
			Total Pending:	**35**	**16**	**10**				
			Total Funded:	**22**	**22**					
Juan de Fuca, Off Oregon										
2001	Giovannoni, Steve	OSU	45N, 130W	8	8				NSF	P
2001	Goldfinger, Chris	OSU	JdF - 40N, 124W	14				14	NSF	P
2001	Johnson, Paul	U.Wash	JdF	10		10			NSF	P
2001	Kastner, Mirian	SIO	40N, 124W	4	4				NSF	P
2001	Levin, Lisa	SIO	Eureka	10		10				F
2001	Lilley, Marv	Uwash	JdF - 48N, 129W	30	30				NSF	P
2001	Voight, Janet	FMNH	41N, 127W	3	3				NSF	P
2001	Voight, Janet	FMNH	Oregon - 36N, 122W	9	9				NSF	P
2001	Voight, Janet	FMNH	JdF - 47N, 129W	4		4			NSF	P
			Total Pending:	**82**	**54**	**14**	**0**	**14**		
			Total Funded:	**10**		**10**				
2002	Lilley, Marv	Uwash	JdF - 48N, 129W	30	30				NSF	P
2002	Voight, Janet	FMNH	JdF - 47N, 129W	5		5			NSF	P
			Total Pending:	**35**	**30**	**5**	**0**	**0**		
2003	Lilley, Marv	Uwash	JdF - 48N, 129W	30	30				NSF	P
			Total Pending:	**30**	**30**	**0**	**0**	**0**		
Off San Diego										
2001	Thistle, David	FSU	San Diego Trough	22	22				NSF	P
			Total Pending:	**22**	**22**	**0**	**0**			
2002	Thistle, David	FSU	San Diego Trough	17	17				NSF	P
			Total Pending:	**17**	**17**	**0**	**0**	**0**		
Off Costa Rica										
2002	Becker, Keir	U.Miami	Costa Rica- 1N, 84W	2		2			NSF	P
			Total Pending:	**2**	**0**	**2**	**0**	**0**		
Northern East Pacific Rise										
2001	Cary, Craig	U.Delaware	EPR - 9N	8	8				NSF	F
2001	Holloway, Jon	AZ State	EPR - 9N	12	8				NSF	P
2001	Schouten, Hans	WHOI	EPR - 9N	23		6		9	NSF	F
2001	VanDover, Cindy	W&M	EPR - 11N	6	6				NSF	F
2001	VanDover, Cindy	W&M	EPR - 9N	5	5				NSf	F
2001	VonDamm, Karen	UNH	EPR- 9N & 21N	27	27				NSF	P
			Total Pending:	**39**	**35**					
			Total Funded:	**81**	**46**	**6**	**0**	**9**		
2002	Holloway, Jon	AZ State	EPR - 9N	12	8				NSF	P
			Total Pending:	**12**	**8**	**0**	**0**	**0**		
Southern East Pacific										
2001	Naar, David	USF	Easter Is - 23S, 112W	27	12	3		3	NSF	P
			Total Pending:	**27**	**12**	**3**	**0**	**3**		

North Pacific										
2001	Smith, Ken	SIO	28N, 141W	14		14			NSF	P
			Total Pending:	**14**	**0**	**14**	0			
2002	Smith, Ken	SIO	28N, 141W	14		14			NSF	P
			Total Pending:	**14**	**0**	**14**	0			
Hawaii										
2000	Garcia, Mike	U.Hawaii	Hawaii	10	10				NSF	F
			Total Funded:	**10**	**10**	**0**	0			
Marianna Forearc										
2001	Fryer, Patty	U.Hawaii	Marianna Forearc	45		45			NSF	P
			Total Pending:	**45**	**0**	**45**	0			
Huon Gulf										
2001	Silver, Eli	UC, Santa Cruz	Huon Gulf - 7S, 147E	35		30		5	NSF	F
			Total Funded:	**35**	**0**	**30**	0			
Indian Ocean										
2001	Fornari, Dan	WHOI	Indian O.	20		10	6	4	NSF	F
2001	Scheirer, Dan	Brown	SE Indian Ridge	39		12	4	10	NSF	P

Appendix IV

OBJECTIVES

- **Evolutionary systematics**

How are hydrothermal vent and sulfide/hydrocarbon seep fauna related?

Are vent species derived from seep ancestors?

Vice versa?

Are deep-sea vent and seep organisms ancient?

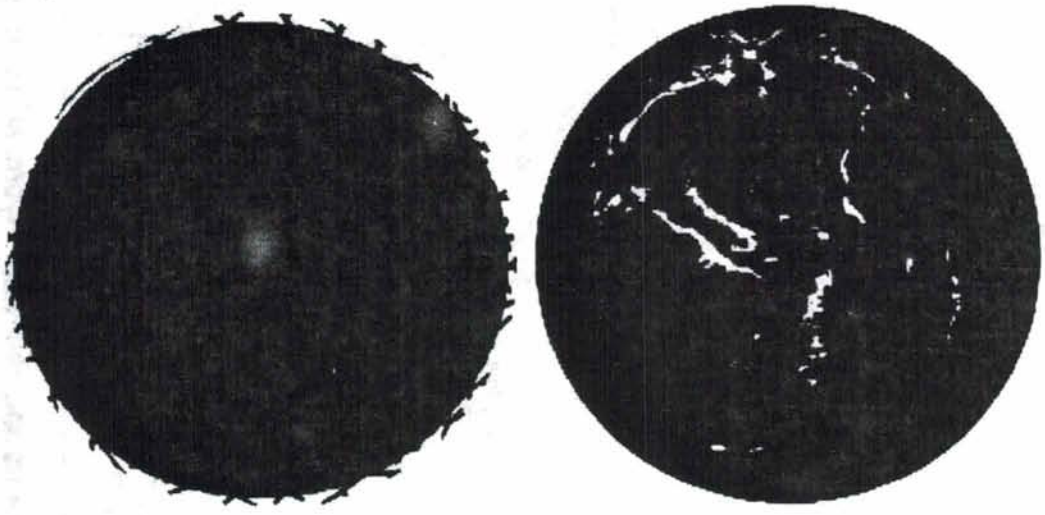
Did they escape global extinction events that devastated biological diversity in the photic zone?

Have the endosymbiotic bacteria evolved in parallel with their invertebrate hosts?

Does coevolution depend on the mode of symbiont transmission (i.e., vertical vs. horizontal)?

- **Phylogeography**

How do organismic genealogies map onto the mid-ocean ridge system?

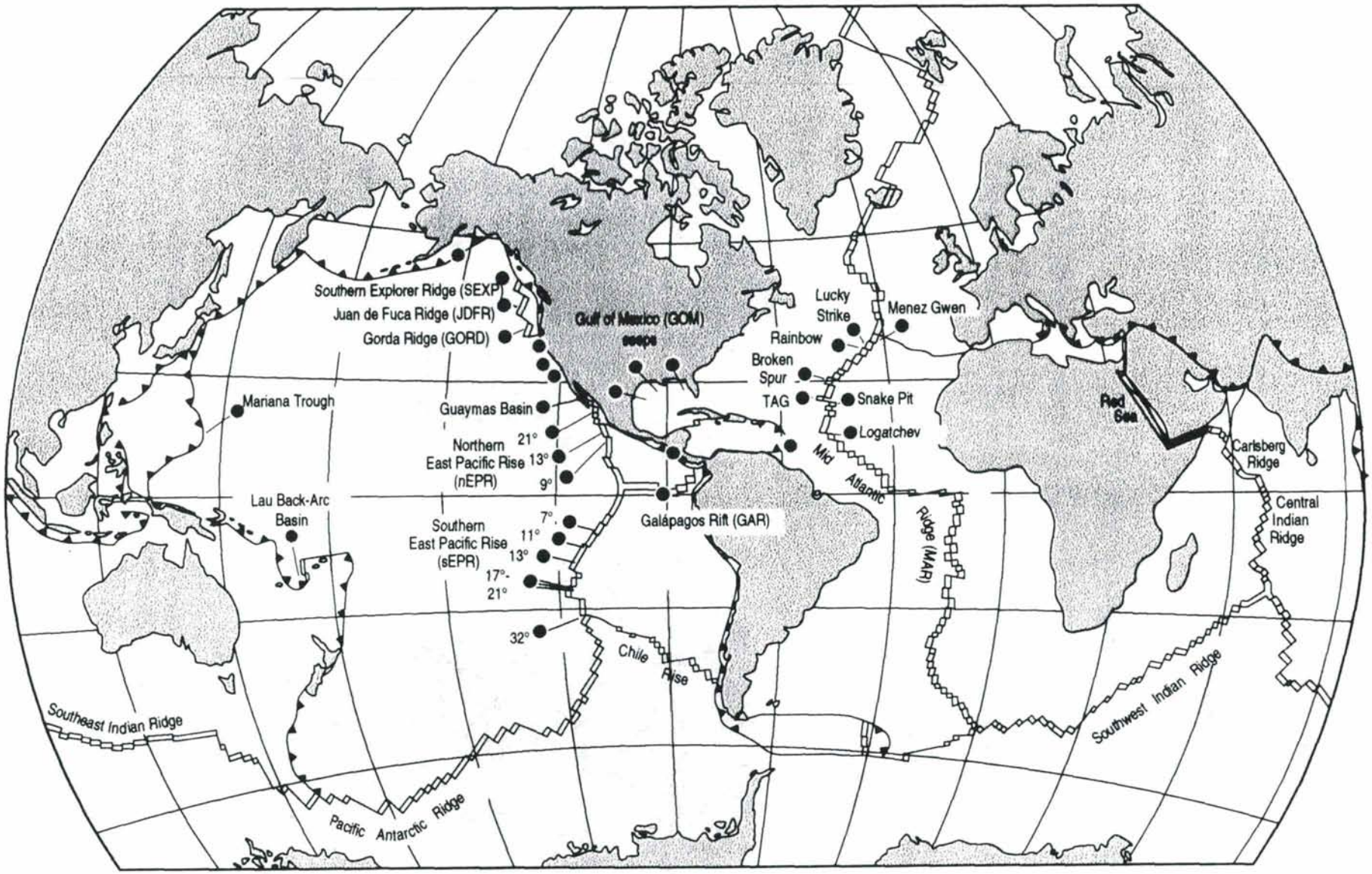


How do the invertebrates disperse between ephemeral vents localities that may be isolated along a ridge axis?

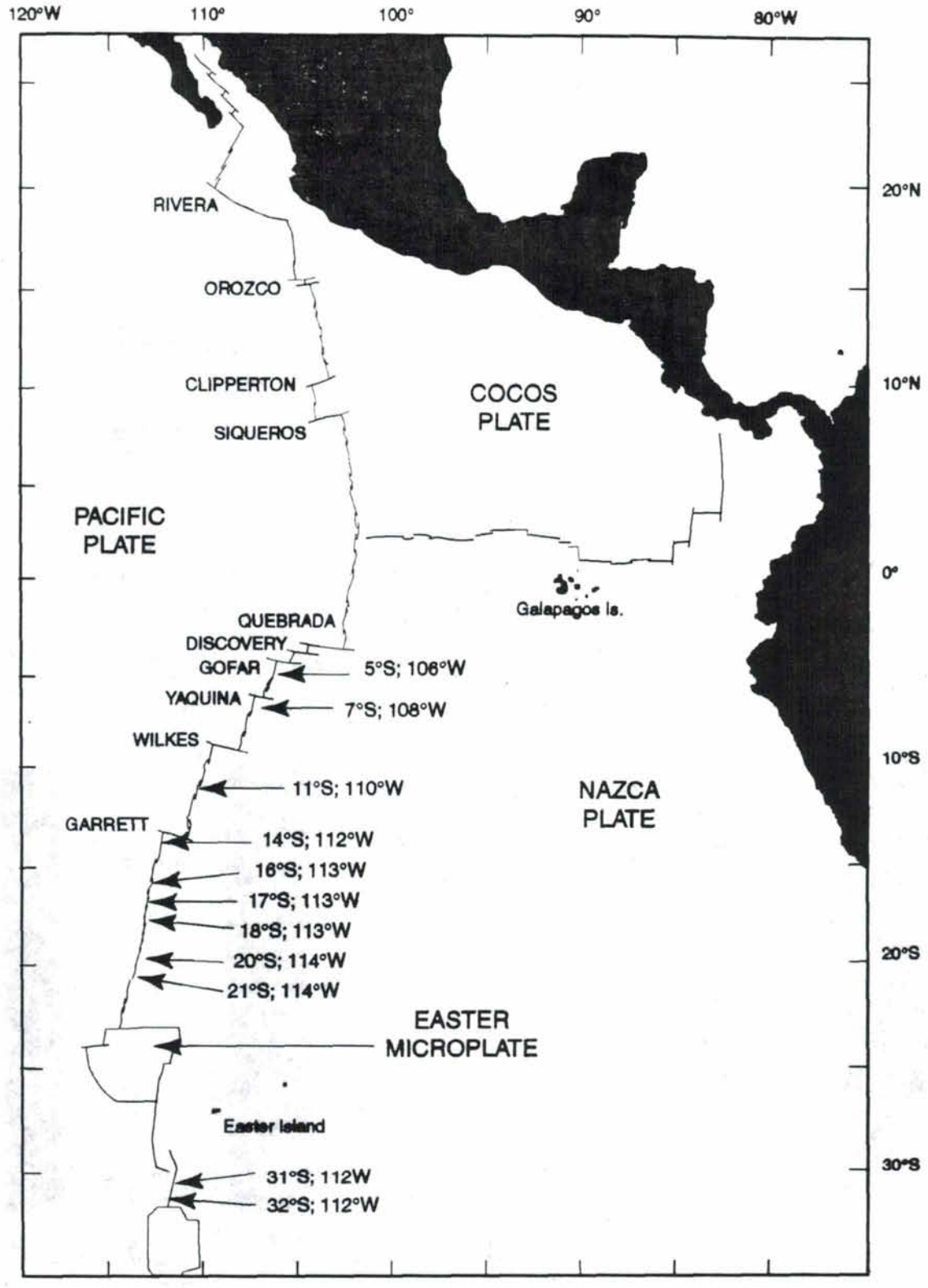
Can seeps and perhaps whale carcasses provide "stepping-stones" for dispersal of vent species?

- **Metapopulation processes**

How do patterns of dispersal, colonization and local extinction affect the retention and distribution of genetic diversity within species?

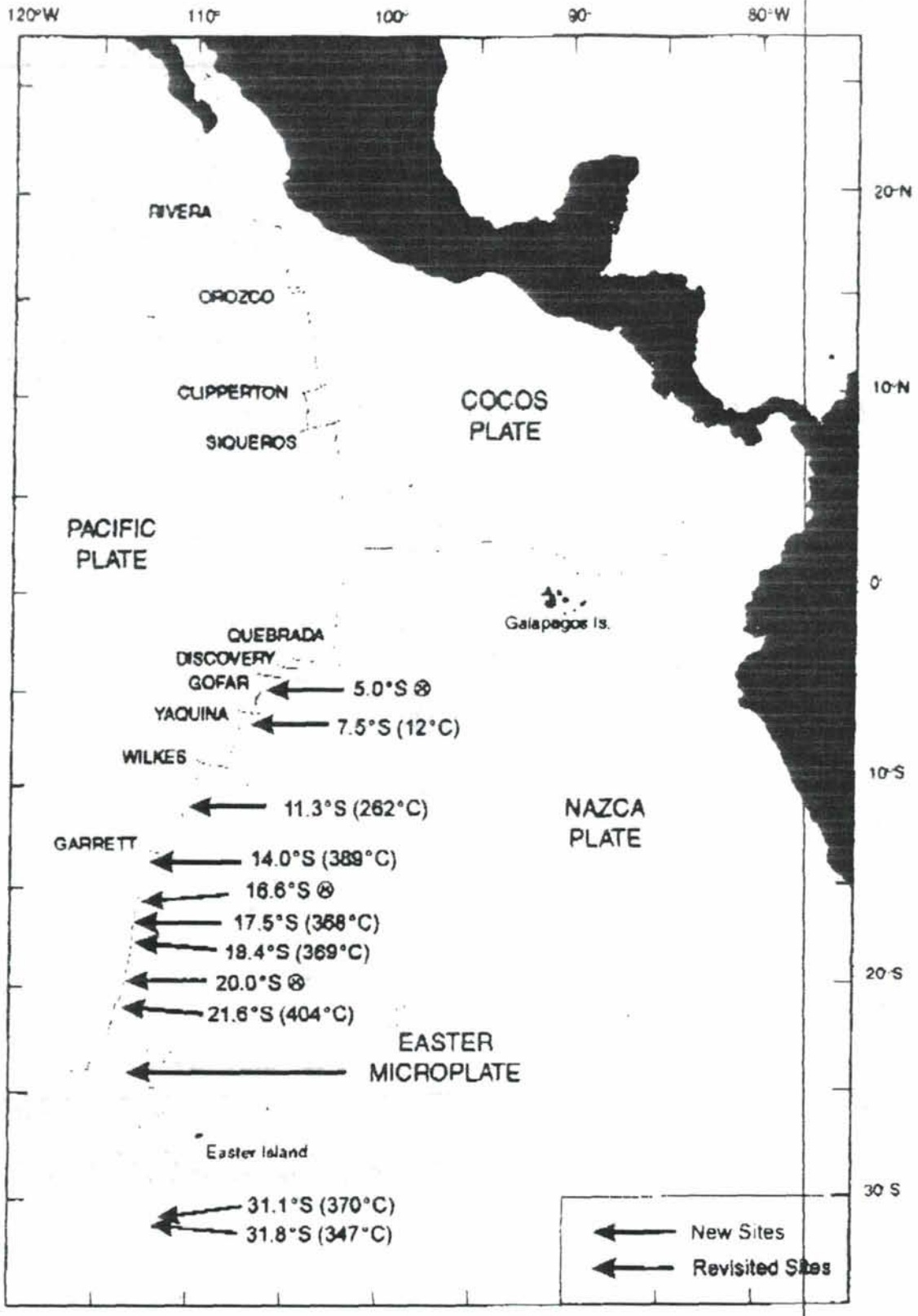


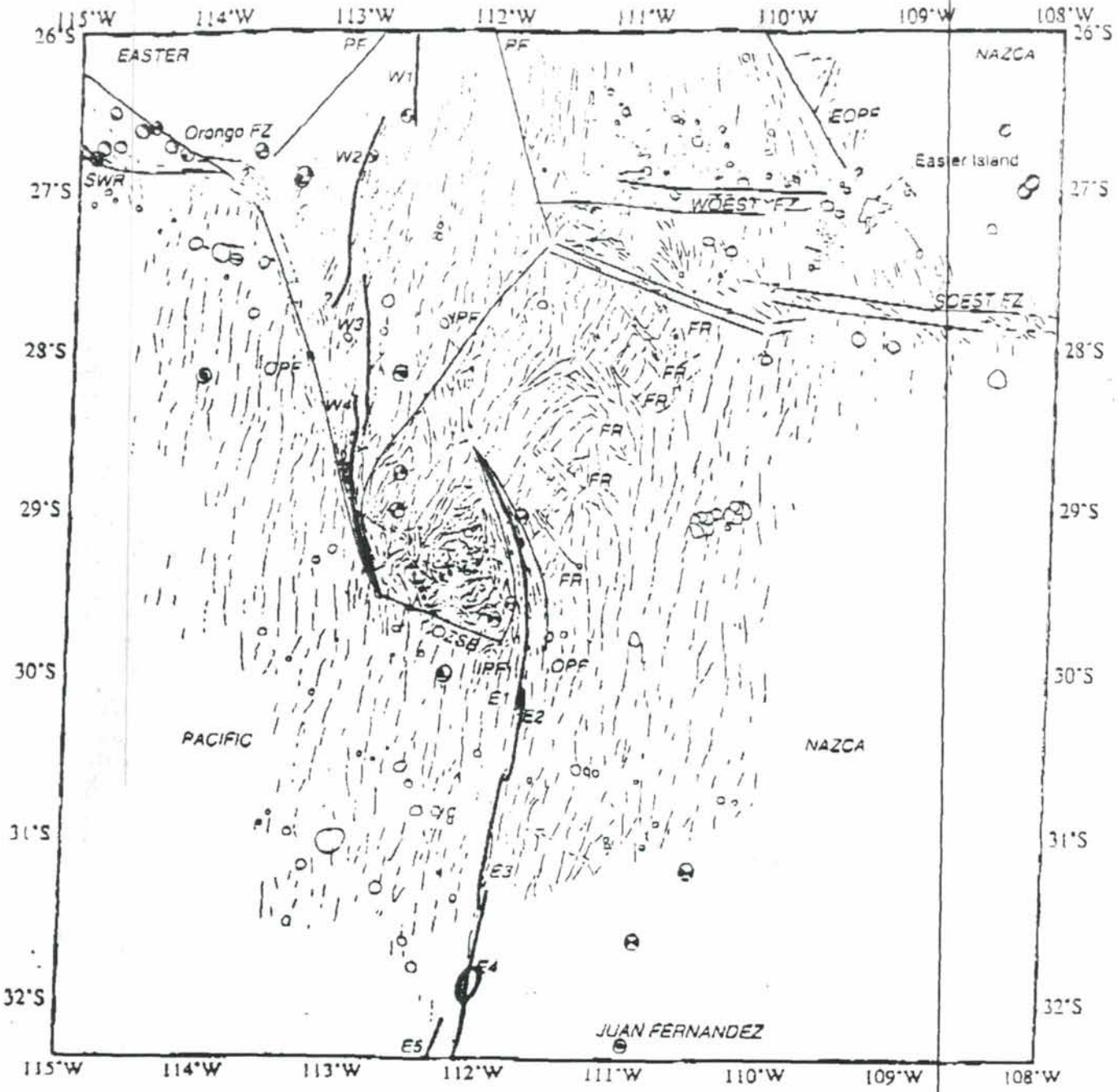
Hydrothermal vents and cold-water hydrocarbon seeps from which we have samples


120°W
110°
100°
90°
80°W
20°N
10°N
0°
10°S
20°S
30°S
RIVERA
OROZCO
CLIPPERTON
SIQUEROS
COCOS
PLATE
PACIFIC
PLATE
Galapagos Is.
QUEBRADA
DISCOVERY
GOFAR
5°S; 106°W
YAQUINA
7°S; 108°W
WILKES
11°S; 110°W
NAZCA
PLATE
GARRETT
14°S; 112°W
16°S; 113°W
17°S; 113°W
18°S; 113°W
20°S; 114°W
21°S; 114°W
EASTER
MICROPLATE
Easter Island
31°S; 112W
32°S; 112°W

Date		site	eta	lv	Nm	speed	hrs	dive	obs1	obs2	Pilot	status
12/16/98	Wed	[redacted]							>>>>:	>>>>>>>>:	>>>>>>>>	>>>>>>> lv Manzanillo
12/17/98	Thu								>>>>:	>>>>>>>>:	>>>>>>>>	>>>>>>> transit day
12/18/98	Fri								>>>>:	>>>>>>>>:	>>>>>>>>	>>>>>>> transit day
12/19/98	Sat								>>>>:	>>>>>>>>:	>>>>>>>>	>>>>>>> transit day
12/20/98	Sun								>>>>:	>>>>>>>>:	>>>>>>>>	>>>>>>> transit day
12/21/98	Mon								>>>>:	>>>>>>>>:	>>>>>>>>	>>>>>>> transit day
12/22/98	Tue	5S	06:00	17:00	165	11.0	15.0	3319	Rona	PIT	Blee	arr 5S--DIVE
12/23/98	Wed	7S	08:00			9.0	0.0	3320	Lutz	Halanych	Pat	arr.7S--dive
12/24/98	Thu	7S				9.0	0.0	3321	Vrijenhoek	Tieger	Blee	dive
12/25/98	Fri	7S		18:00	287	9.0	31.9	3322	Butterfield	O'Mullan	Pat	dive--lv
12/26/98	Sat	[redacted]							>>>>:	>>>>>>>>:	>>>>>>>>	>>>>>>> transit day
12/27/98	Sun	11S	01:53	16:00	197	11.0	17.9	3323	Lutz	Rona	Blee	arr. 11S--dive--lv
12/28/98	Mon	14S	09:54			9.0	0.0	3324	Trefrey	PIT	Pat	dive
12/29/98	Tue	14S		16:00	167	9.5	17.6	3325	DeRonde	Mariana	Blee	dive
12/30/98	Wed	16S	09:34	18:00	41	9.0	4.6	3326	Lupton	Lutz	Pat	arr 16S--dive
12/31/98	Thu	17S				9.0	0.0	3327	Vrijenhoek	Dimeo	Blee	dive
01/01/99	Fri	17S				9.0	0.0	3328	Lutz	Hurtado	Pat	dive
01/02/99	Sat	17S				9.0	0.0	3329	Roe	Mitsubyishi	Blee	dive
01/03/99	Sun	17S				9.0	0.0	3330	Butterfield	Ishibashi	Pat	dive
01/04/99	Mon	18S				9.0	0.0	3331	DeRonde	Greene	Blee	dive
01/05/99	Tue	18S				9.0	0.0	3332	Longnecker	PIT	Pat	dive
01/06/99	Wed	18S		17:00	92	9.0	10.2	3333	Ishibashi	Sampson	Blee	dive
01/07/99	Thu	20S	03:13	17:00	90	9.0	10.0	3334	Lutz	Lupton	Pat	dive
01/08/99	Fri	21S	03:00	17:00		9.0	0.0	3335	Trefrey	PIT	Blee	dive
01/09/99	Sat	21S		14:30	439	11.0	39.9	3336	Lupton	Butterfield	Pat	weather day
01/10/99	Sun	[redacted]							>>>>:	>>>>>>>>:	>>>>>>>>	>>>>>>> transit day
01/11/99	Mon								>>>>:	>>>>>>>>:	>>>>>>>>	>>>>>>> transit day
01/12/99	Tue								>>>>:	>>>>>>>>:	>>>>>>>>	>>>>>>> transit day
01/13/99	Wed	31S	07:06			9.0	0.0	3337	Vrijenhoek	Hey	Pat	dive
01/14/99	Thu	31S				9.0	0.0	3338	Lutz	Meaener	Blee	dive
01/15/99	Fri	31S		19:00	40	8.0	5.0	3339	Won	Speck	Pat	dive
01/16/99	Sat	32S	00:00			9.0	0.0	3340	Vrijenhoek	Hey	Blee	dive
01/17/99	Sun	32S				9.0	0.0	3341	Speck	Roe	Pat	dive
01/18/99	Mon	32S		19:00	305	10.0	30.5	3342	Vrijenhoek	Lupton	Blee	dive--transit
01/19/99	Tue	[redacted]							>>>>:	>>>>>>>>:	>>>>>>>>	>>>>>>> transit day
01/20/99	Wed								>>>>:	>>>>>>>>:	>>>>>>>>	>>>>>>> transit day

Atlantis-Alvin Cruise 3-30



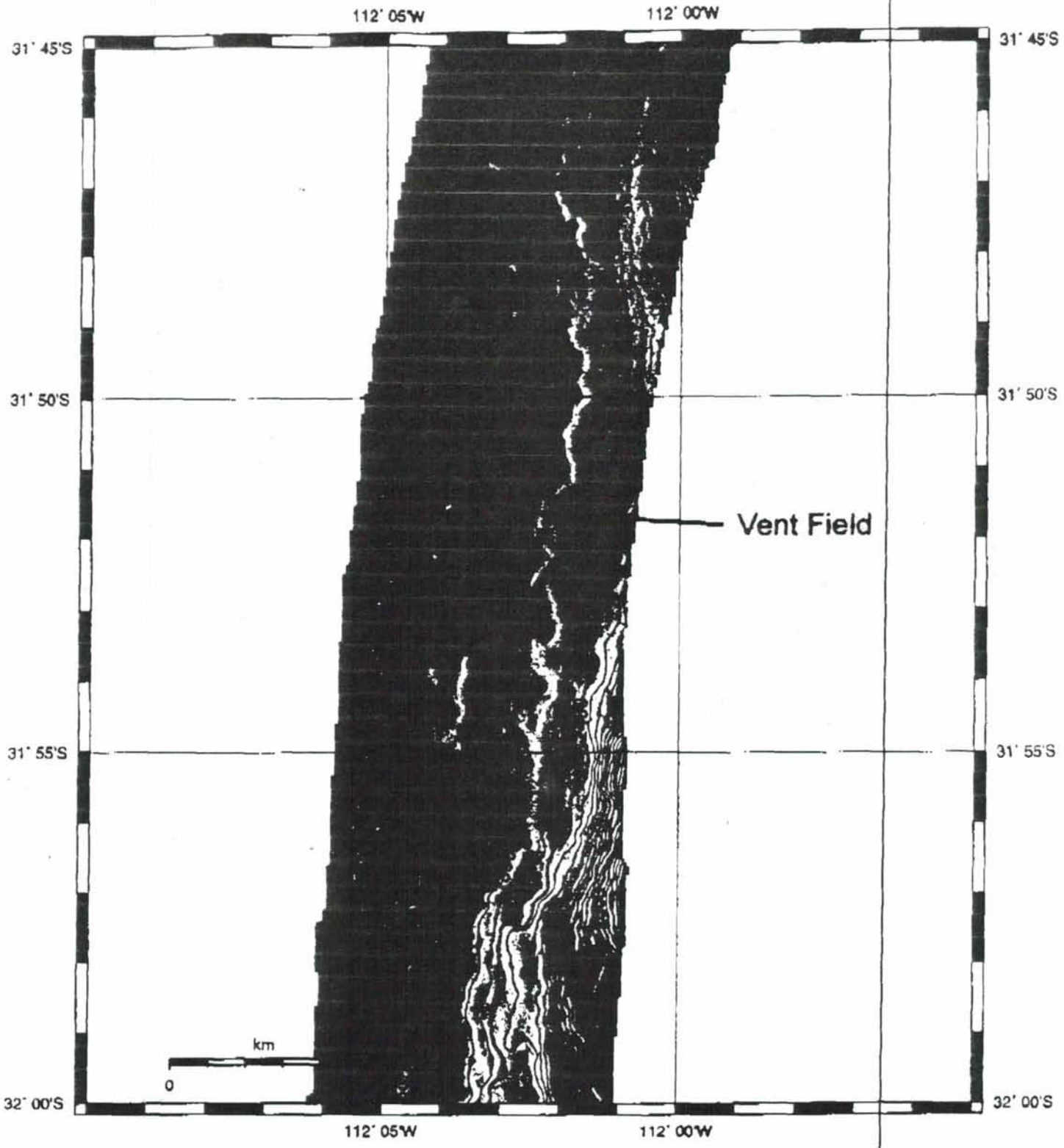


from Hey et al. (1995)

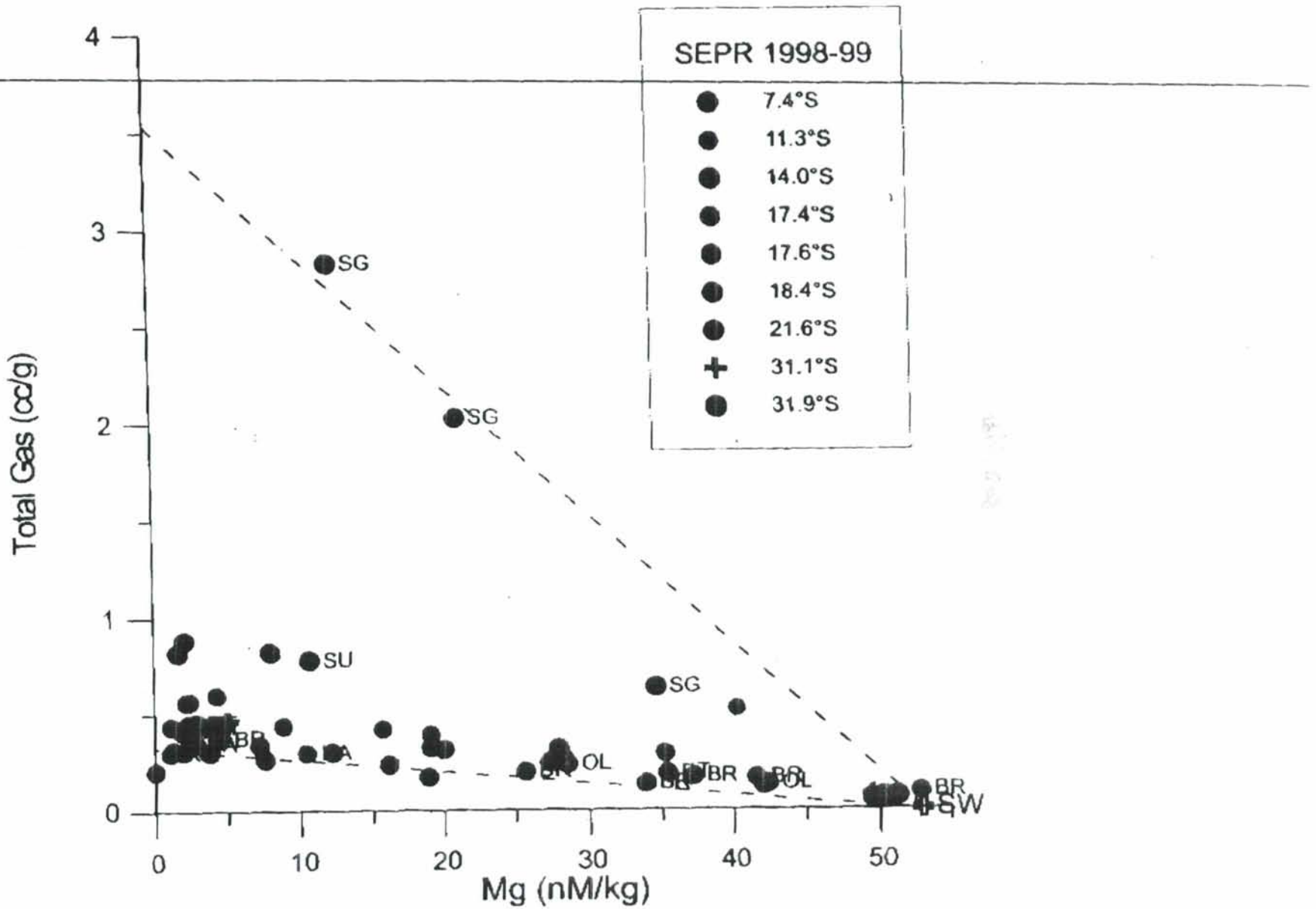
Vents Rich in Magmatic Gases

	CO_2 (mM/kg)	^4He (μM/kg)
Most Vents	<20	<1
Loihi	296	>6.6
Axial – Virgin Mound	200-285	11
Axial – Castle	200	9.8
9°N – A Vent	120-161	4-7
9°N – M Vent	263	16.5
*32°S EPR – Snow Ghosts	156	7.6

direct degassing of magma chamber?



Bathymetry from Hey et al. (1995)


SEPR 1998-99
7.4°S
11.3°S
14.0°S
17.4°S
17.6°S
18.4°S
21.6°S
31.1°S
31.9°S
Total Gas (cc/g)
Mg (nM/kg)
0
1
2
3
4
0
10
20
30
40
50
SG
SG
SU
SG
OL
BR
SW

R/V Atlantis Cruise AT3-31: the STOWA Cruise

Volcanology

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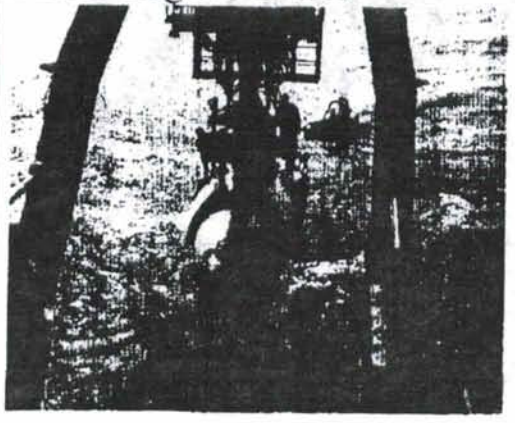
Rodey Batiza
Eric Bergmanis
Ken Rubin
Tracy Gregg
Karl Grönvold
Ken Macdonald
Scott White
Mario Aigner-Torres



Mussels

Cindy Van Dover
Elizabeth Boyle
Linda Popels

ABE

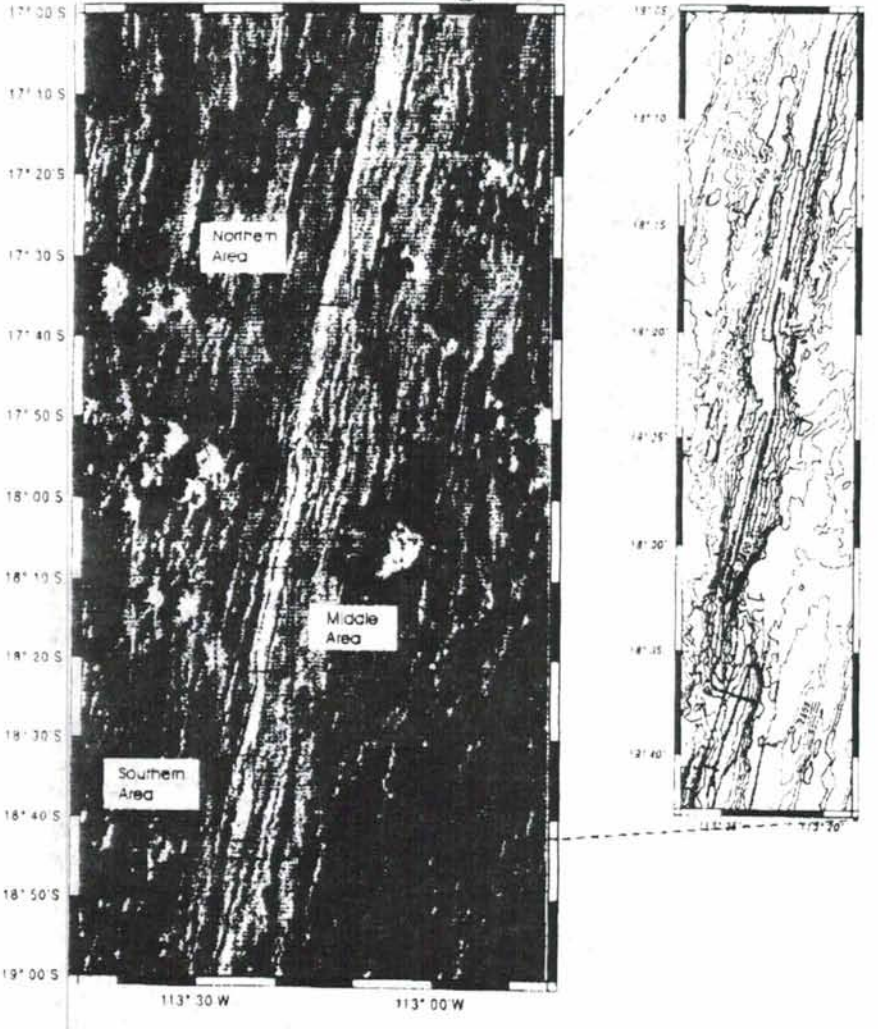
Marie-Helene Cormier
William Ryan
Wen Jin
Anjana Shah

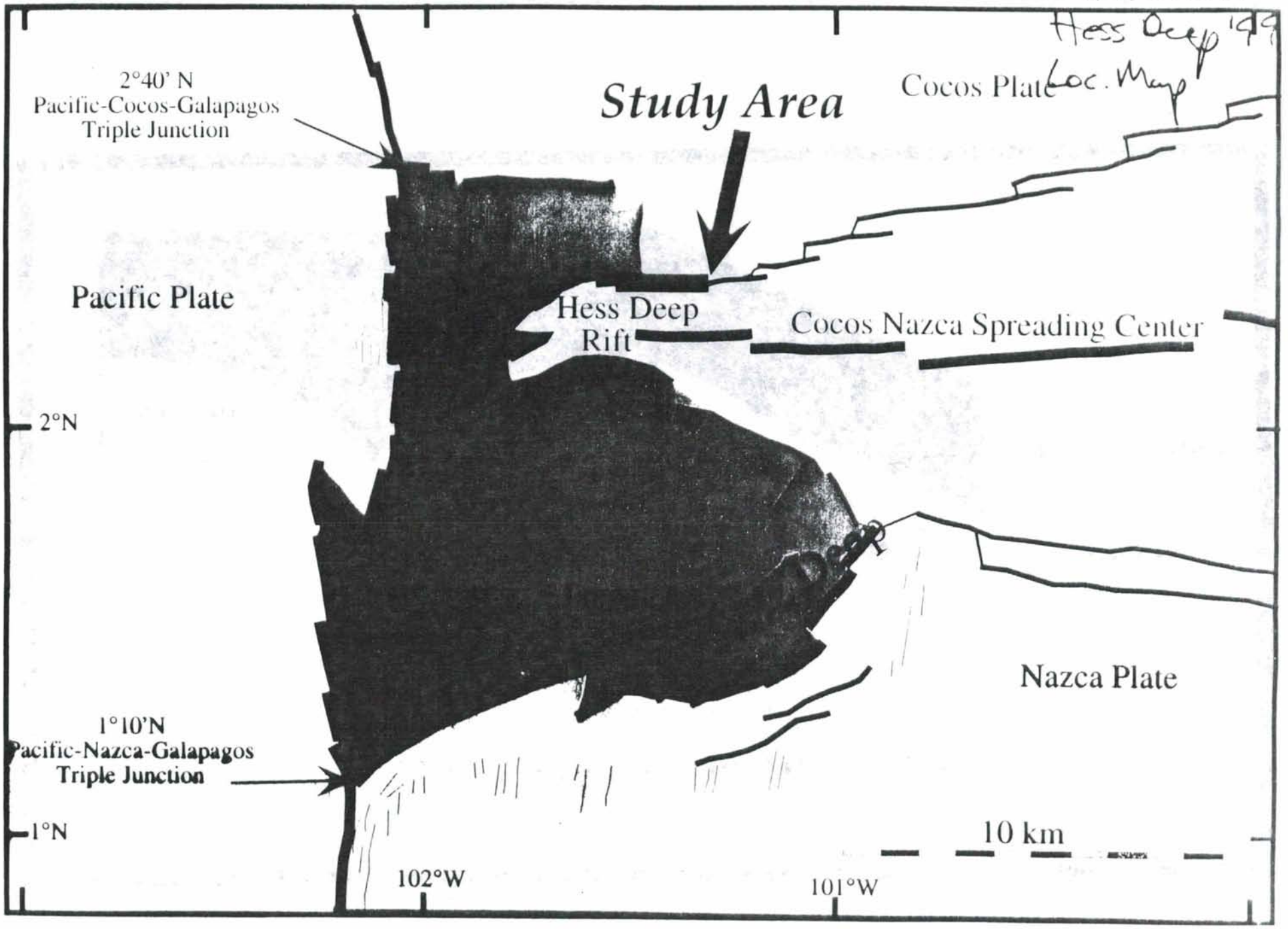
Volcanological Investigations at a superfast spreading mid-ocean ridge

- 135 km of 120 KHz track (~160 km^2 of seafloor imaged) in four days

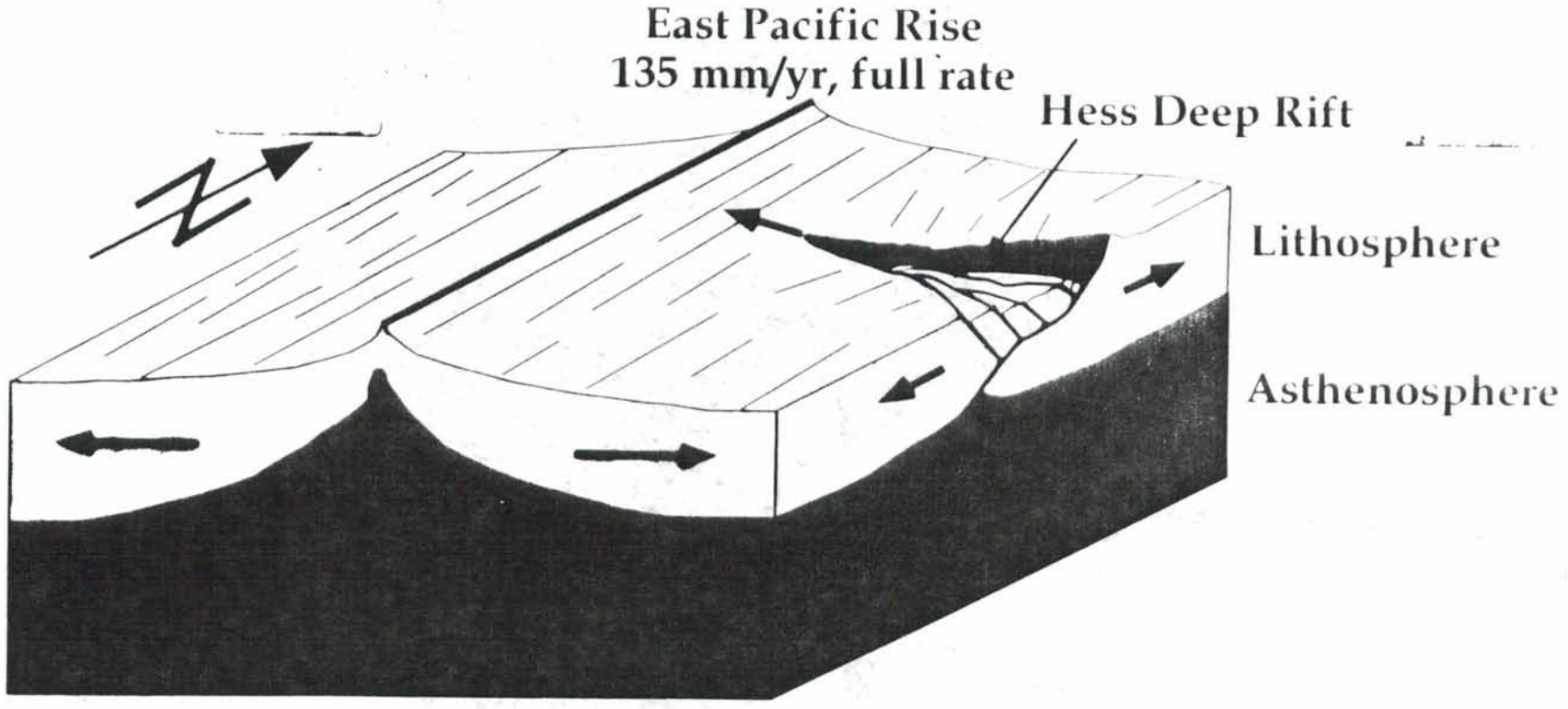
- 23 Alvin dives (of 24 planned - 3 were biology dives funded by Van Dover)
  - track ave >5 km per dive
  - bottom time ~ 5.5 hrs
  - 232 rock samples collected

- 92 Wax core and dredge stations



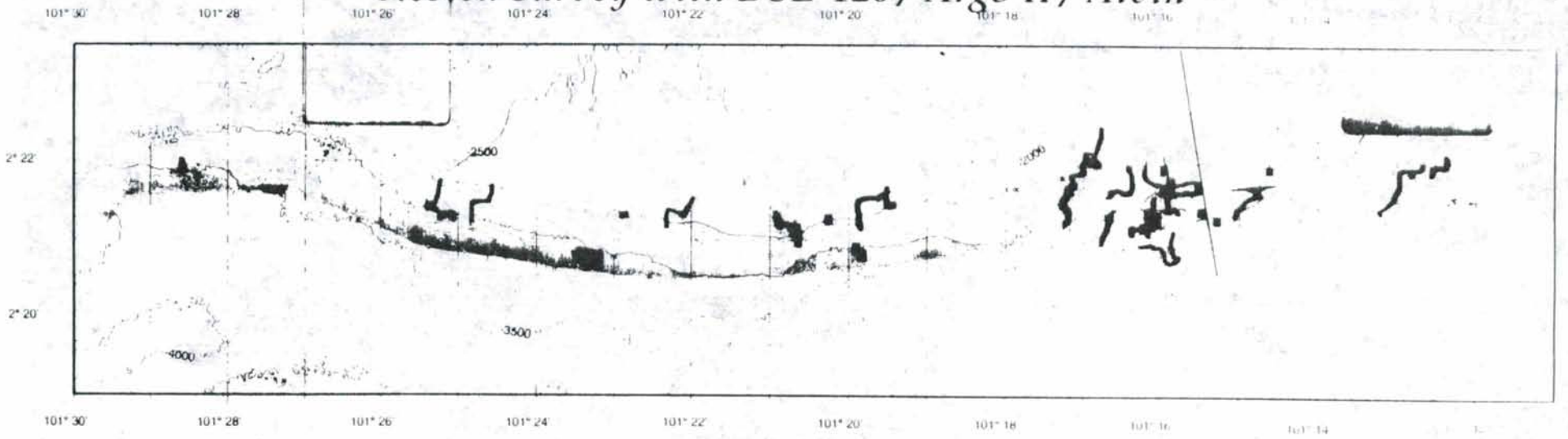

Duke Univ.
Hess Deep '99
Loc. Map
2°40' N
Pacific-Cocos-Galapagos
Triple Junction
Study Area
Cocos Plate
Pacific Plate
Hess Deep
Rift
Cocos Nazca Spreading Center
2°N
Nazca Plate
1°10'N
Pacific-Nazca-Galapagos
Triple Junction
1°N
10 km
102°W
101°W

Tectonic Setting of the Hess Deep Rift



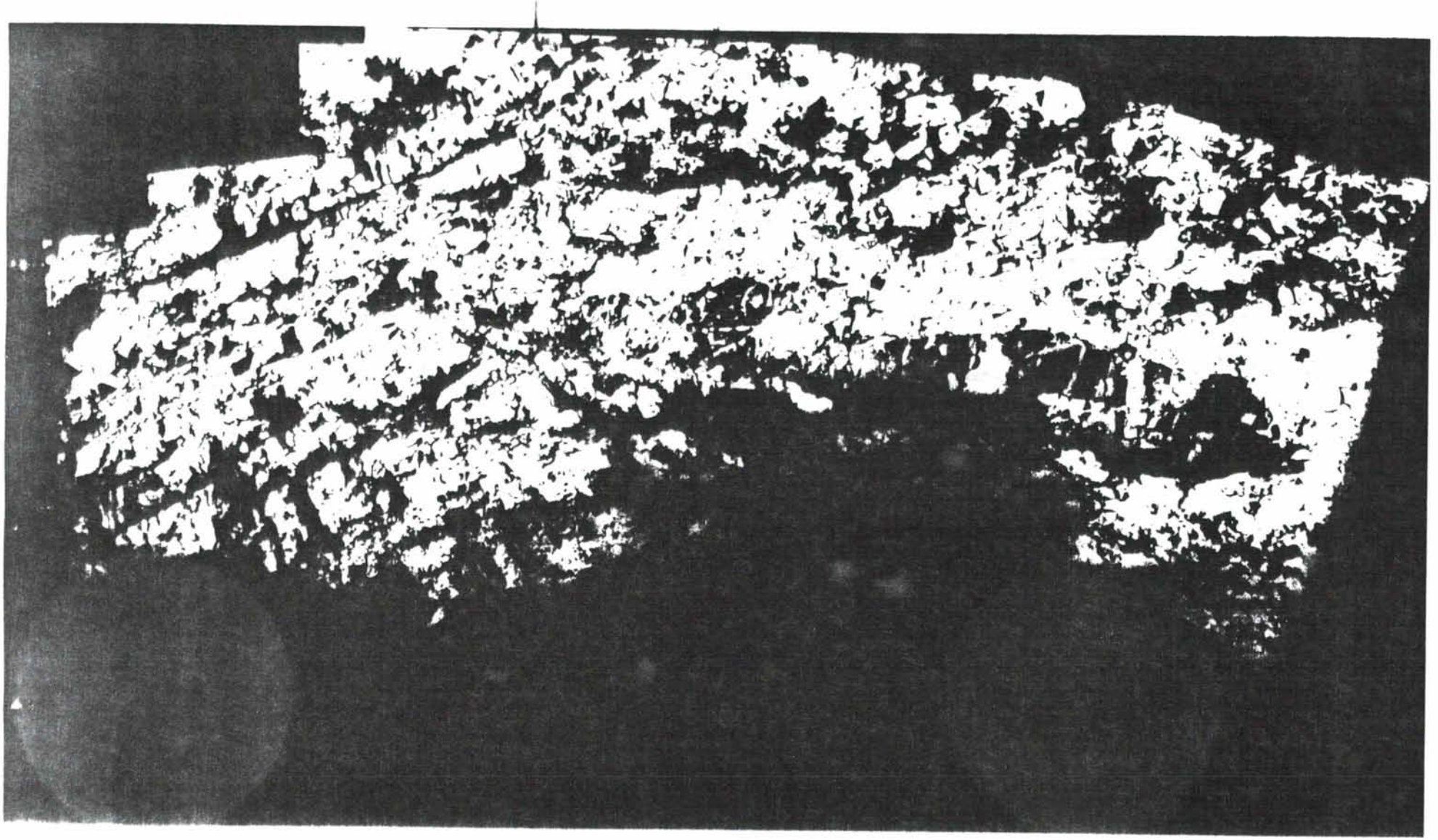
Hess Deep '99:

Nested Survey with DSL-120 / Argo II / Alvin

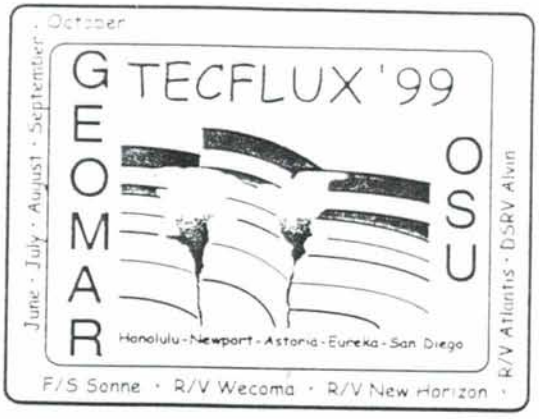


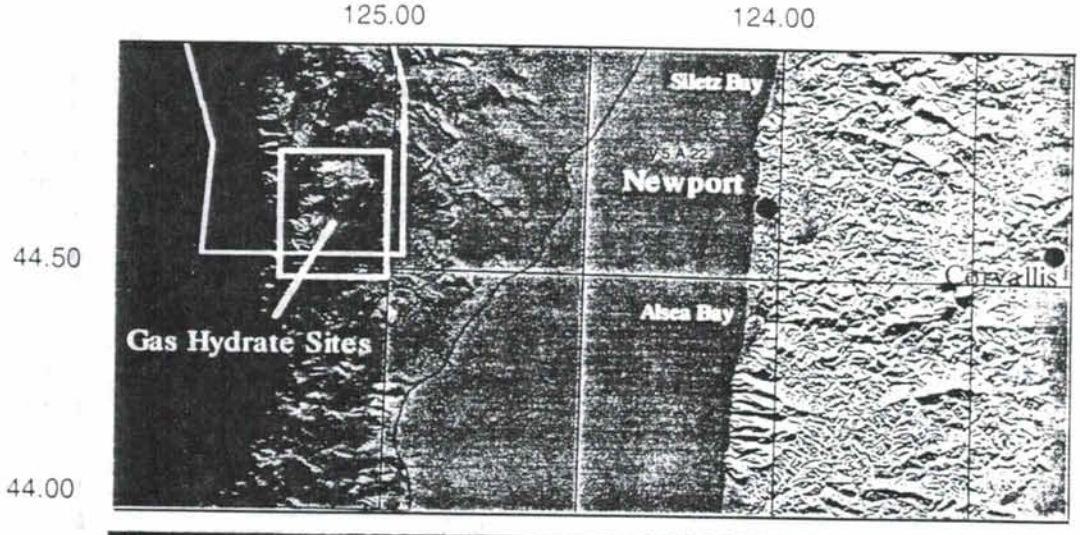
To EPR

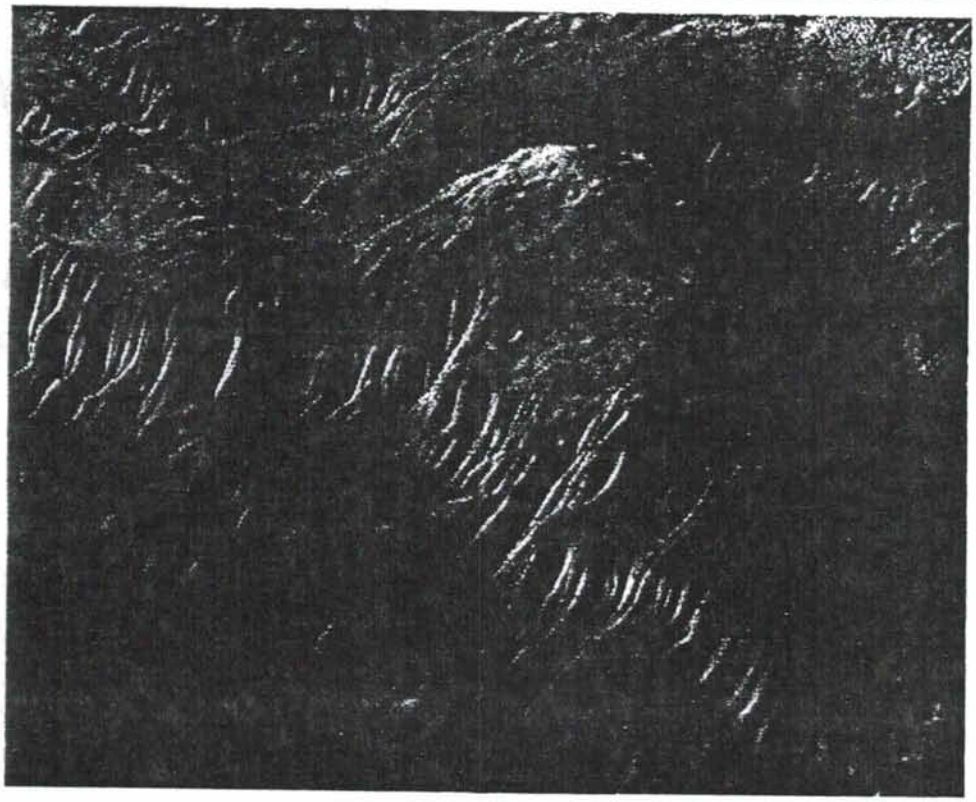
10 km= 150 ky spreading

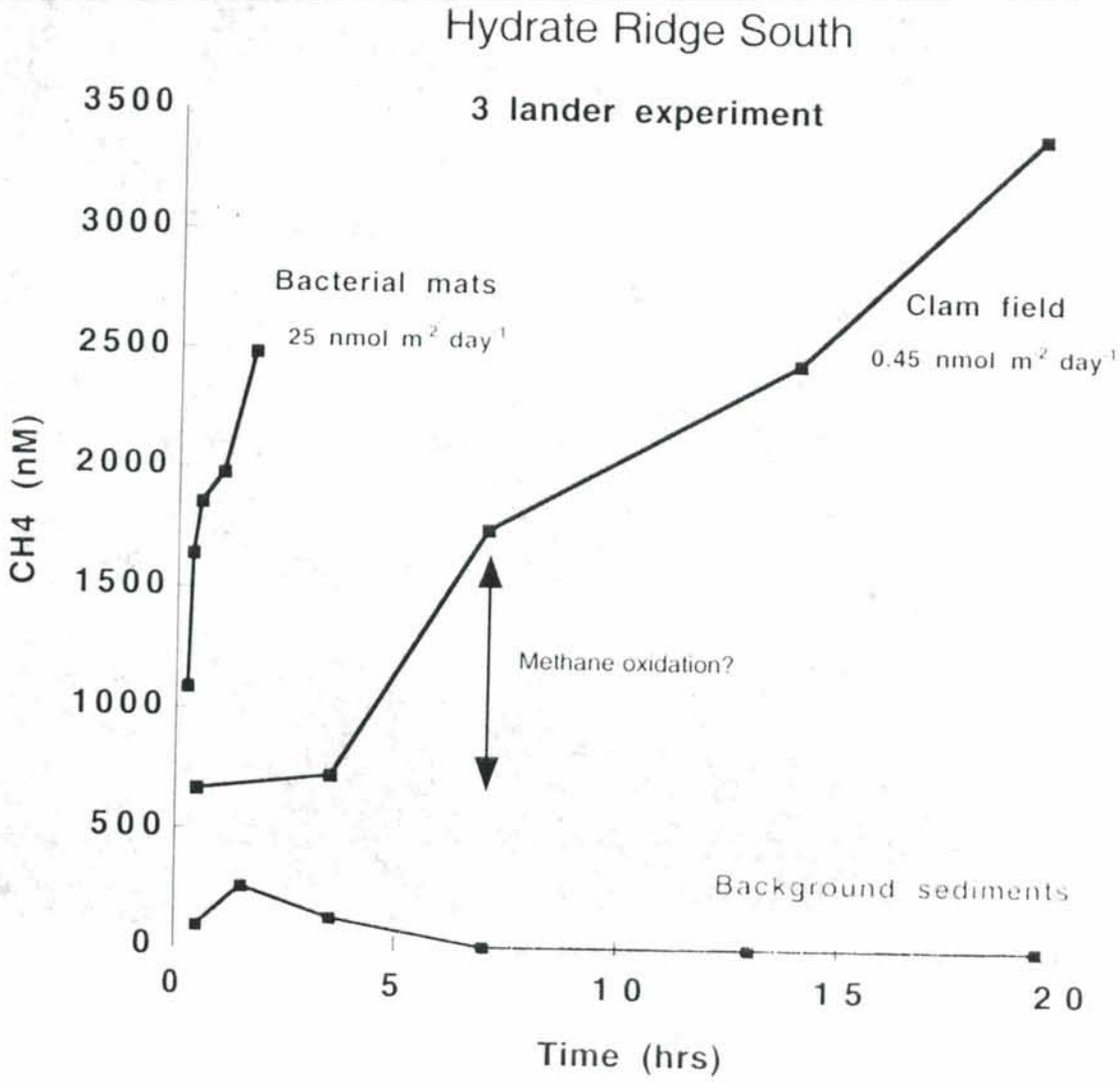


HYDRATE RIDGE, CASCADIA

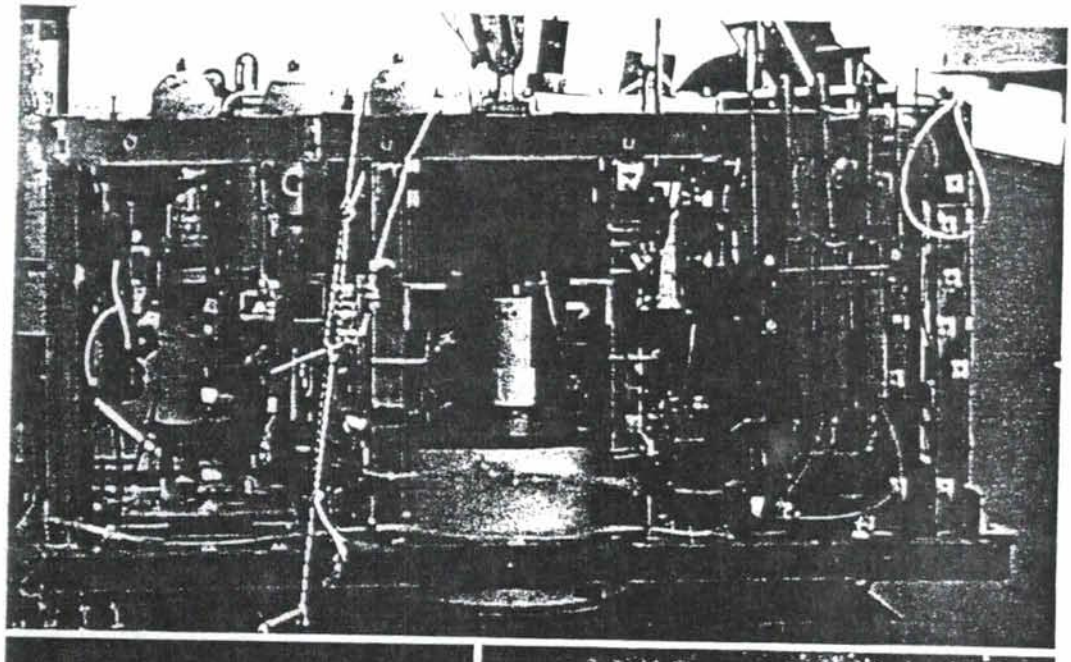


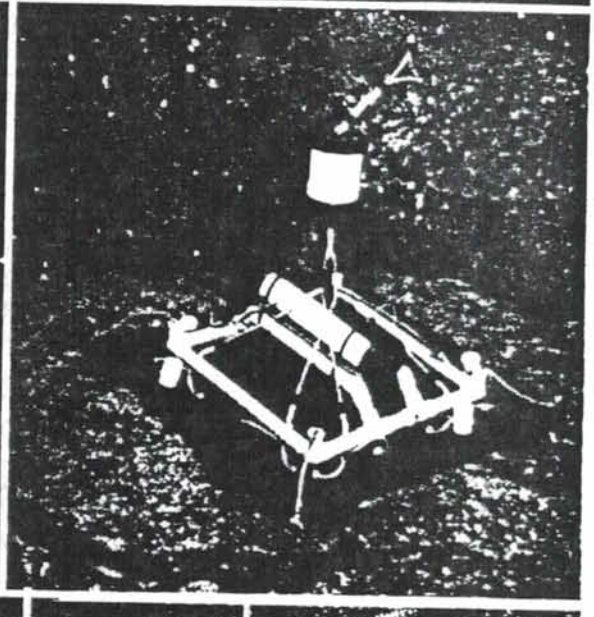


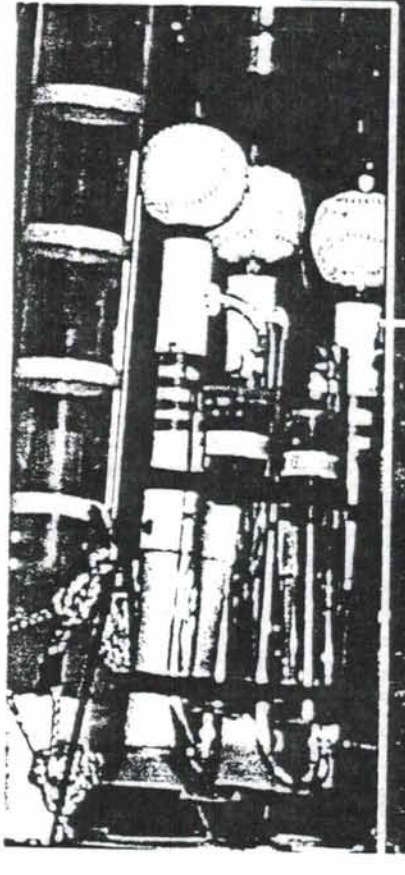


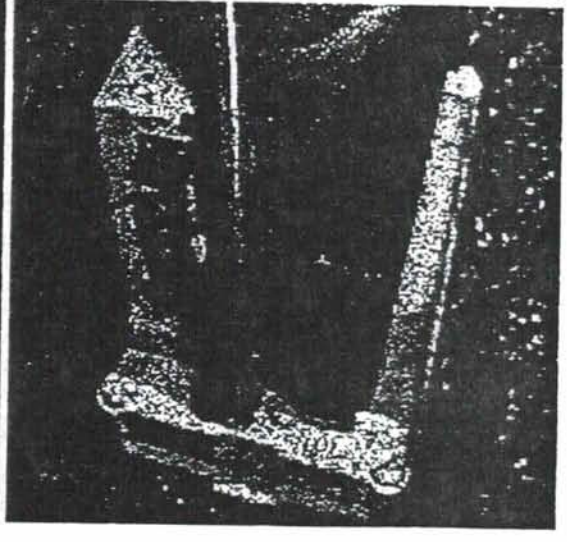

Hydrate Ridge South
3 lander experiment
3500
3000
2500
2000
1500
1000
500
0
CH4 (nM)
Bacterial mats
25 nmol m-2 day-1
Clam field
0.45 nmol m-2 day-1
Methane oxidation?
Background sediments
0
5
10
15
20
Time (hrs)

TECFLUX 99





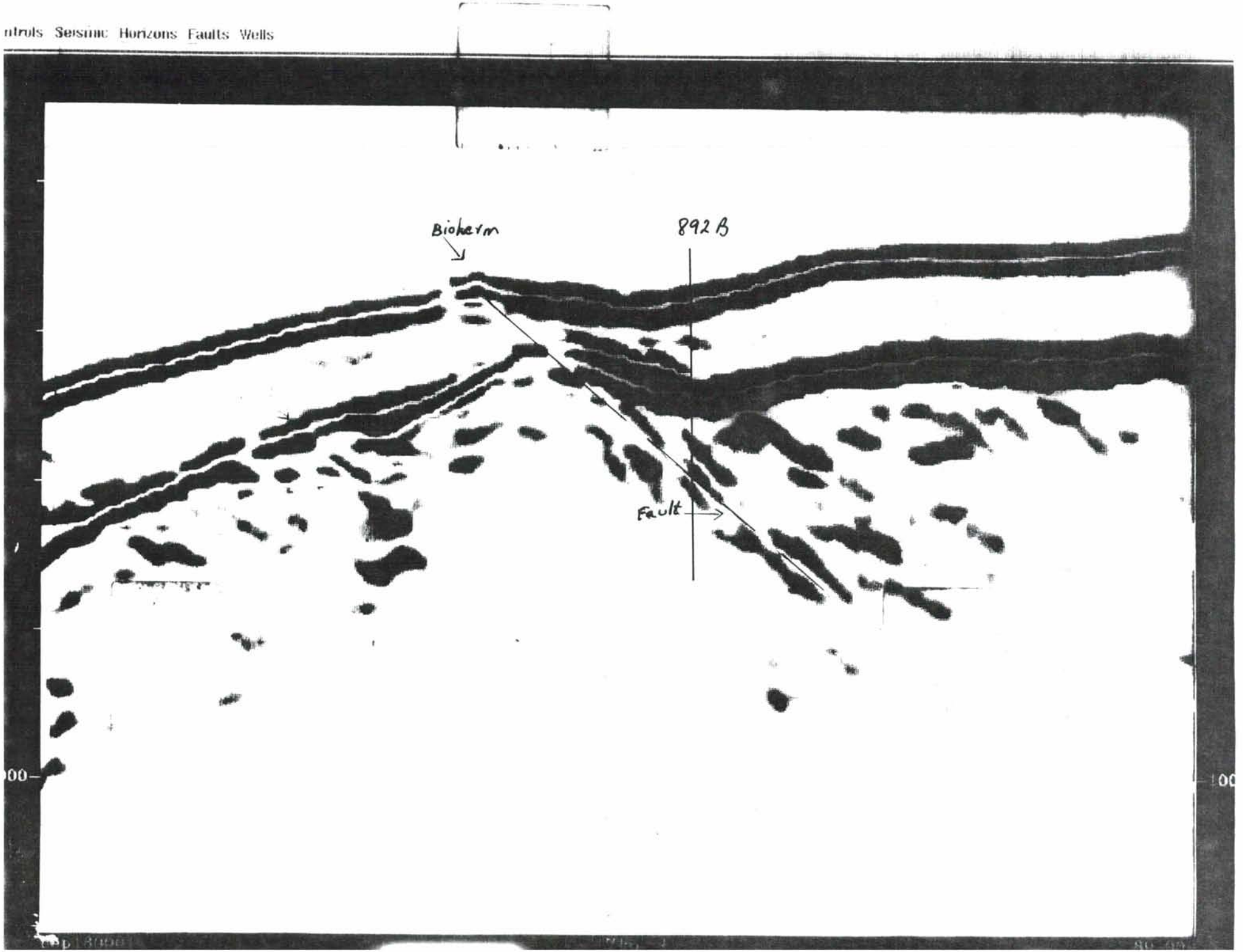


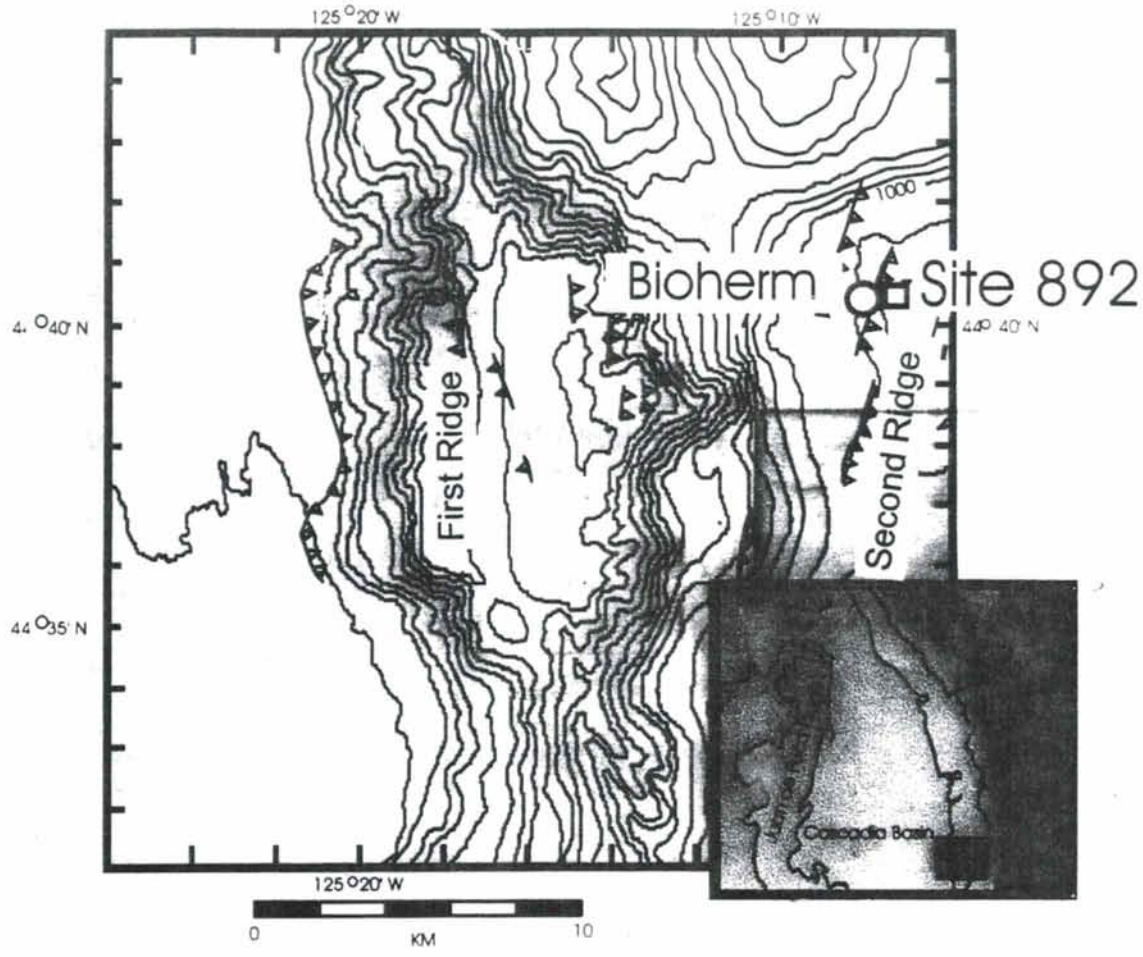


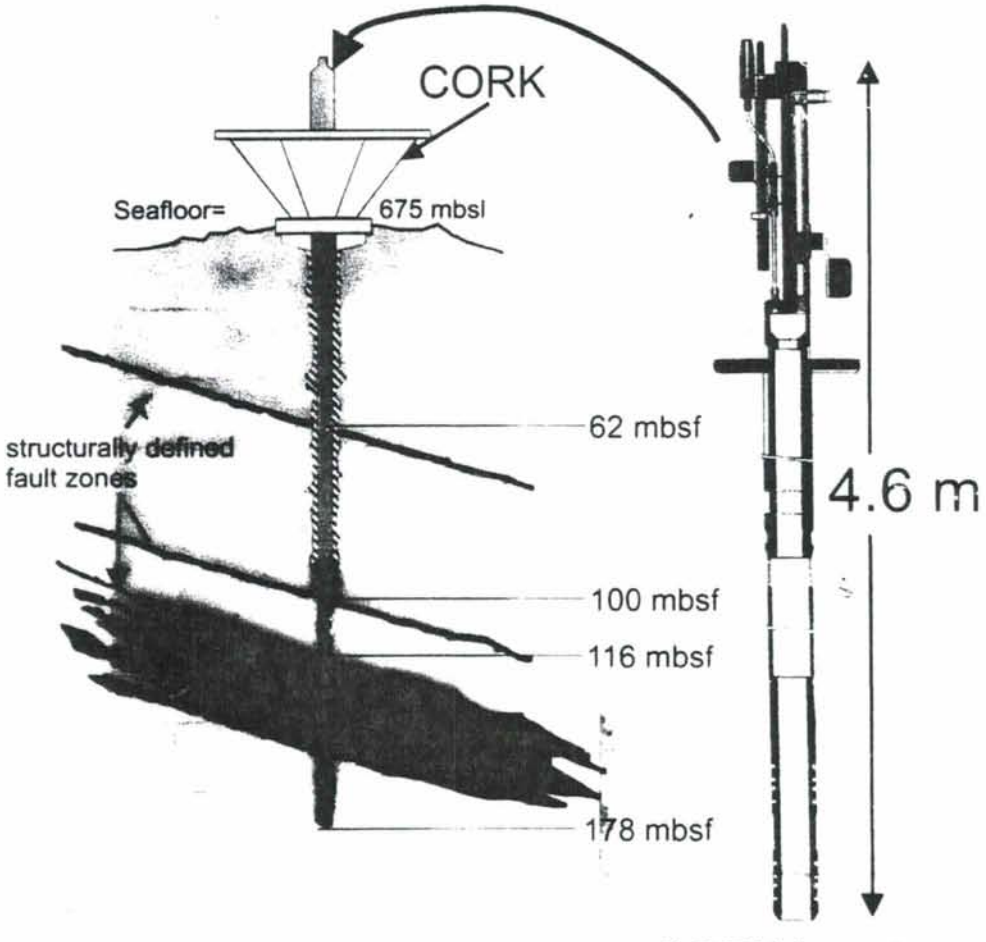
Active C Flux on the Cascadia Accretionary Prism: *In-situ* Measurement of Hydrocarbon Sequestration as Gas Hydrates and Authigenic Carbonate Deposits

Co-PI's: Bobb Carson, Miriam Kastner, and Doug Bartlett

(Hans Jannasch)


ntrols Seismic Horizons Faults Wells
Bioherm
892 B
Fault



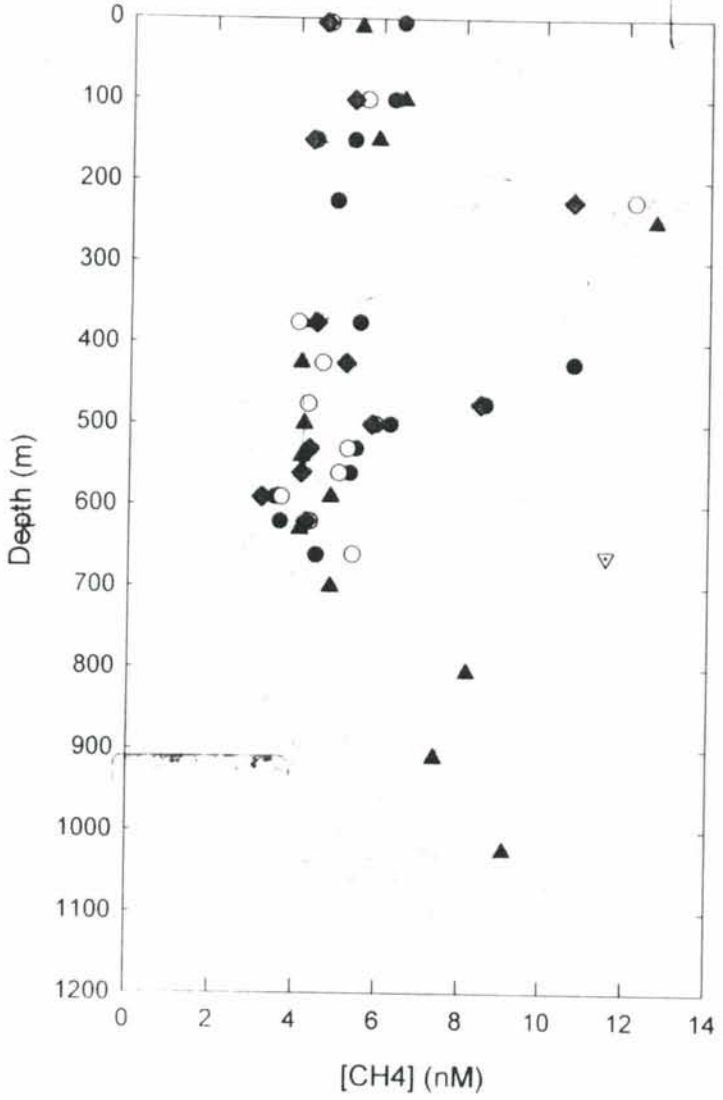


CORK Insert
w/ hydraulic port

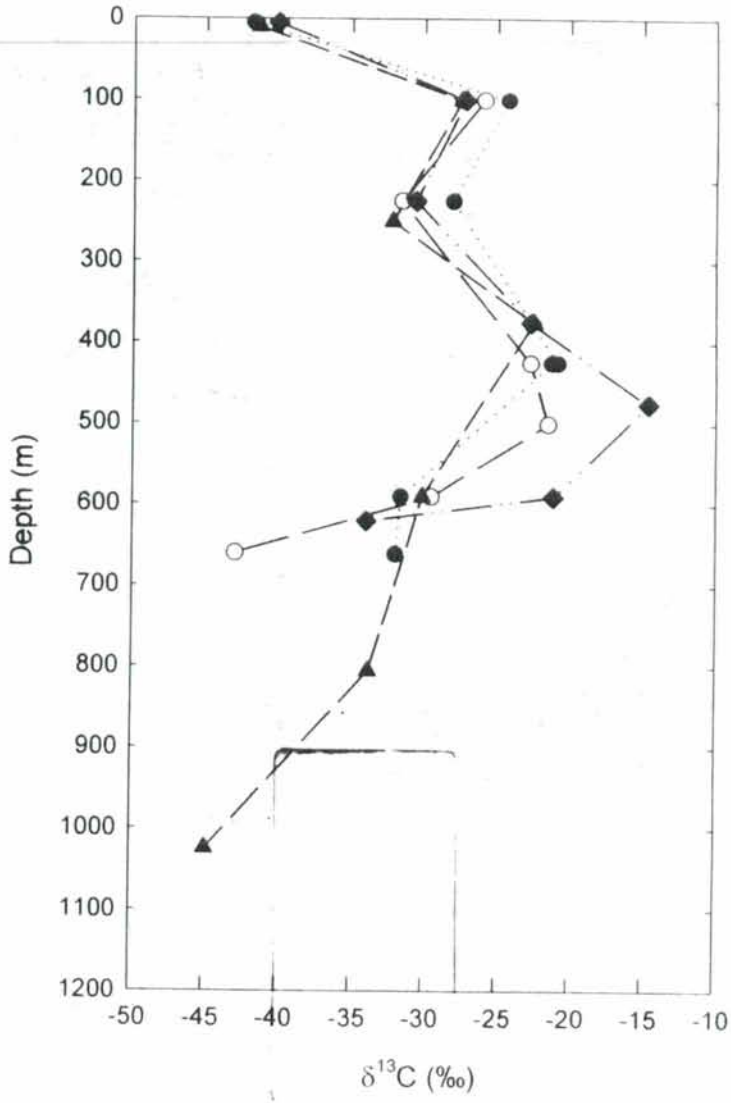
• $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$ ($\Delta Alk = 0$)

• $CH_4 + SO_4^{-2} + 2H^+ \rightarrow CO_2 + 2H_2O + H_2S$ ($\Delta Alk = +2$)

Cyclic II methane (Casts I-IV)



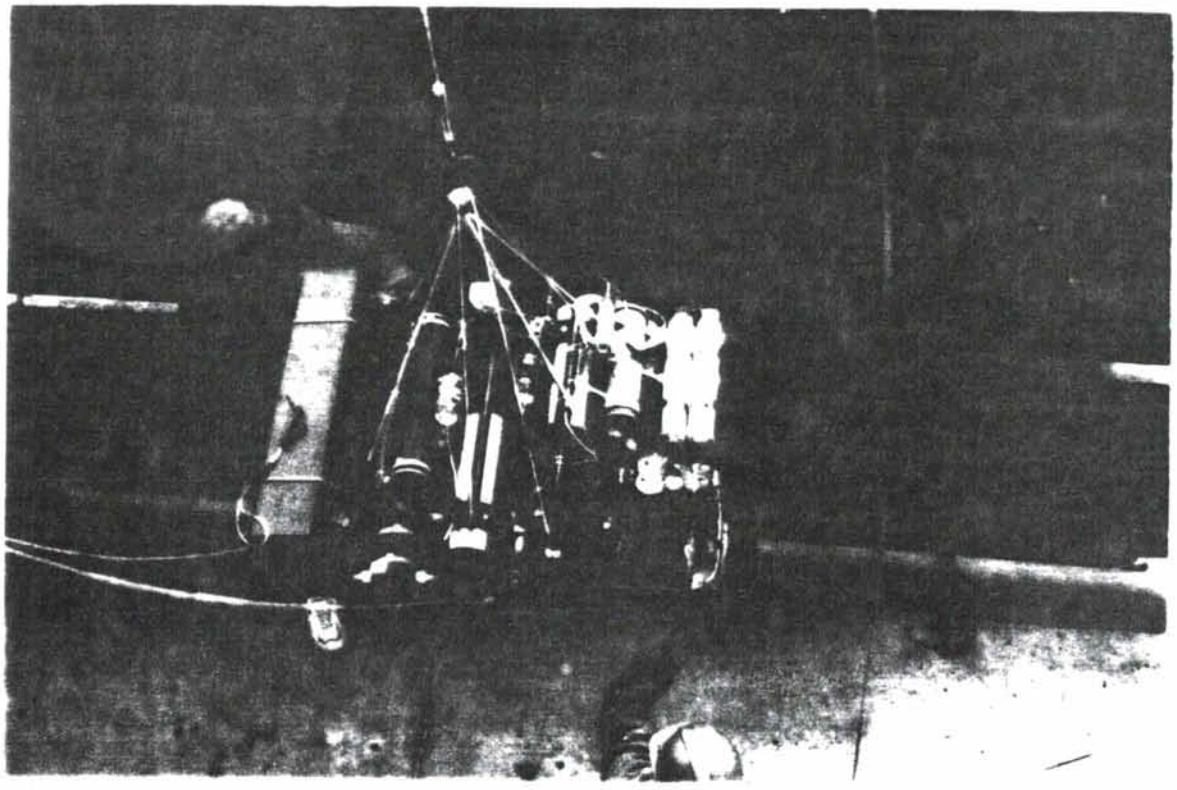
Cyclic II $\delta^{13}C$ in methane (Casts I-IV)



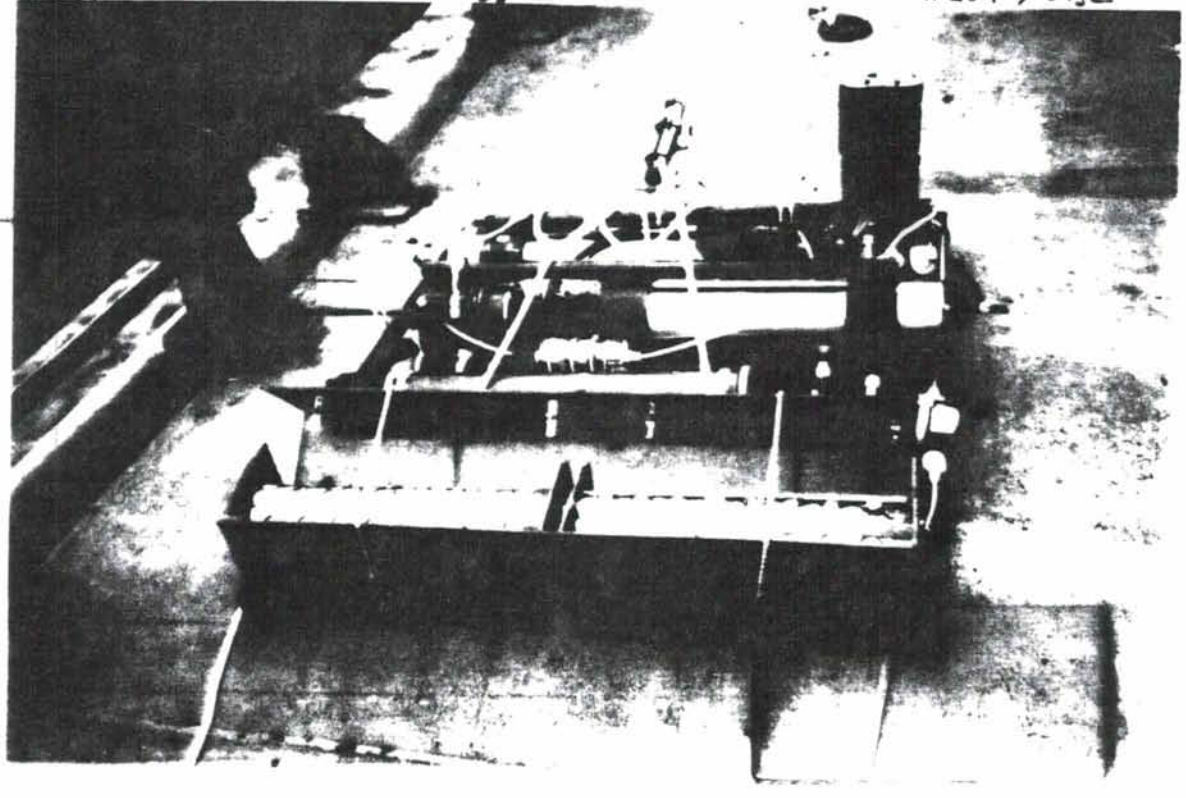
- ● Cast I - Lat.: N44 deg. 40.537', Long.: W125 deg. 07.086'; Date: 6/26/99 - 6/27/99
- ○ Cast II - Lat.: N44 deg. 40.51', Long.: W125 deg. 07.41'; Date: 6/26/99 - 6/27/99
- ◇ Cast III - Lat.: N44 deg. 39.786', Long.: W125 deg. 6.422'; Date: 6/26/99 - 6/27/99
- ▲ Cast IV - Lat.: N 44 deg. 35.8', Long.: W 125 deg. 5.2'; Date: 6/28/99
- ▽ Site 8 Bottom Water - Lat.: N44 deg. 40.104', Long.: 125 deg. 3.049'; Date: 6/29/99

Age of Cemented Clams, Bioherm, Cascadia Margin

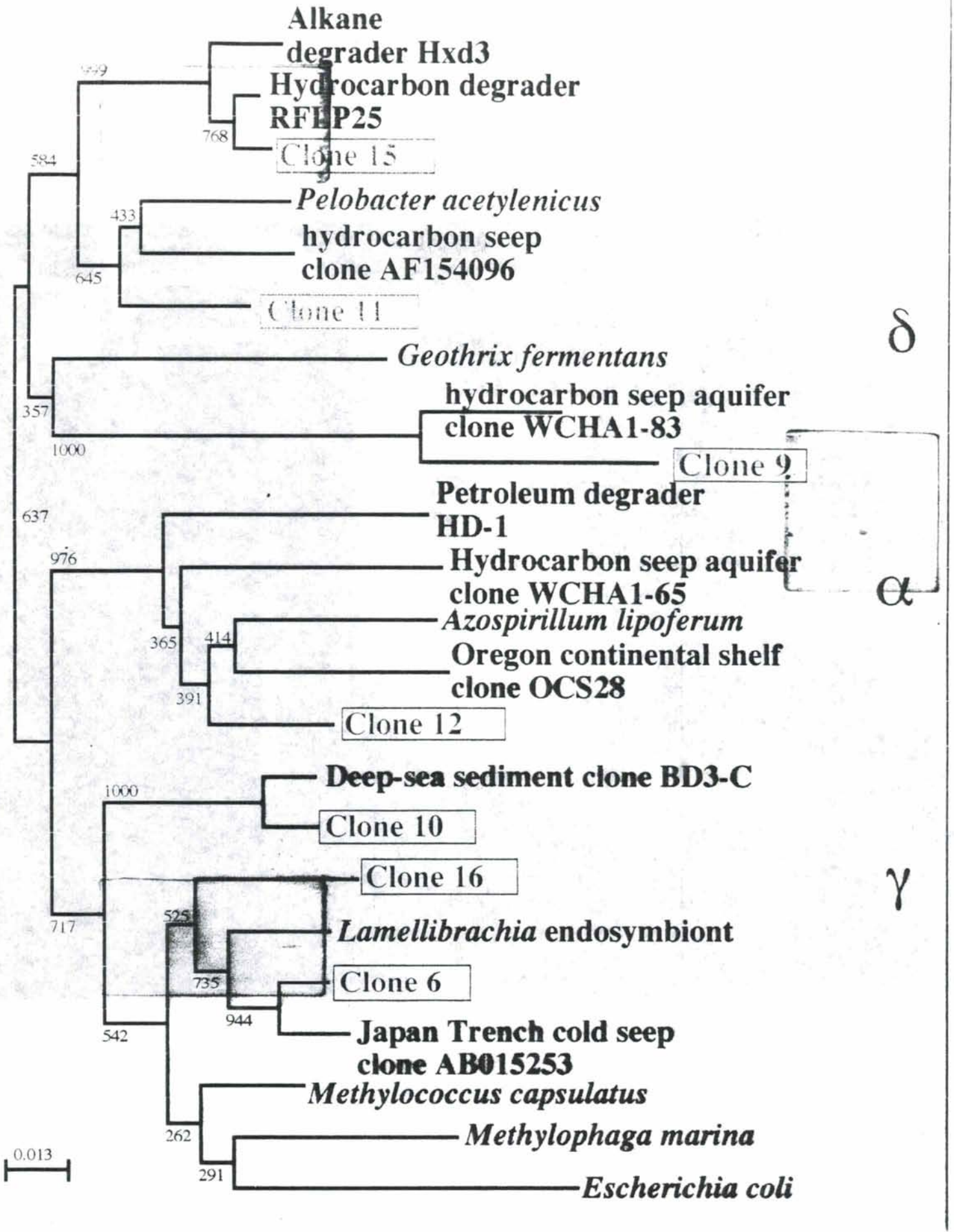
	$\delta^{13}C$ (‰, PDB)	$\delta^{18}O$ (‰, PDB)	$^{14}C_{corr}$ (years B.P.)
Clam IRL #1	- 4.08	4.61	23,930 ± 100
Clam IRL #2	- 0.99	4.32	21,130 ± 80
Carbonate Cement IRL	- 48.39	3.54	27,850 ± 120

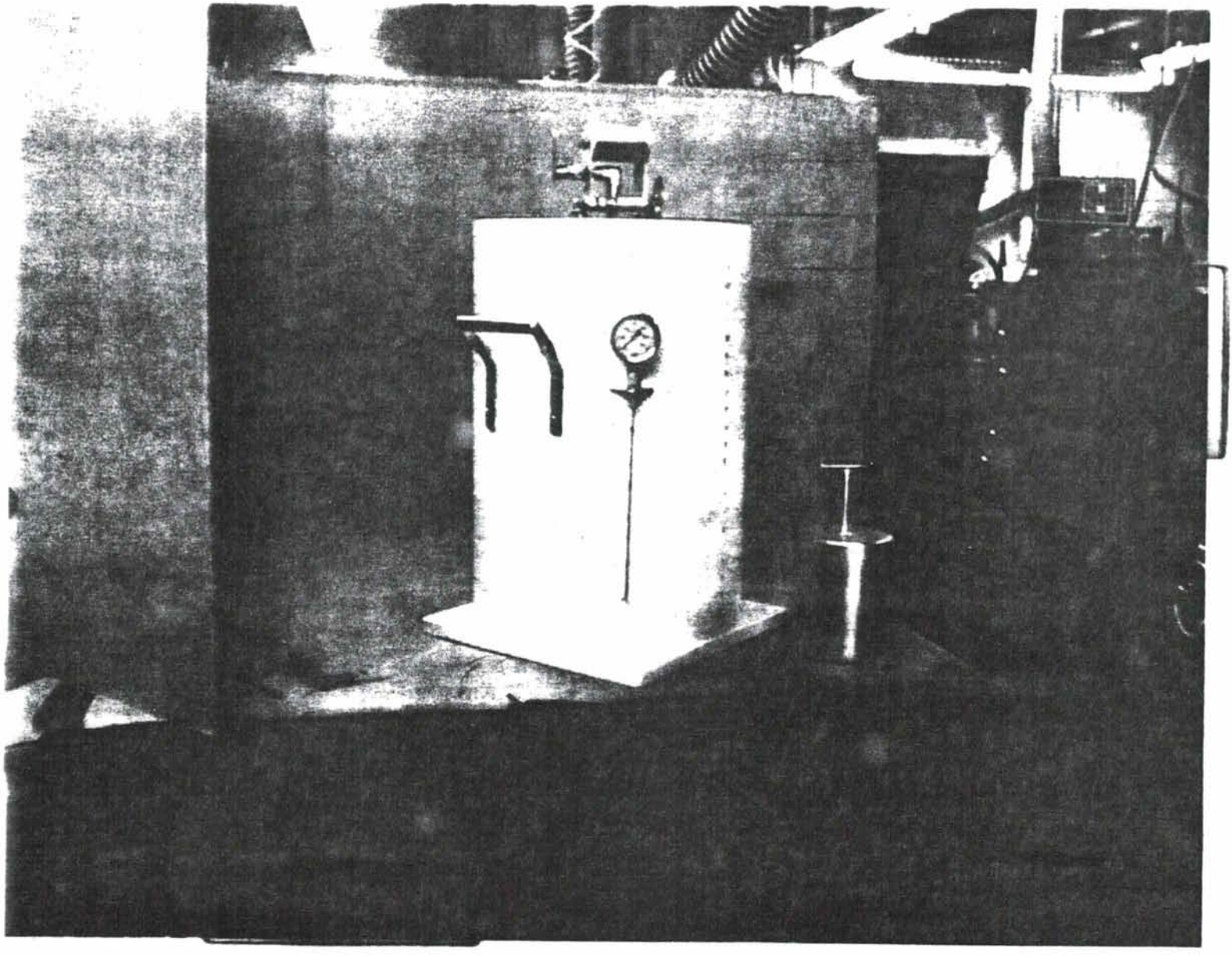


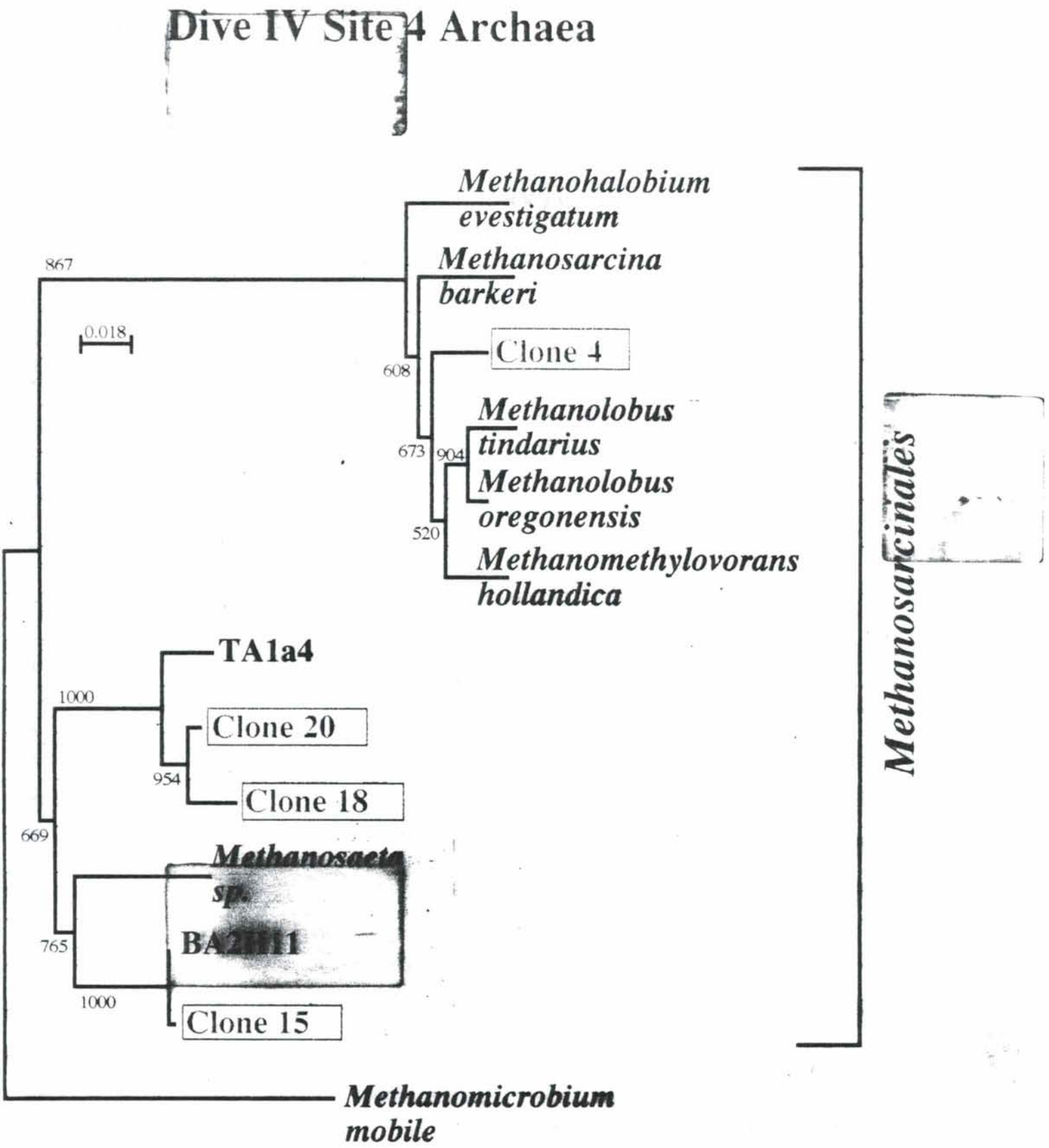
- Osmosamplers → teflon / Cu
- Differential press. Transducer
- Bypass valve; Data logger
- Reaction Chambers → Anoxic / oxic → carb… / Biolo…
- Flowmeters → Osmosamplers / Optical Sectors / Heat Pulse



Dive IV Site 4 Proteobacteria






Dive IV Site 4 Archaea
Methanohalobium evestigatum
Methanosarcina barkeri
867
0.018
Clone 4
608
Methanolobus tindarius
673
904
Methanolobus oregonensis
520
Methanomethylovorans hollandica
Methanosarcinales
TA1a4
1000
Clone 20
954
Clone 18
669
Methanosaeta sp.
765
1000
Clone 15
Methanomicrobium mobile

CORKs 99

At Sea Goals:

- → Download temperature and pressure data.
- → Retrieve data loggers, thermistor strings, and OsmoSamplers.
- → Conduct *in situ* calibration.
- → Log boreholes for temperature.
- → Collect fluids in boreholes.
- → Plug boreholes.

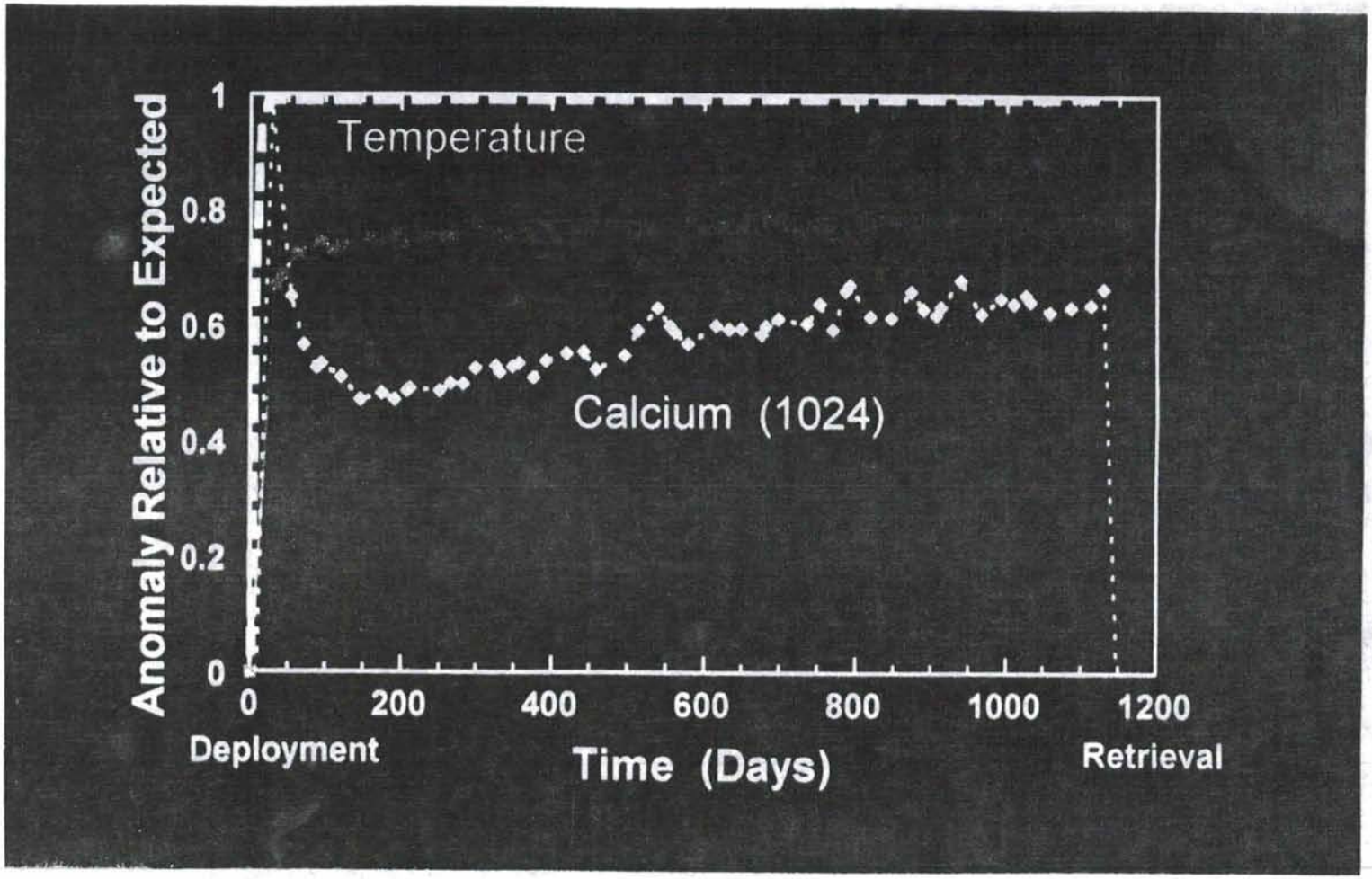
Alvin and the Control Vehicle

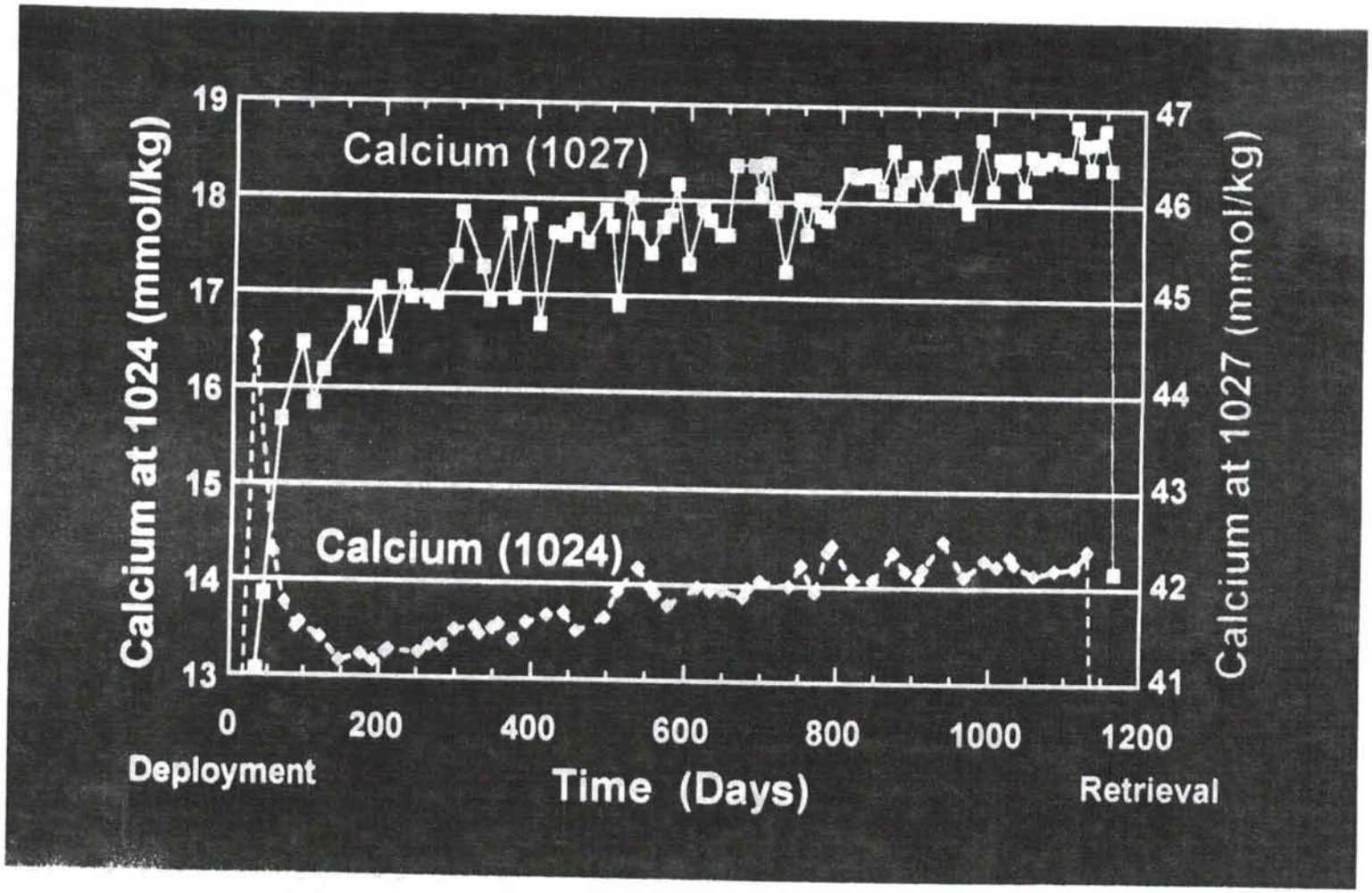
Operational Difficulties

- → Two groups (bunks and baskets)
- → Wire pull strength <4000 pounds at 2600 m water depth
- → Temperature effects on wireline tools

Operational Successes

- → Joint operations
- → Heavy gear with Alvin
- → Reenter a 3.5" hole with a 2" instrument at a water depth of 2600 m
- → Placement of instruments on the seafloor
- → Wireline water sampler


Anomaly Relative to Expected
1
0.8
0.6
0.4
0.2
0
Temperature
Calcium (1024)
0
200
400
600
800
1000
1200
Deployment
Time (Days)
Retrieval


Calcium (1027)
Calcium (1024)
Calcium at 1024 (mmol/kg)
Calcium at 1027 (mmol/kg)
19
18
17
16
15
14
13
47
46
45
44
43
42
41
0
200
400
600
800
1000
1200
Deployment
Time (Days)
Retrieval

In-Situ Measurement and Monitoring of Dissolved H2, H2S, and pH in Mid-Ocean Ridge Hydrothermal Fluids: I

- **P.I.'s**: Bill Seyfried, Kang Ding University of Minnesota, Meg Tivey, WHOI

- **Project Description**: Field Testing at Endeavor (JFD) of an array of electrochemical sensors for measurement of dissolved gases (H2, H2S) and pH in high temperature vent fluids.
  - Culmination of three year experimental effort involving sensor development (calibration of electrochemical and material properties) in aqueous NaCl fluids at high T and P (UM)
  - Development of pressure sealed-electronics package for high impedance measurements (Tivey/Bradley (WHOI)

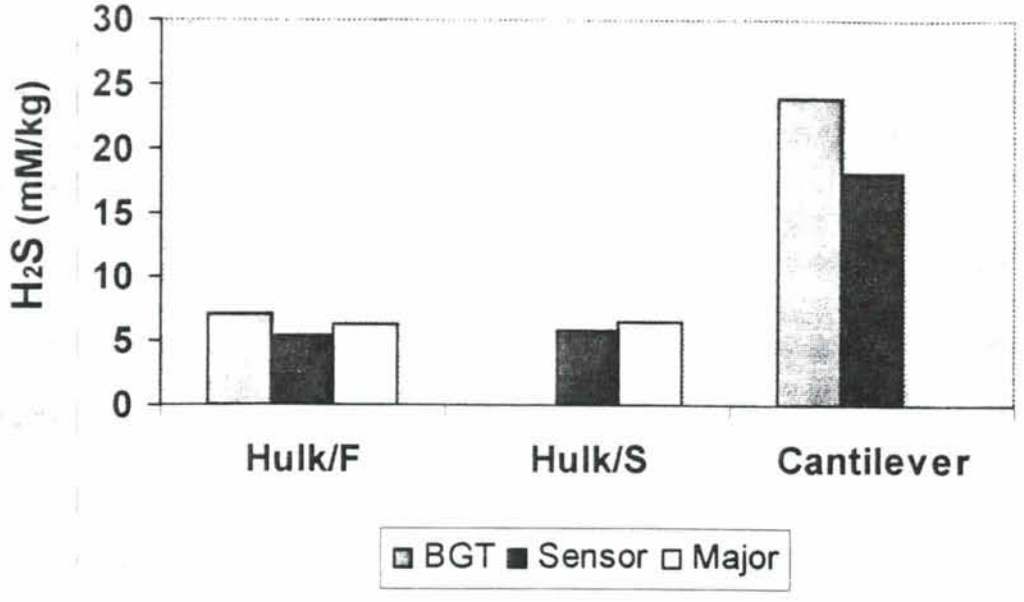
In-Situ Measurement and Monitoring of Dissolved H2, H2S, and pH in Mid-Ocean Ridge Hydrothermal Fluids: II

- **Voyage** - Leg: AT 3-39 Voyage Dates:12 Sept - 01 Oct 1999
- Chief Sci (s): Becker/Kastner/Seyfried
- **ALVIN Dives**: 3468, 3470, 3474, 3478
    - Bradley ICL used as sensor interface with submersible
- **Participants and Testing Strategy**
  - M. Lilley/E. Olson (UW) Gas sampling and measurement
  - J. Seewald (WHOI) Fluid/Gas Sampling and measuremt
  - Meg Tivey (WHOI) Sulfide samples/logistics
  - M. Berndt (UM) Fluid sampling
  - Naimbin Dong (UM) Electronics
  - K. Ding (UM) Sensor Applications

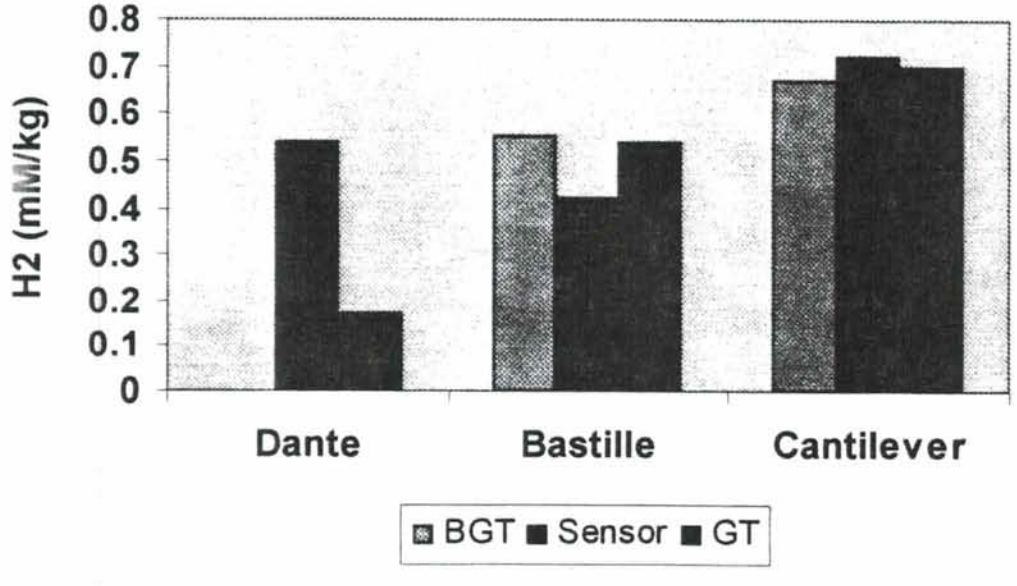
Results of in-situ measurement of vent fluids chemistry

Location	T(C)	pH*in-situ*	$H_{2(aq)}$ (mM/Kg)	a x 1000	$H_2S_{(aq)}$ (mM/Kg)	a x 1000	
Hulk-F	337	4.40			5.43	6.94	3468/H3
Hulk-S	330	4.32			5.89	7.39	3468/H3
Dante	363	5.15	0.54	0.78			3470/H1
Bastille	255	3.95	0.42	0.46			3470/H1
Cantilever	370				17.28	18.14	3474/H1
	368		0.72	0.76			3474/H1

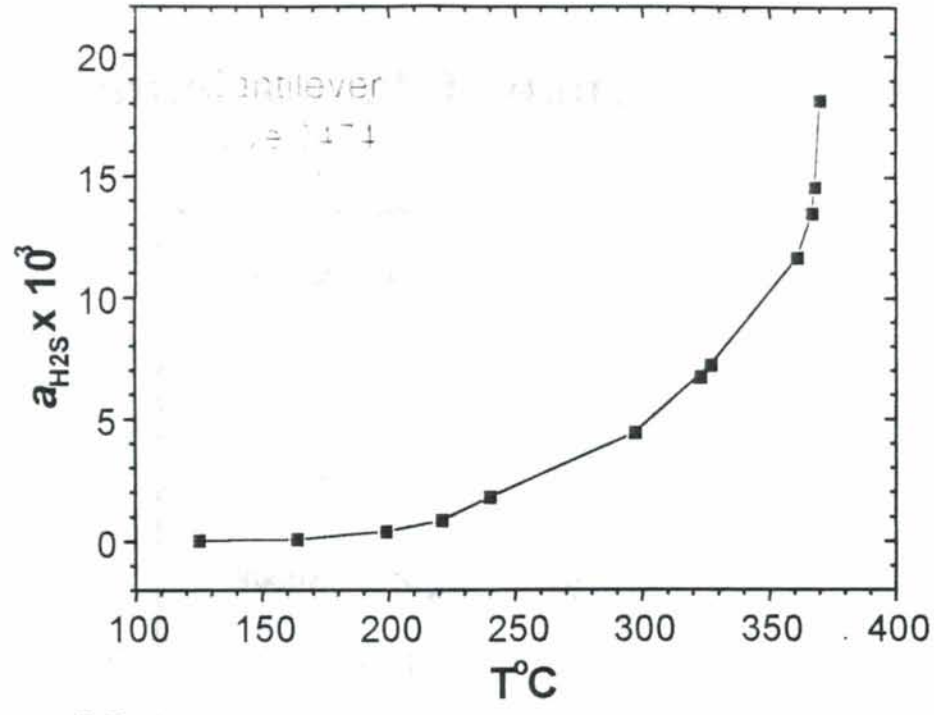
Comparison of dissolved H_2S concentrations measured by using different methods

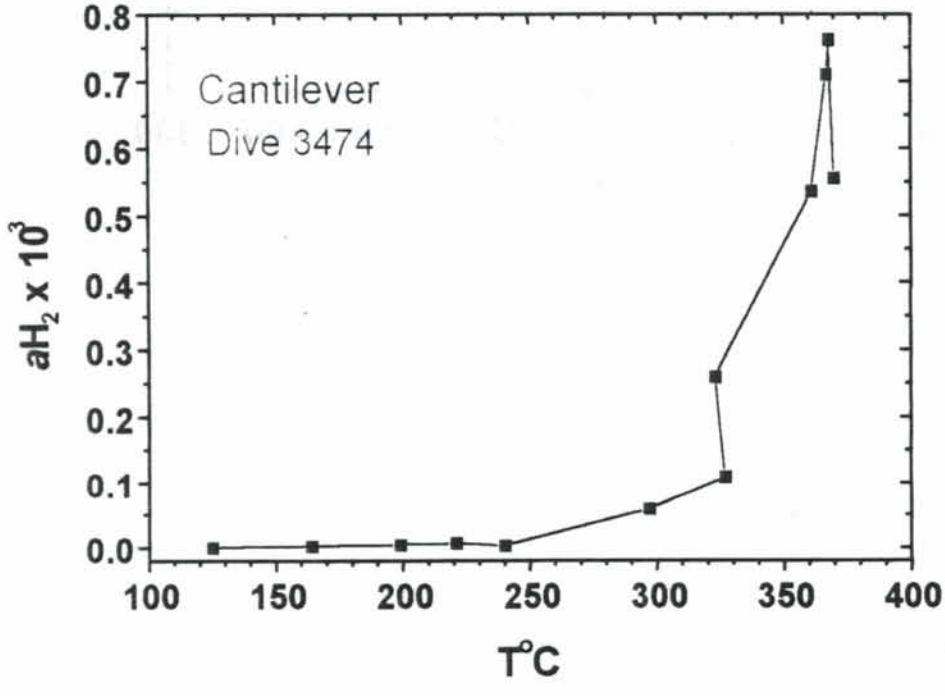


Comparison of dissolved H_2 concentrations measured by using different methods

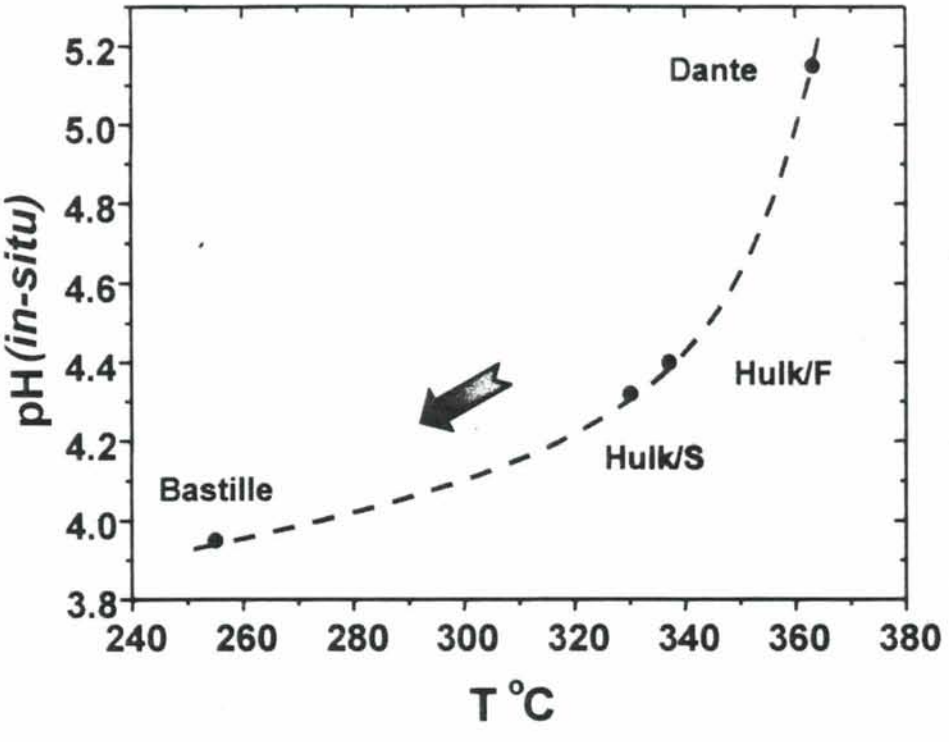


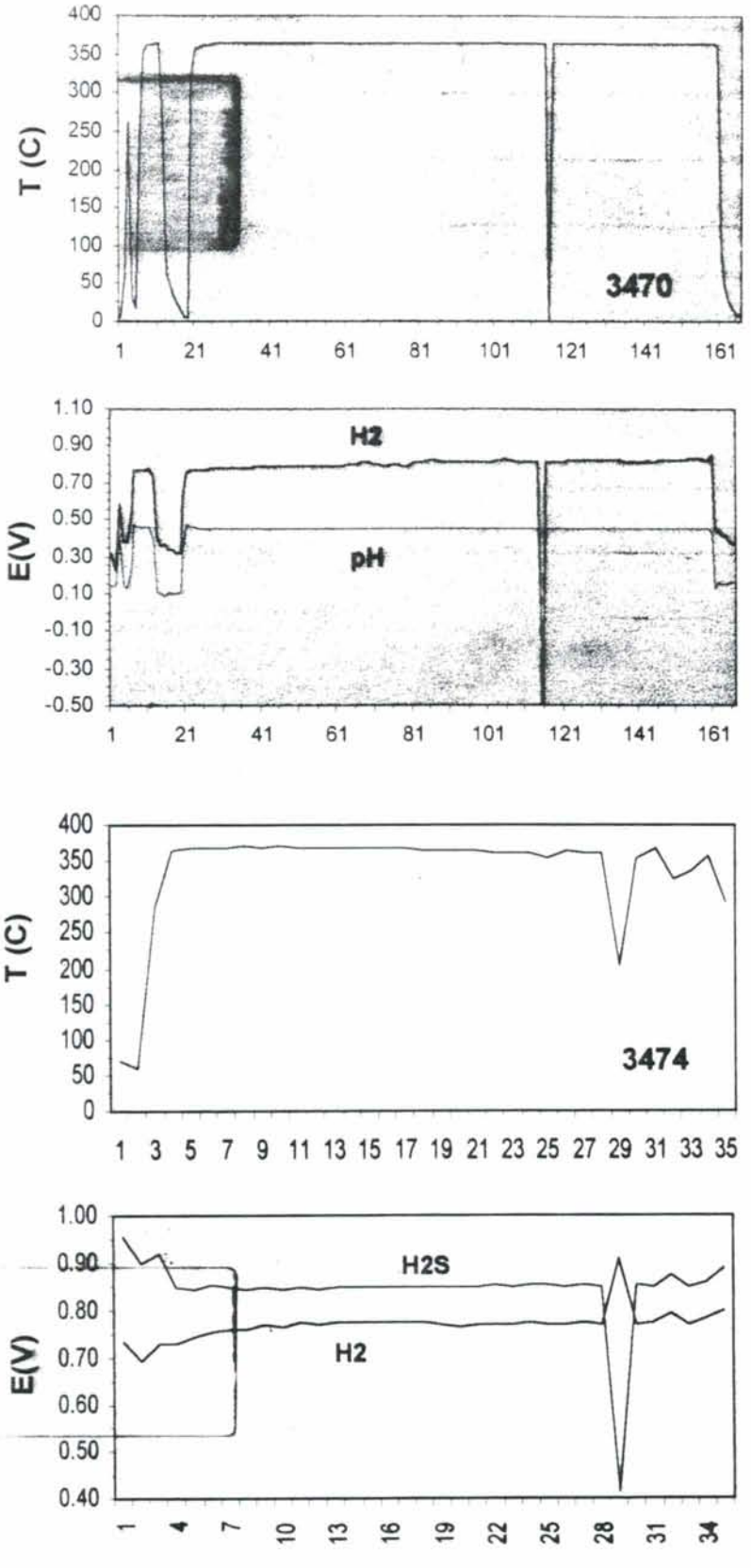
Real time relationship between dissolved gases and temperature from a single vent site





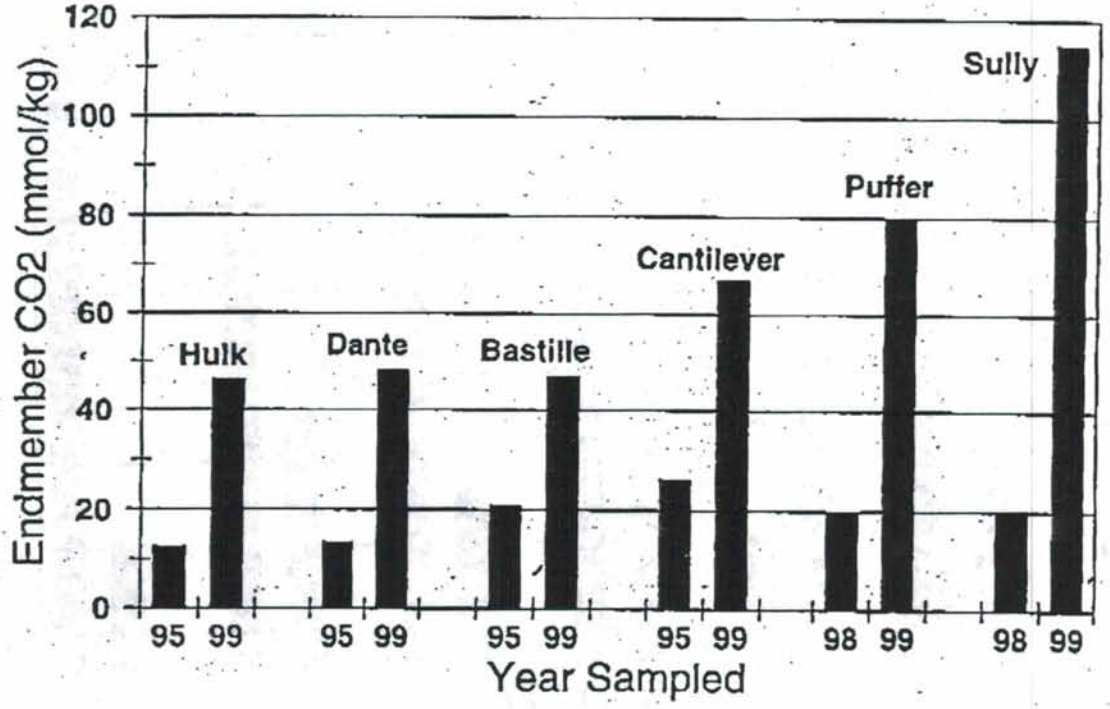
In-situ pH as a function of temperature




T (C)
400
350
300
250
200
150
100
50
0
1
21
41
61
81
101
121
141
161
3470
E(V)
1.10
0.90
0.70
0.50
0.30
0.10
-0.10
-0.30
-0.50
H2
pH
T (C)
3474
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35
E(V)
1.00
0.90
0.80
0.70
0.60
0.50
0.40
H2S
H2
1 4 7 10 13 16 19 22 25 28 31 34
N of data points in 5 sec interval

Endeavour Main Field CO2

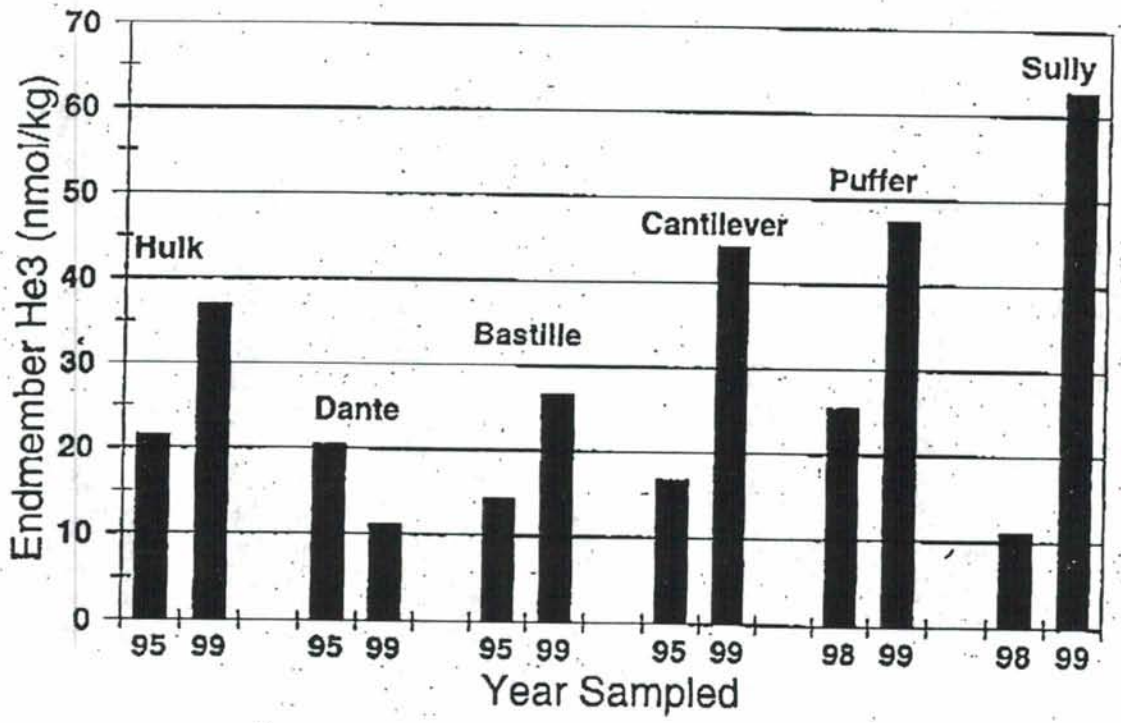
Before and After June 1999 Earthquakes



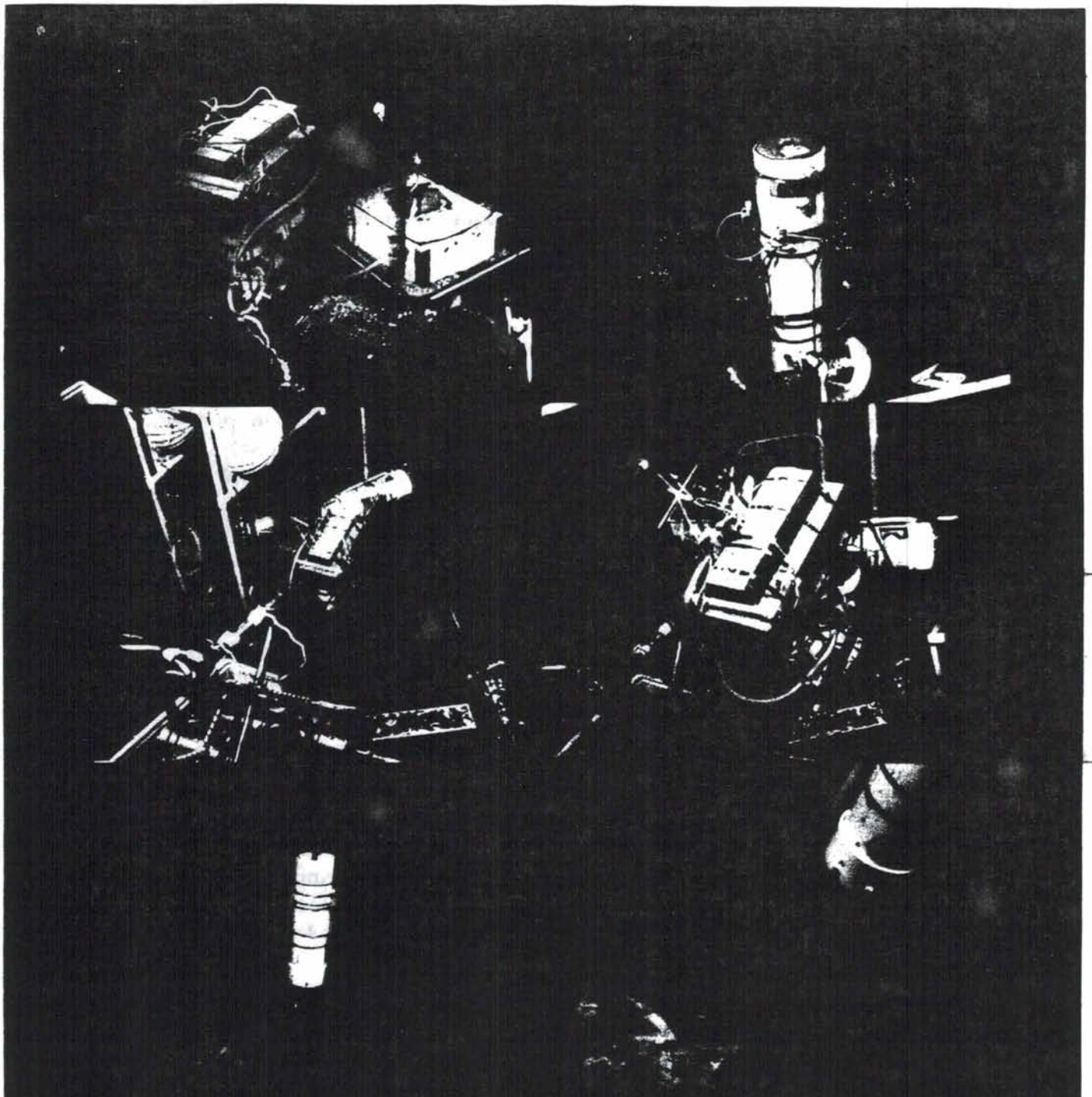
Marv Lilley
University of Washington

Endeavour Main Field He3

Before and After 1999 Earthquakes



John Lupton
NOAA/PMEL

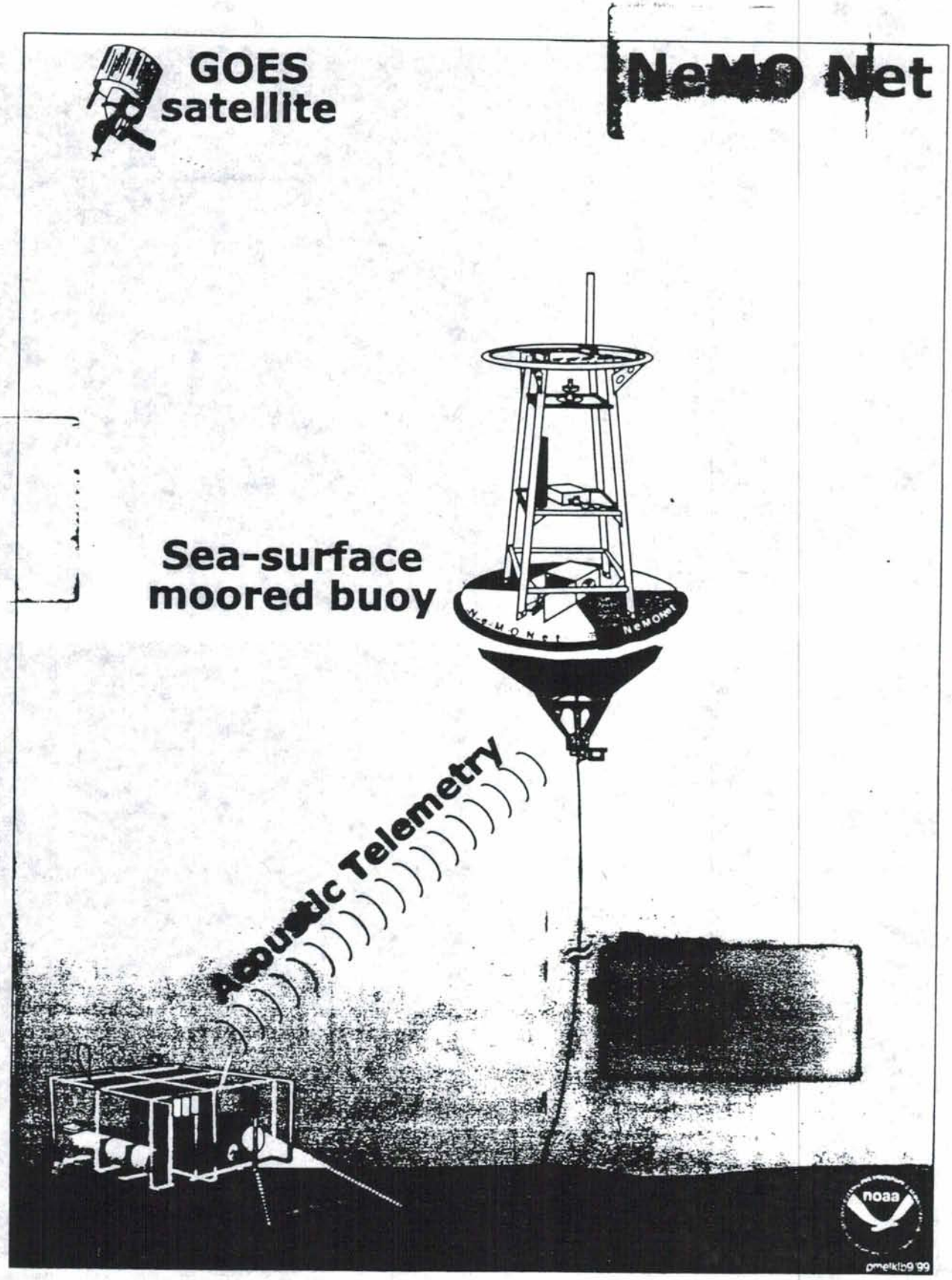


O 9 5 days
T ngs: 9
A erings: 2
Total Jason Bottom Time 74 hours

Early manipulator/connector failures fixed
JASON & tireless/creative/skilled crew = Long bottom times
& successful mission

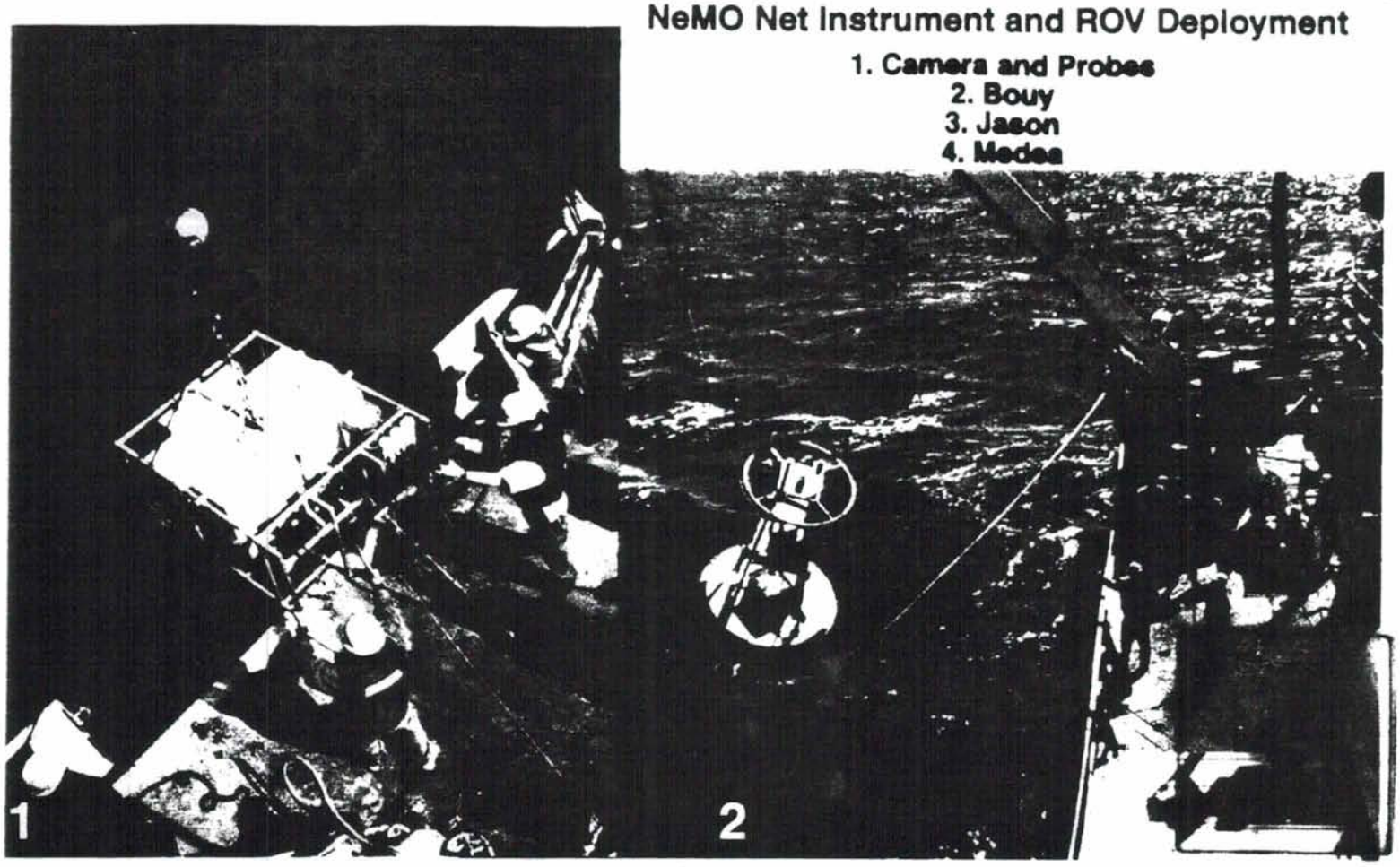
JASON Dive Summary

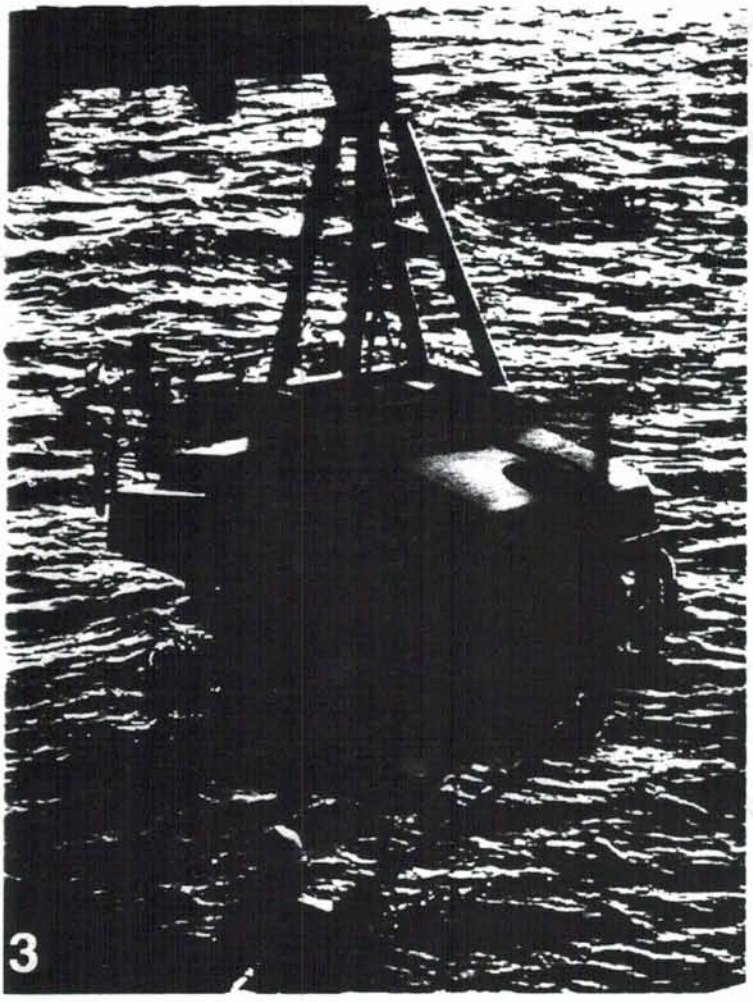
Lowering No.	Date (GMT)	Bottom time	Site	Major Objectives
254	8/27-28/99	20 hrs	1026b	Recover BC1026-9L; PUFS-1; magnetite separator; push cores (Elevator 1)
255	8/28/99	--	1026b	Aborted due to manipulator and thruster problems
256	8/29/99	--	1026b	Aborted due to manipulator problems
257	8/31/99	15 hrs	Axial	Recover BC-Ax-1L; PUFS-2; magnetite separator; Ti-samplers (Elevator 2)
258	9/1-2/99	7.3 hrs	Endeavour	Recover BC-End-1L; sediment cores; Ti-samplers; biological samples
259	9/2/99	16 hrs	1026b	PUFS-3; deploy BC-1026-10m; Ti-samplers (Elevator 3)
260	9/3/99	10.75 hrs	Baby Bare	Recover BC-BB-2L; sediment cores; deploy heat flow blanket; recover Osmosampler; Ti-sampler (Elevator 4).
261	9/4/99	2 hrs	1026b	Recover BC-1026-10m; deploy BC-1026b-11m (to be recovered by Wheat, Becker, Davis); Ti-sampler
262	9/4-5/99	2.75 hrs	Baby Bare	Recover thermal blanket; aid elevator weight release (Attempt to recover BC-BB-3L and 4L; lost during recovery of Elevator 4)
9 total lowerings		73.8 total hrs		

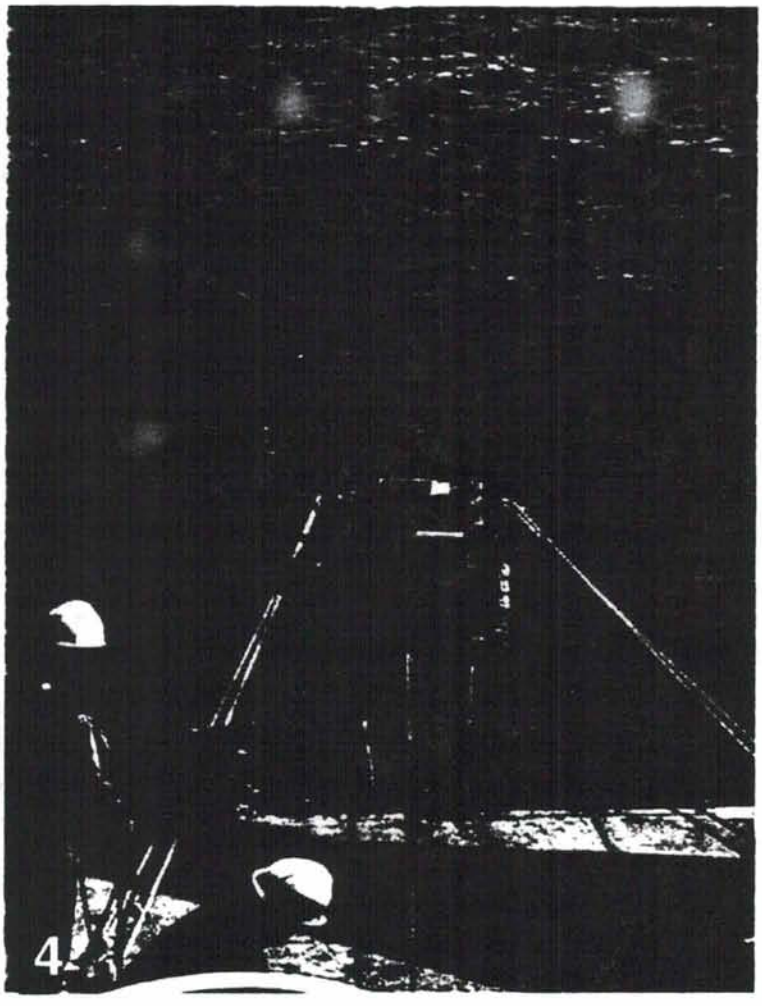

GOES satellite
NeMO Net
Sea-surface moored buoy
NeMONet
Acoustic Telemetry
noaa
pmelkb9'99

NeMO Net Instrument and ROV Deployment

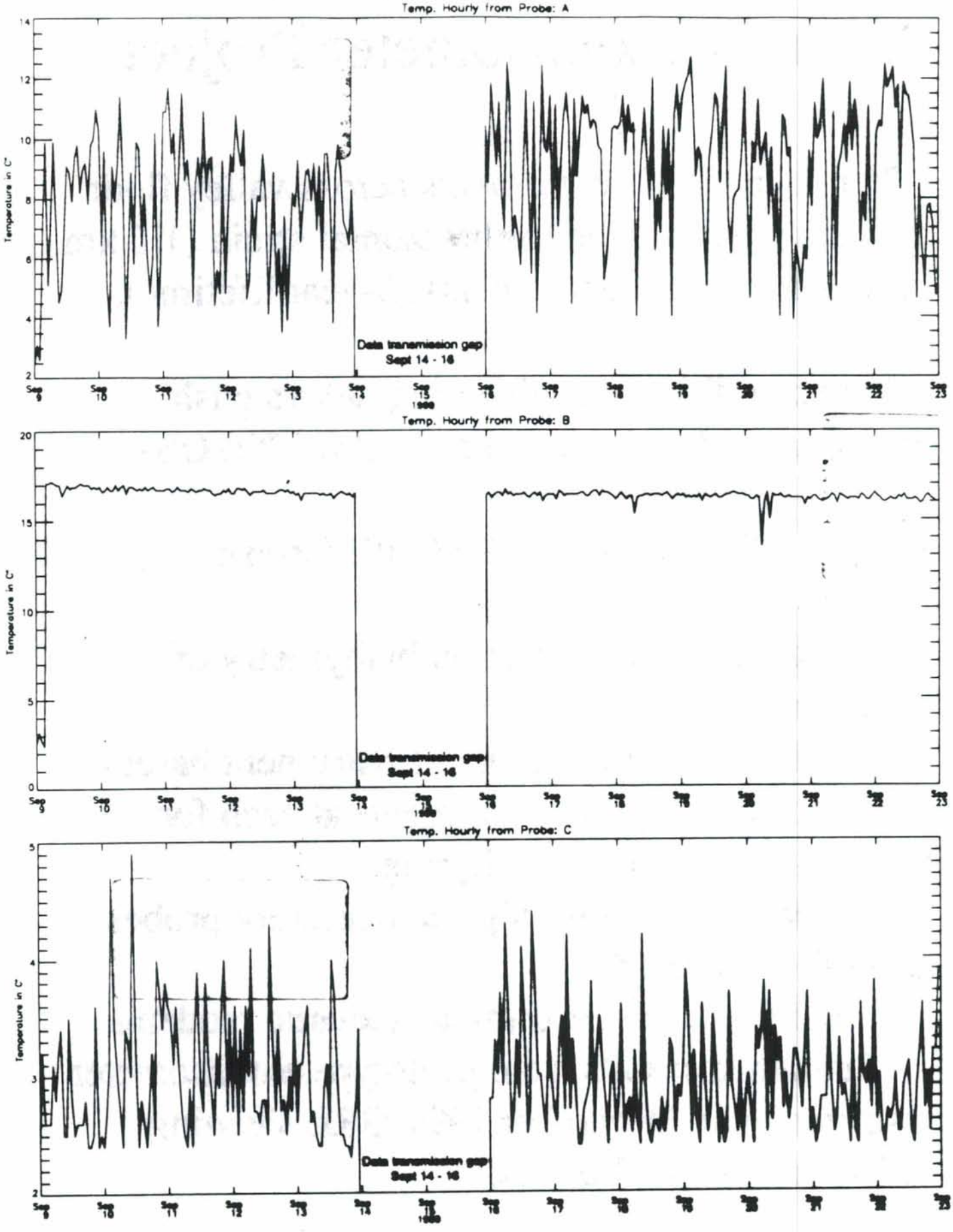
1. Camera and Probes
2. Bouy
3. Jason
4. Medea







Real-time Temperature Data from NeMO Net



Acoustic Extensometer Project

• Plan: deploy 12 instruments across valley floor at south Cleft to monitor horizontal strain (1.5 km baseline; daily measurements; 5-year lifetime).

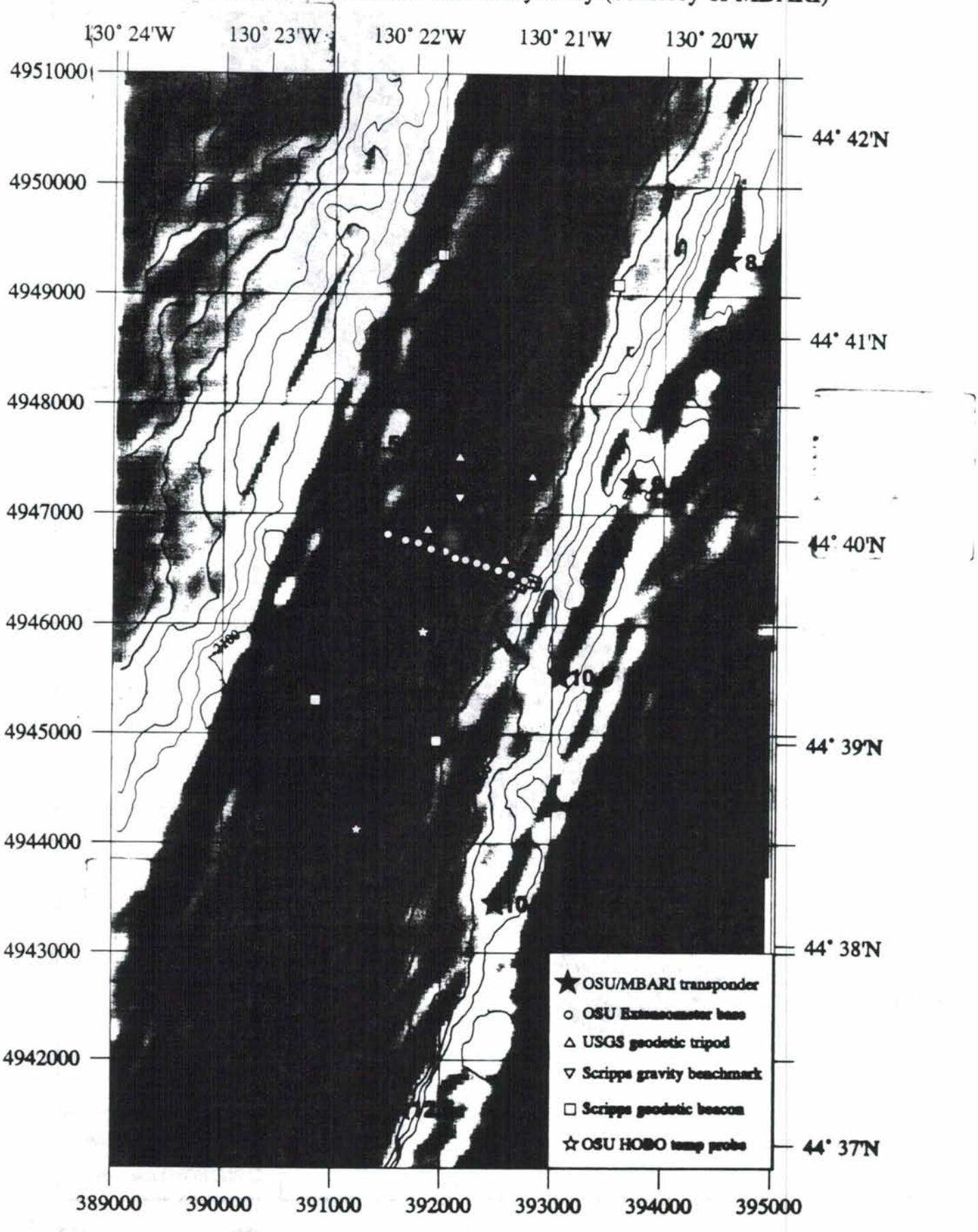
• Status: additional engineering delays push deployment date back to June 2000 (ROPOS).

• Accomplishments in 1999 (with Jason):

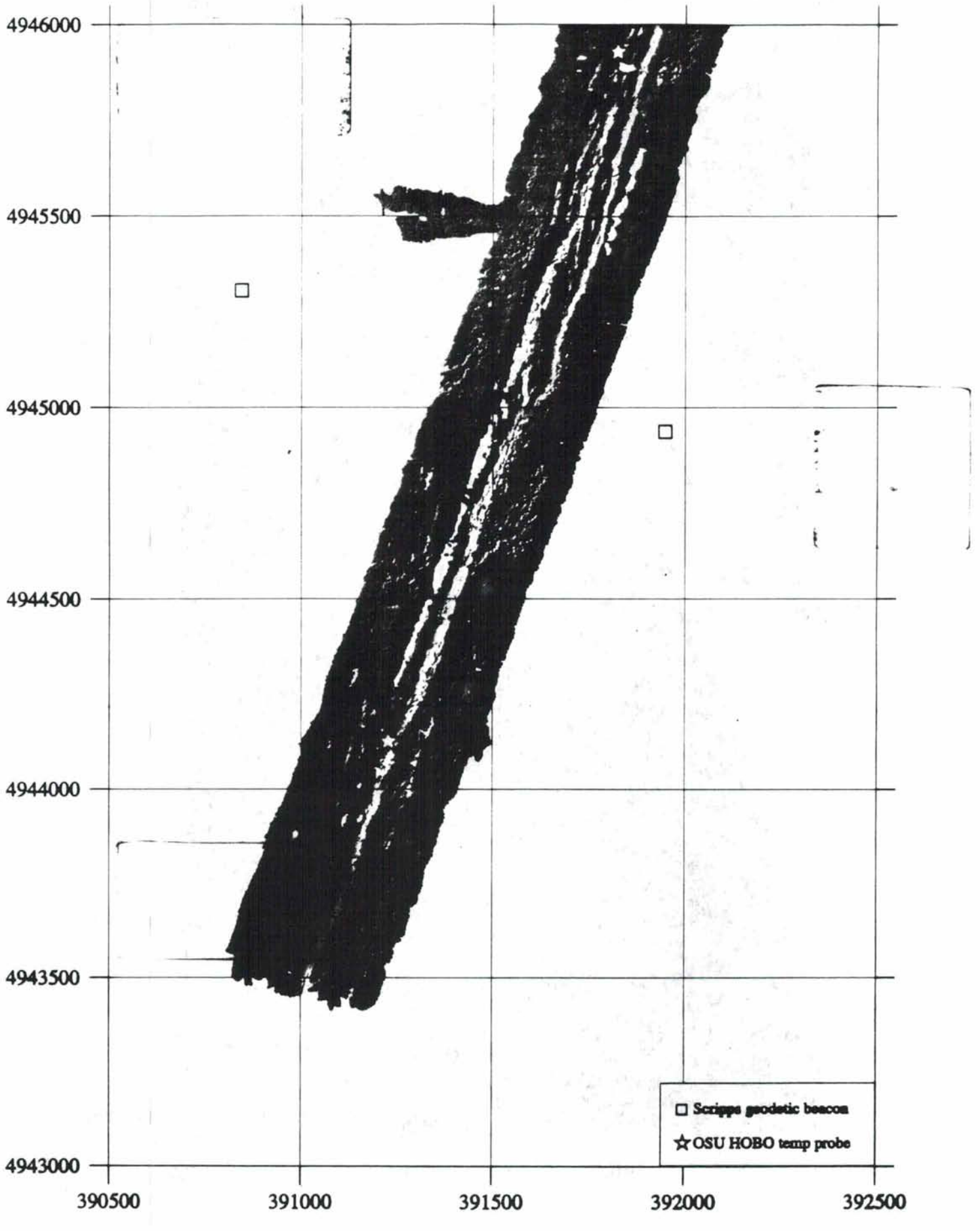
- Imagenex high-resolution bathymetry of deployment site
- Deployed 12 benchmarks (instrument bases) and made pressure measurements at each for vertical deformation monitoring
- Deployed 3 HOBO high-temperature probes at south Cleft vent sites
- Field testing of instrument acoustic modems
- Published results from prototype extensometer instruments in December 1999 GRL showing deflation at Axial Volcano

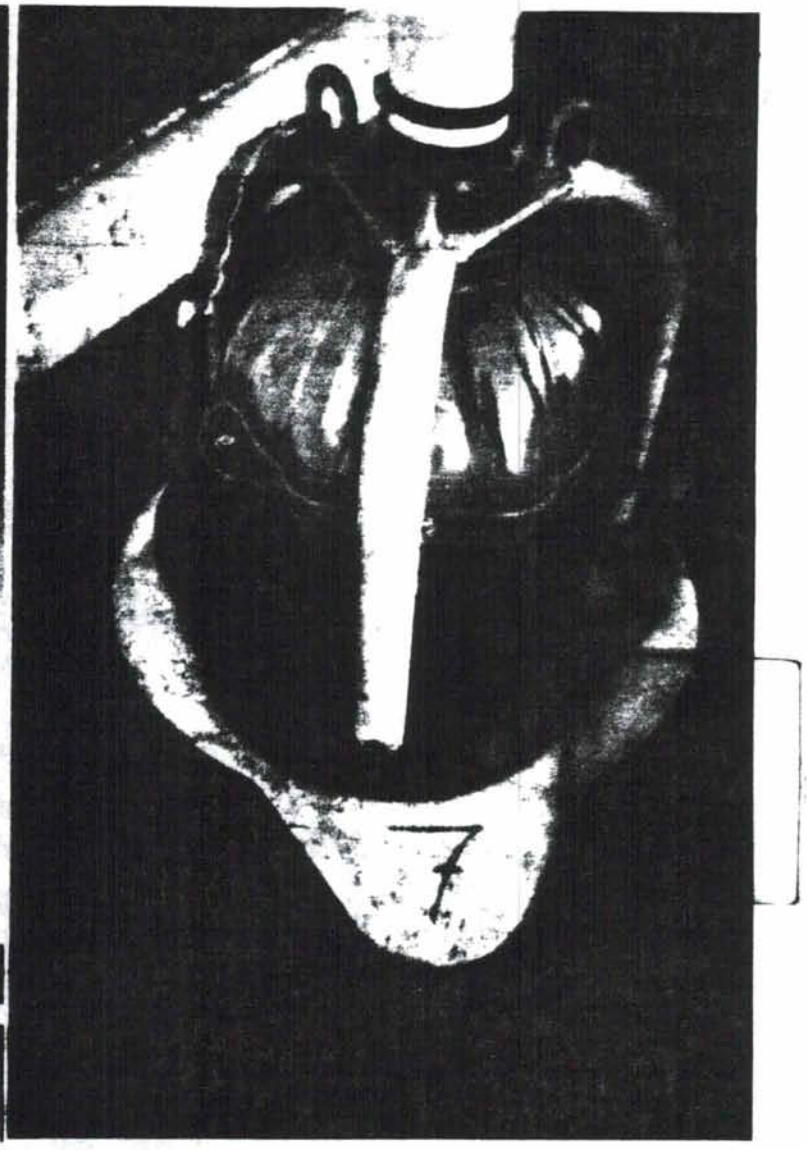
South Cleft

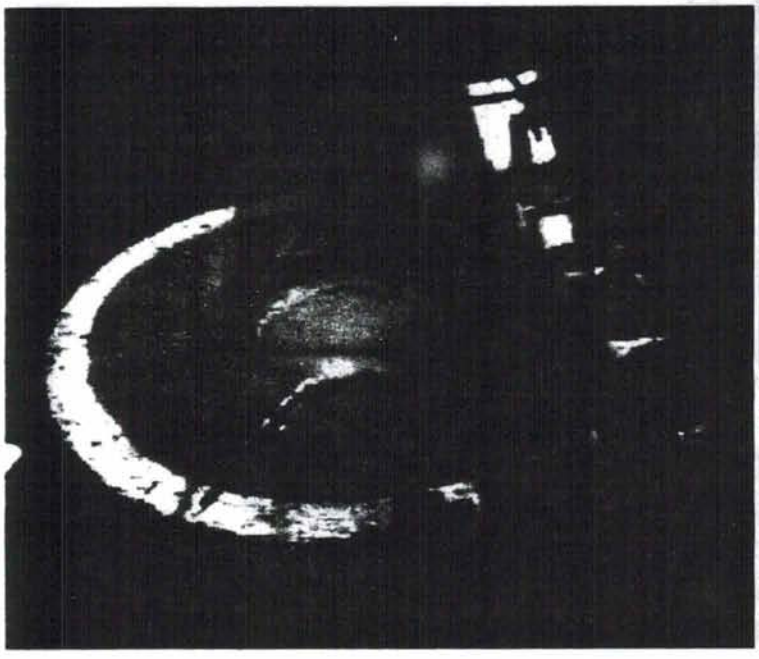
Jason dive tracks on EM300 multibeam bathymetry (courtesy of MBARI)

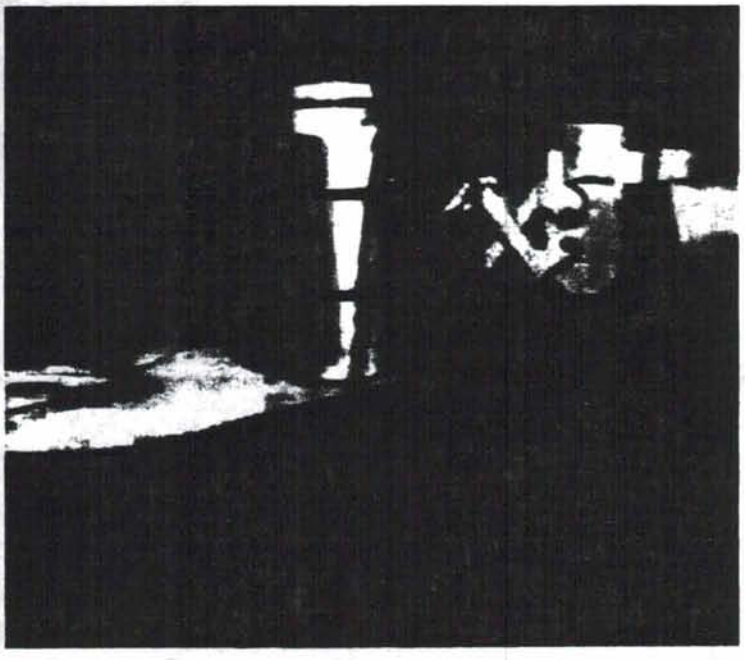


Imagenex coverage - Plume site

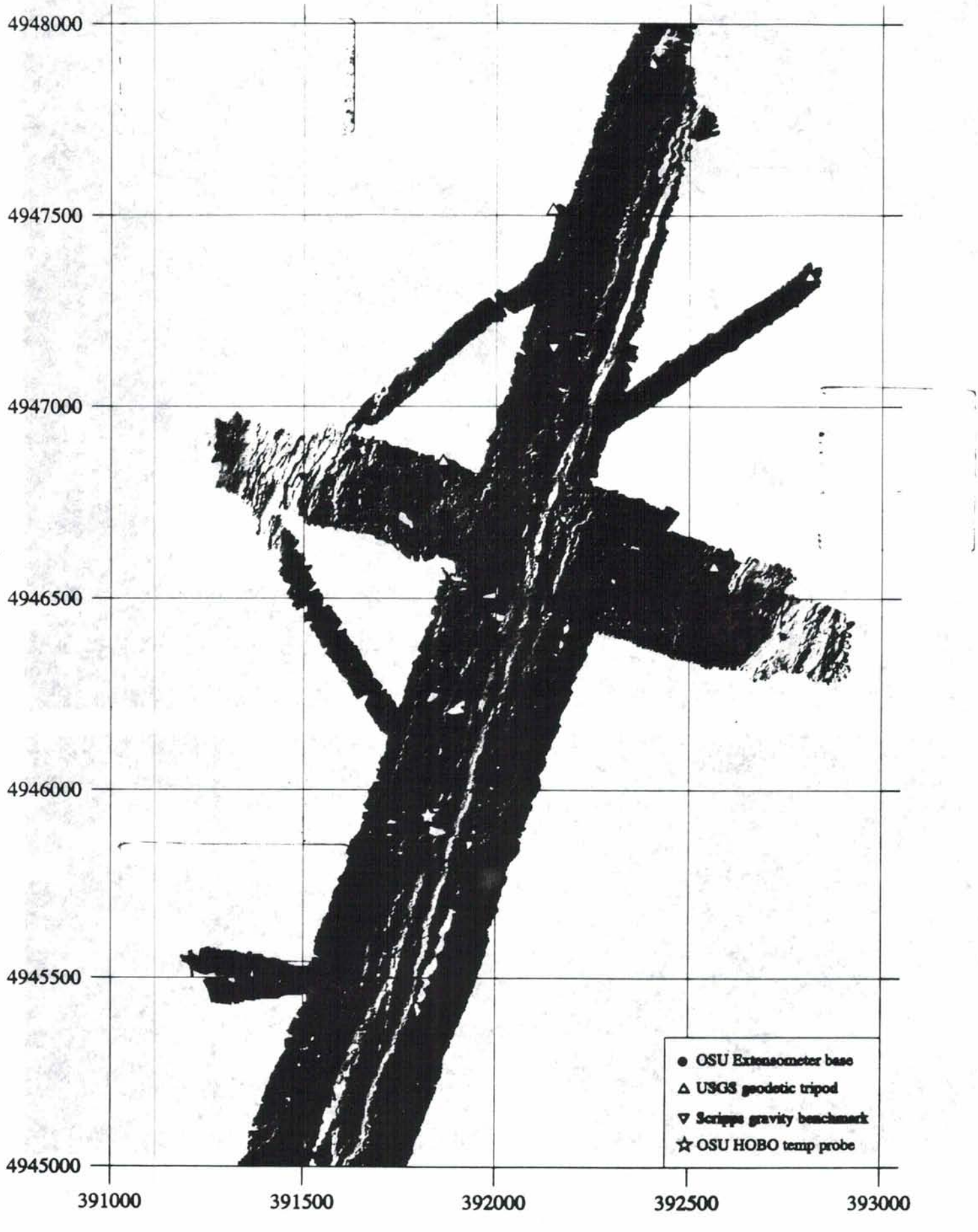








Imagenex coverage - Vent1 site - with extensometer deployment sites



Appendix V

Alvin Dive Statistics
1964 - 1999

• Total Dives	3,502
• Total Depth (meters)	7,191,806
• Average Depth per Dive (meters)	2,054
• Total Time Submerged (hrs.)	23,952
• Average Time Submerged per Dive (hrs.)	6.84
• Total Persons Carried	10,506

DESSC Meeting
December 1999

Appendix VI

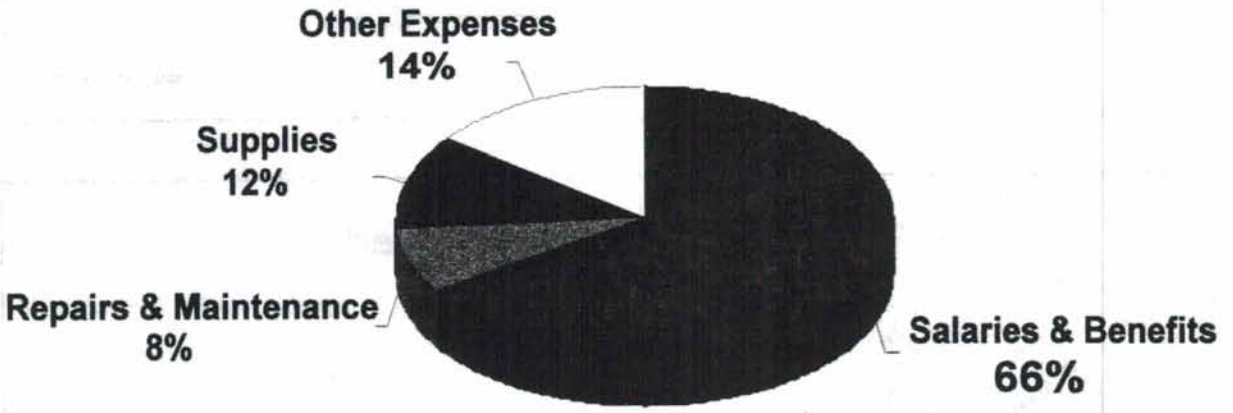
National Deep Submergence Facility

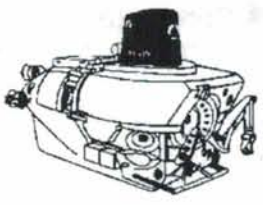
Woods Hole Oceanographic Institution

1999

Operations Personnel	16
Engineering / Management Personnel	11

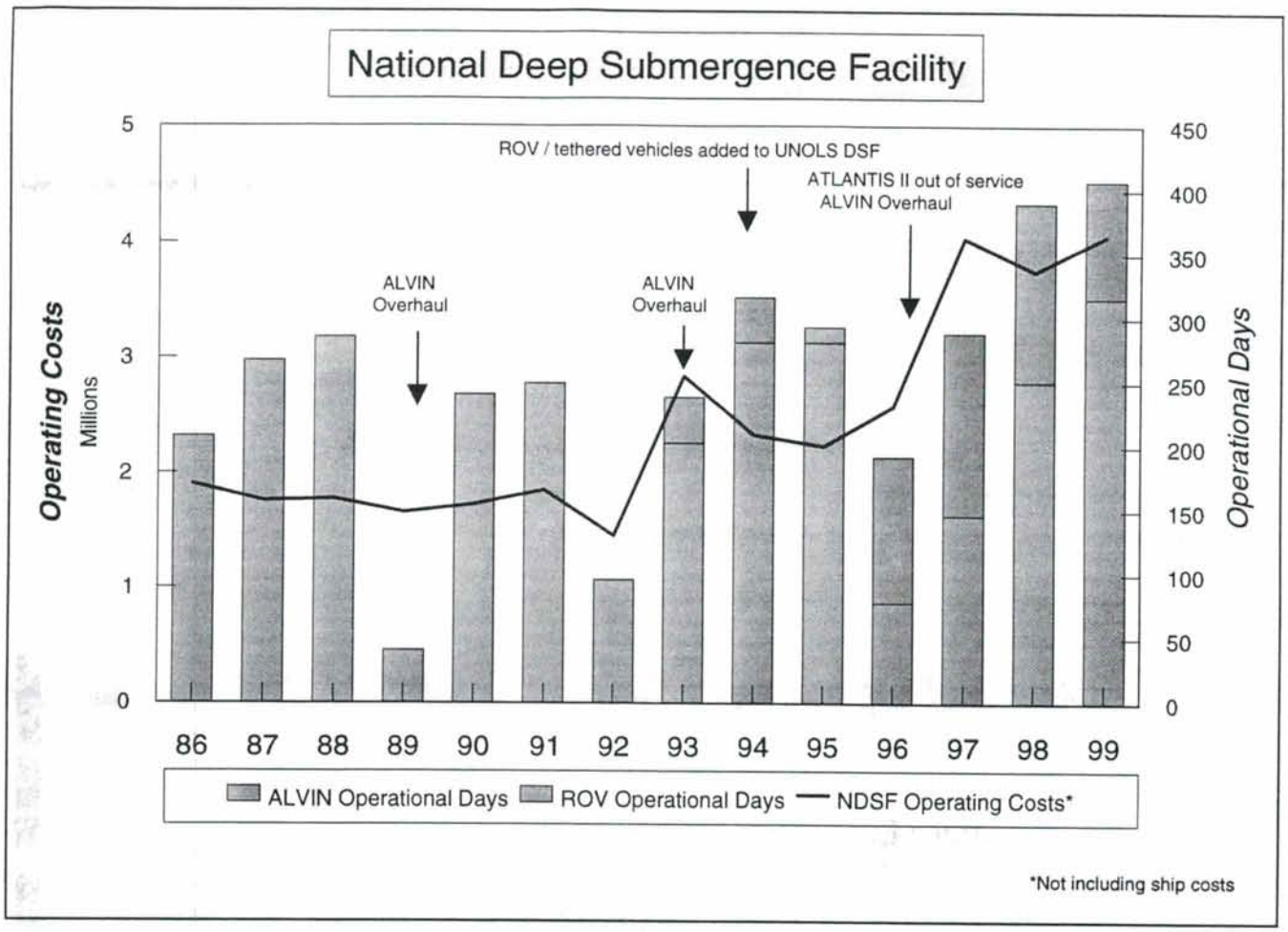
Annual Operating Costs: $4,057,650

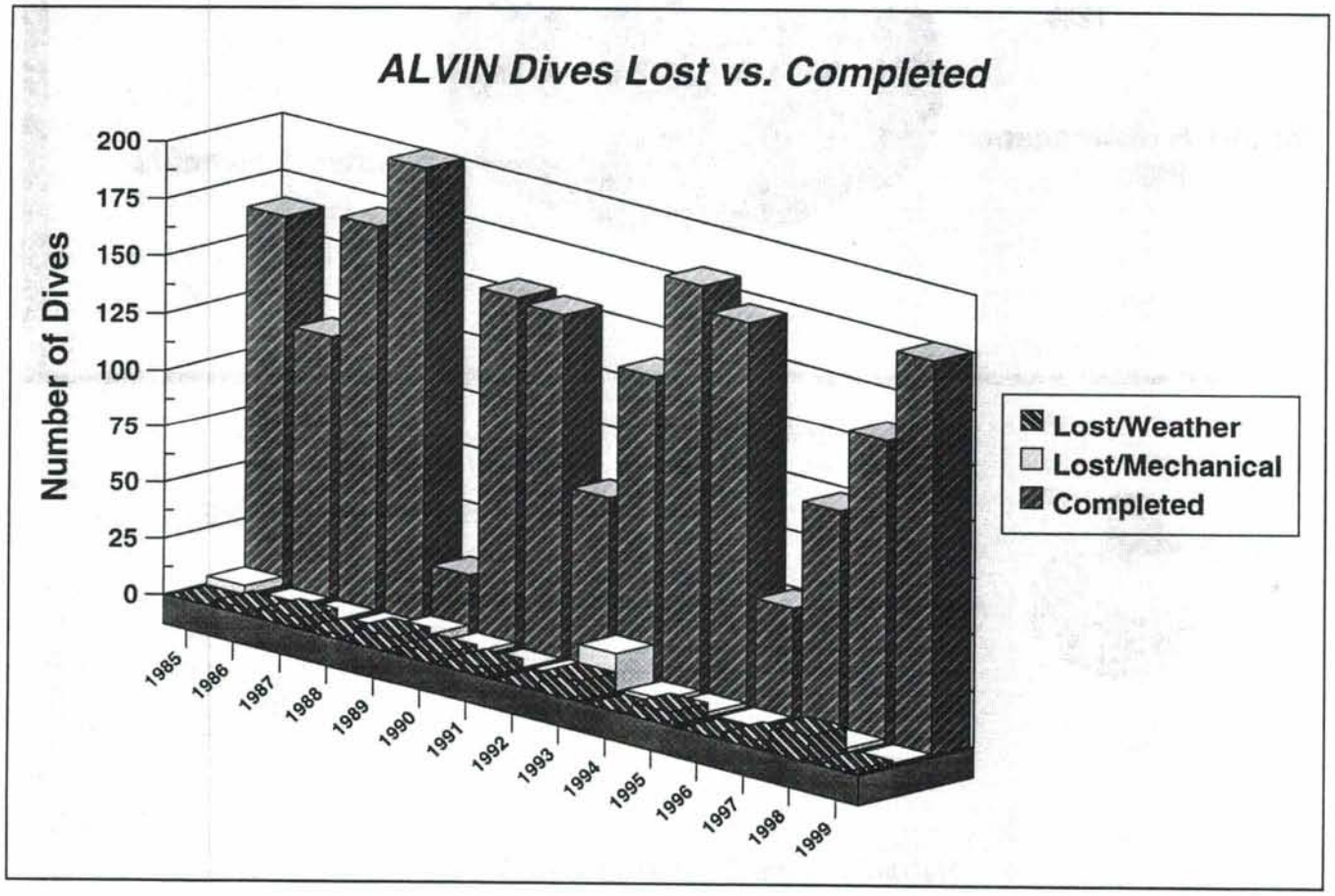




DSV-2
ALVIN

Remotely Operated Vehicles
Jason
Argo2
DSL-120

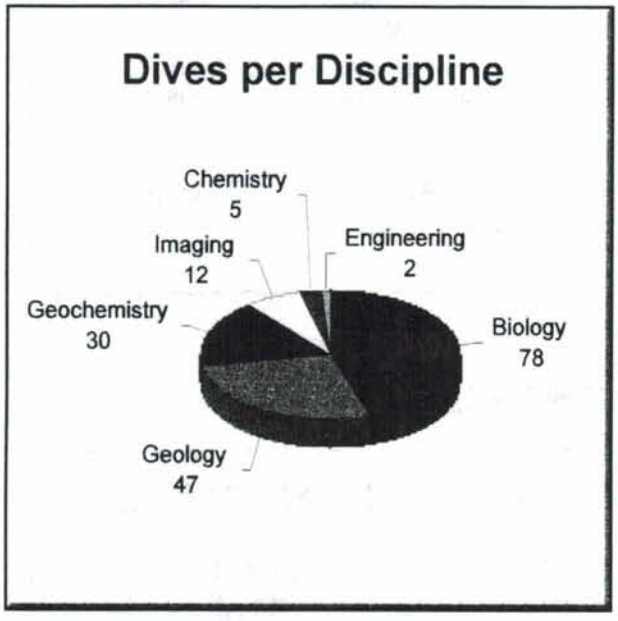

National Deep Submergence Facility
ROV / tethered vehicles added to UNOLS DSF
ATLANTIS II out of service
ALVIN Overhaul
ALVIN
Overhaul
ALVIN
Overhaul
Operating Costs
Millions
Operational Days
0
1
2
3
4
5
0
50
100
150
200
250
300
350
400
450
86 87 88 89 90 91 92 93 94 95 96 97 98 99
ALVIN Operational Days
ROV Operational Days
NDSF Operating Costs*
*Not including ship costs


ALVIN Dives Lost vs. Completed
Number of Dives
0
25
50
75
100
125
150
175
200
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
Lost/Weather
Lost/Mechanical
Completed

DSV-2 ALVIN

Operating Days	335
Dives	175
Average Depth	2386 m
Average Dive Duration	8.1 hrs
Average Bottom Time	5.3 hrs

(Same bottom time as 1998 with 40 more dives)



15 Science Programs

Vrijenhoek/Lupton	Southern EPR
Sinton/Van Dover	Southern EPR
Karson	Hess Deep
Mullineaux, ***et al.***	Northern EPR
Cary, ***et al.***	Northern EPR
Carson	Oregon Margin
Torres	Southern California
Duncan, ***et al.***	Gulf of Alaska
Lonsdale/Levin	Gulf of Alaska
Fisher/Cavanaugh	Juan de Fuca
Becker, ***et al.***	Juan de Fuca
Walden	Juan de Fuca
Smith	Southern California
Lutz/Van Dover	Northern EPR
Mullineaux, ***et al.***	Northern EPR

2 dives lost to weather, 1 to mechanical problems

Highlights:

- ✔ 38 dives on the Southern East Pacific Rise
- ✔ First dives north of 50° latitude in the Gulf of Alaska
- ✔ First use of an IMAX camera in ALVIN, filming vents at 9°N EPR

National Deep Submergence Facility
http://www.marine.whoi.edu

Remotely-Operated Vehicles

1999 DSL/DSOG Operations Summaries By Cruise

Cruise ID(s)	Vessel	Chief Sci(s)	Work Area	Vehicle(s)
Sinton99	ATLANTIS	Sinton/UH	Southern EPR 18S, 113W	DSL-120
Karson99	ATLANTIS	Karson/Duke	Hess Deep 2N, 101W	DSL-120 Argo2
Med99	NO. HORIZON	Ballard/IFE	SE Med Sea 32N, 34E	DSL-120 Jason
Cowen99	THOMPSON	Cowen/UH Johnson/UW	Juan de Fuca 47N 127W	Jason
Chadwick99	THOMPSON	Chadwick/OSU	Juan de Fuca 46N 129W	Jason
Chave99	THOMPSON	Chave/WHOI	H2O Site 28N, 142W	Jason

1999 DSL/DSG Vehicle Lowering Summaries

Vehicle	Lowerings	Bottom Hrs	Lowering Hrs	Miles Covered
Jason	31	476.0	544.5	119.0
Argo2	11	162.4	209.1	41.3
DSL-120	6	196.2	211.5	211.5
Totals	**48**	**834.6**	**965.1**	**371.8**

Highlights:

- ✔ SM2000 multi-beam sonar used successfully
- ✔ H2O junction box and IRIS seismometer recovered/redeployed w/ Jason
- ✔ Control van replacement
- ✔ 57,324 electronic still camera photos
- ✔ 45 transponders launched
- ✔ 9 elevators used
- ✔ 2 EXACT deployments

Appendix VII

Atlantis Projects Completed in 1999

1. Replaced anchors with Baldt Stockless Snug Stowing Anchors
2. Installed Ozonator in Potable Water System along with Charcoal Filters
3. Completed Top-end Overhauls of all 6 Caterpillar Engines
4. Replaced All Fuel Injectors with New Models to Reduce Smoke
5. Upgraded G.E. Control System Call System
6. Upgraded the Power Limit Feature in the G.E. System
7. Completed the Upgrading of the Cranes to Dual Functions and Greater Speed
8. Corrected the Swinging Beam Sticking
9. Added an Additional Camera Run for CCTV for Hydrowinches
10. Provided Additional Storage for Personnel in Main Deck Fwd Ladderway

Designs/Projects Funded/To Be Completed

1. Counter-balanced Sheave on Port Hydroboom
2. Capability to Hang Two Sheaves off of Stbd Hydroboom
3. *Alvin* Support Boat Upgrades
4. Bow Thruster Noise Abatement (design)
5. Improve Lab Power Distribution (design)

Summer 1999

1	A-frame Calibrate pressure transducers	Sloan	Completed
2	A-frame calibrate torque wrenchs	NSP	Completed
3	A-frame change oil ~ 300 hours	NSP	Completed
4	A-frame Change out brake pads	NSP	Completed
5	A-frame Correct Latch Drifting	NSP	Completed
6	A-frame replace fwd anti-swing cylinder	NSP	Completed
7	A-frame install hour meter	NSP	Completed
8	A-frame Reweld Top Plate on Stbd Leg	NSP	Completed
9	A-frame Shorten Flange on Tail Winch Guide	NSP	Completed
10	A-frame Tail Winch Seal Job	Hold	Completed
11	ANCHOR CLANK	NSP	Completed
12	Change oil on anchor windlass	Crew	Completed
13	Change oil on traction winch	Crew	Completed
14	Change Steering Gear hydrualic Oil	Crew	Completed
15	Check Jacket Water Coolers	NSP	Completed
16	Electrical - Clean Circuit Breakers	Clewes	Completed
17	Electrical - Install meters on Switchboard	Clewes	Completed
18	Electrical - Install UV trip on circuit P-433	Clewes	Completed
19	Eng - New Injectors on Cats	Cat	Completed
20	Eng - Replace turbo cartridges & 6,000 hour thermostat change	Cat	Completed
21	Eng - Top End Overhaul 1-3516, 2-3508	Cat	Completed
22	GE - correct alarm problems	GE	Partial
23	GE - Power Limit Upgrade	GE	Completed
24	GE - Y2K	GE	Completed
25	GE - Upgrade call system	GE/Chip	Completed
26	GE - Change out Bridge Alarm	Crew	Completed
27	Install lockers in forward ladderway	NSP	Completed
28	Install new bunks	NSP	Completed
29	Installed Bunk lights for new berths	Chip	Completed
30	Potable Water Tanks Install Ozonator	Delta/Chip	Completed
31	Potable Water Tanks Open and Clean	Crew	Completed

Summer 1999 - Continued

32	Potable Water Tanks Piping for Ozonator	NSP	Completed
33	Fire Damper Port & Stbd ER	NSP	Completed
34	Fire Damper Incinerator Room	NSP	Completed
35	Stbd Crane Telescoping	NSP	Completed
36	Stbd Crane Sloppy and Boom Noise	NSP	Completed
37	Hydroboom Isolation Problem	NSP	Completed
38	Aft Hydroboom Personnel guard	NSP	Completed
39	Carpet Cleaning	Express	Completed
40	Trip Hazard Fly Bridge	NSP	Completed
41	Halogen Light ROV Deck Relocate	NSP	Completed
42	Uncontaminated S/W Piping Repair in HydroLab	NSP	Completed
43	Padeye for A-frame at Hanger	NSP	Completed
44	Half Rounds at 4 Bits on 01 Level	NSP	Completed
45	Install Rope Guards at Stern Quarters	NSP	Completed
46	Camera Run on 03 for Hydrowinch	NSP/Chip	Completed
47	Science Run From Hydrowinch to Comp. Lab	NSP/Chip	Completed
48	Repair Potable Water Leak in Engine Room	NSP	Completed
49	Alvin Elect Shop A/C Drain Relocation	NSP	Completed
50	Relocate Emergency F.O. Shutdown Mn Dk Port	NSP/Chip	Completed
51	Repair Bow Thruster Cooling Valve Stem	NSP	Completed
52	Add By-pass Capability around B/T&Prop Cooling	NSP	Completed
53	Remount Pre-lube Pumps off Engine Mounts	Crew/NSP	Completed
54	Fuel Oil Purifier Rep	AlfaLaval	Completed
55	Provide Oil drums for Oil Removal	NSP	Completed
56	Repair Hiab Crane Hydraulic Leak	NSP	Completed
57	Contruct Pager Cabinet Foundation	NSP	Completed
58	Repaired #1 A/C chiller (major failure)	Quality Ref	Completed
59	Added Water Facet in Galley By Serving Line	NSP	Completed
60	Added Water Facet in Galley By Hypersteamer	NSP	Completed
61	Replaced both Sets of brake bands on A-frame	NSP	Completed
62	Installed Charcoal Filters in Potable Water System	NSP	Completed
63	Repaired Dishwasher	J.P. Foods	Completed
64	Repaired both Copy Machines	Xerox	Completed

Summer 1999 - Continued

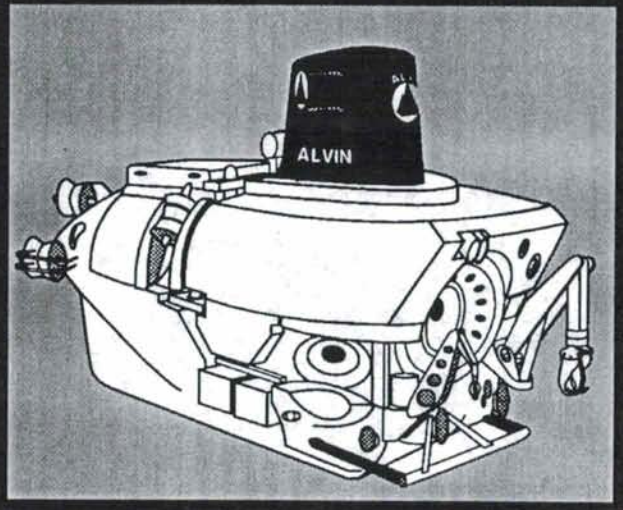
65	Lifestream Assistance with RO's	Lifestream	Completed
66	Segregated 24 volt supply to Cimplicity due to UV Install	Chip	Completed
67	Changed Hydraulic Oil both Cranes	NSP	Completed
68	Bought and Mounted Overhead Screen in Library	NSP	Completed
69	Sperry Radar repairs	Sperry	Completed
70	Repaired Simrad Nav System	Simrad	Completed
71	Installed Additional Lights Dry Stores	Chip	Completed
72	Installed Duplex Outlet Exercise Room	Chip	Completed
73	Installed Duplex Outlet Chief Sci Room	Chip	Completed
74	Installed Duplex Outlet Captains Room	Chip	Completed
75	Repaired Outlet Ships Office	Chip	Completed
76	Installed Duplex Outlet Forward Sci Hold	Chip	Completed
77	Rewired Capstan	Chip	Completed
78	Repaired Range in Galley	CEGA	Completed
79	Repair Ruptured Hose on Aft Hiab	NSP	Completed

Fall 1999

1	A-frame replace aft anti-swing cylinder	NSP	Completed
2	A-frame re-torqued relief valve	NSP	Completed
3	Eng - Top End Overhaul 2-3516, 1-3508	Cat	Completed
4	Service liferafts	Vernon Ship	Completed
5	Machine Pins for Hydro boom	NSP	Completed
6	Service out board engines	H&H Marine	Completed
7	Service portable and fixed fire ext.	America' Finest	Completed
8	Install new Anchors	NSP	Completed
9	Complete Fire danper Installation	NSP	Completed
10	Repair Starboard Crane	N.Amer. Crane	Completed
11	Instal Rope Guard on 70 HP Outboard	NSP	Completed
12	Repaired 480 Switchboard	Sloan	Completed
13	Circuit Breaker Spares	Clewes	Completed

Appendix VIII

Alvin Upgrades



Alvin Upgrades

Current Projects

- In hull digital camera
- SM2000 multibeam sonar
- Video router upgrade
- Ring laser gyro
- Virtual Alvin
- Data logger
- Steerable elevator
- Inductively coupled link (ICL)

Alvin Upgrades

Video Router Upgrade

- COTS components (extensive re-packaging)
- Y/C signals throughout
  - accepts composite or component sources
  - hooks for R/G/B or Y/R-Y/B-Y
- Inputs
  - 8 video sources (4 inside, 4 outside)
  - in-hull microphones
- Outputs
  - 4 VCR (w/ embedded timecode)
  - 4 monitor (w/ selectable text overlays)
- Separate monitor & VCR channel selection

Alvin Upgrades

Planned Projects

- Doppler/Ring Laser Gyro nav system
- In hull digital cameras
- Observer HMI lights

Alvin Upgrades

Overhaul

- Hard mount observer video controls
- Modify interior floor space arrangement
- Science basket modifications
- Lateral thruster with DP system
- Battery monitoring
- Manipulator upgrades
- Acoustic modem
- External still camera changes

Magnetic Media Cost Comparison

Hi8 vs. Digital

Sony P6-120HMPX Hi8 video tape	$ 8.29
Sony PDV124N digital video tape	$30.90

ALVIN	Hi8	Digital
2 recorders 6 tapes/recorder/dive 175 dives/year	$17,409	$64,890

Jason		
4 recorders 9 tapes/recorder/18 hr. avg. dive 30 dives per year	$ 8,950	$33,372

Appendix IX

NDSF Tethered Vehicles

1999

- Overhaul of HIAB crane
- Overhaul of traction winch after 5000+ hours of operation
- Cleaning, lubrication and testing of main tow cable
- Frame grabber added to control van data logger
- Deep Simrad SM2000 sonar acquired and tested
- Medea heavy lift capability refined
- Reduction of DSL-120 sonar processing backlog

2000

- Replacement of tool van
- Specification and purchase of neutral umbilical
- Evaluation of digital video recording medea
- Complete first year of ROV Upgrade effort

DSL-120 Status

- DSL-120 Vehicle Tow Dynamics Evaluation/Improvement
- DSL-120 hardware, data and processing evaluated by personnel from HMRC
- OIC Bathymetry AVG creation and evaluation

- Data Reprocessing Status

EDREX97 (Delaney): Completed – SideScan and Bathymetry Reprocessed

HEY-SEPR98 (Hey): Completed – SideScan and Bathymetry Reprocessed

SINTON-SEPR 99 (Sinton): Completed - SideScan Reprocessed

PUNA98 (Smith): Ongoing

Completed generation of new DSL-120 Intermediate data

Bathymetry re-processing with new flat bottom tables undergoing evaluation and testing

Upgrades to NDSF ROVs

Jason II

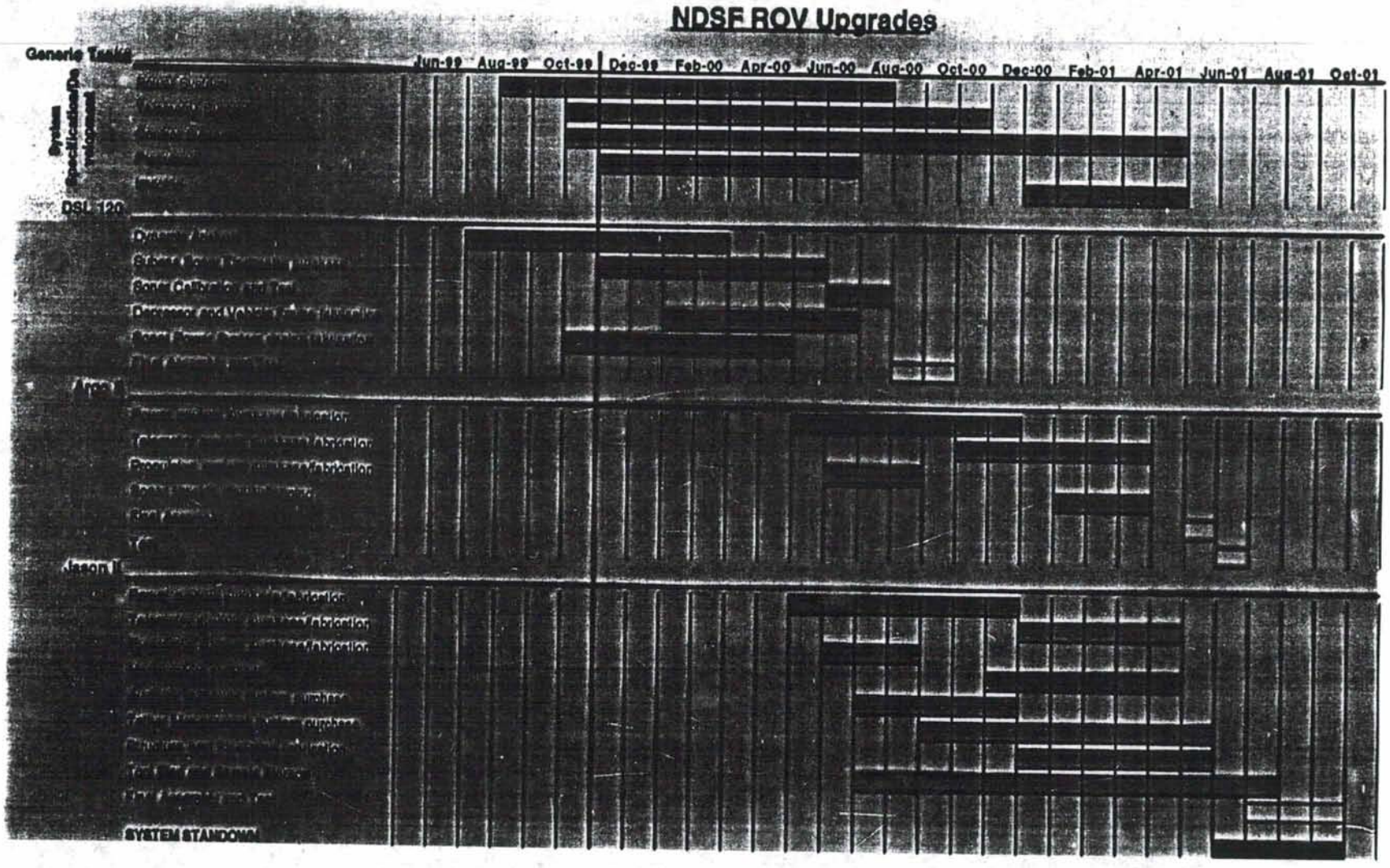
- Improve manipulative capabilities
- Increase sample and equipment payload capacity
- Increase speed and thrust
- Increase depth rating to 6500 meters
- Include tether management

Argo II

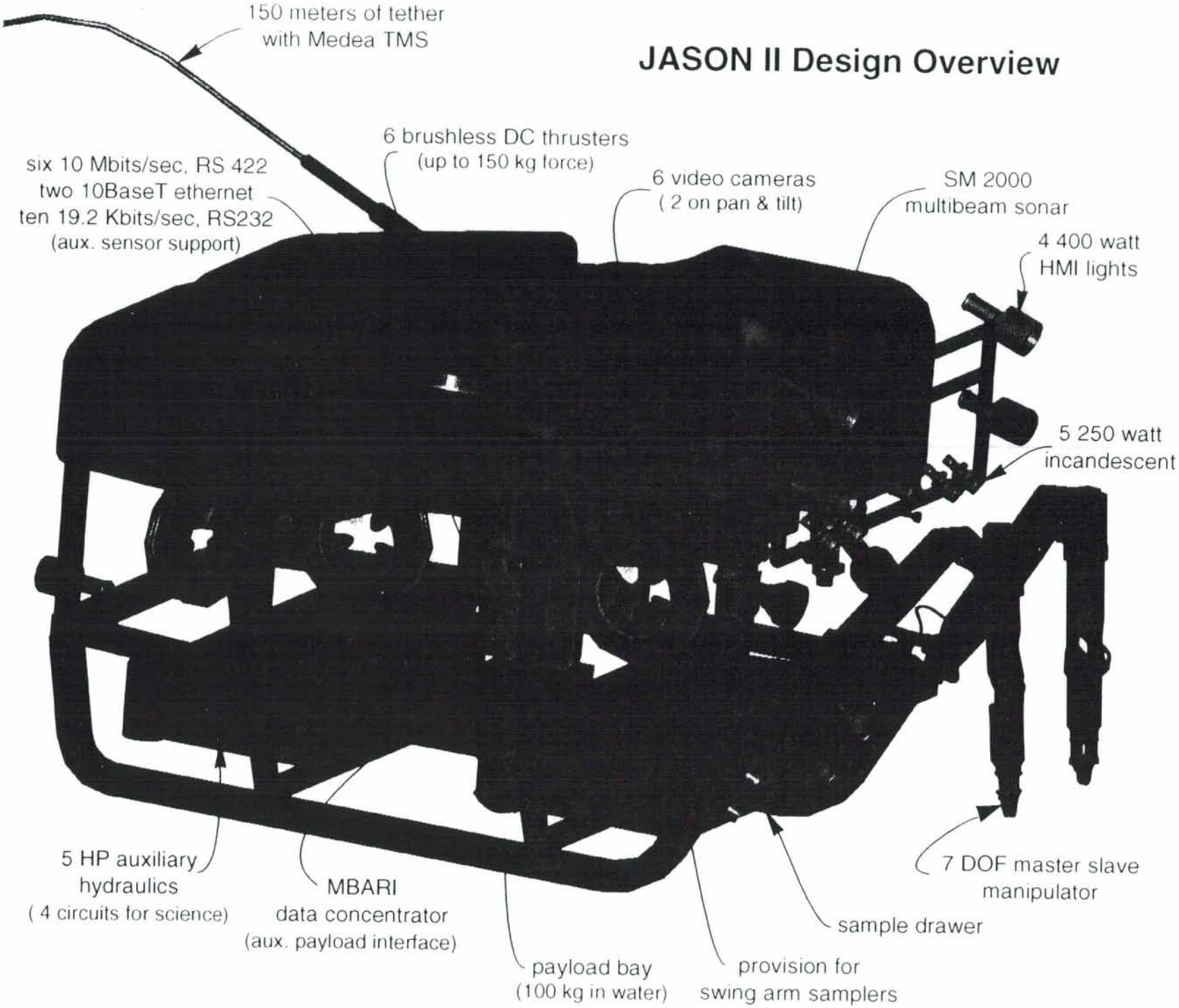
- Build common control/telemetry for compatibility with Jason II a DSL-120
- Dedicated sensors
- Increase lighting and power of maneuvering thrusters

DSL -120

- Build common control/telemetry for compatibility with Jason II a Argo II
- Dedicated sensors
- Increase payload and improve tow dynamics
- Improve sonar transmit and receive electronics

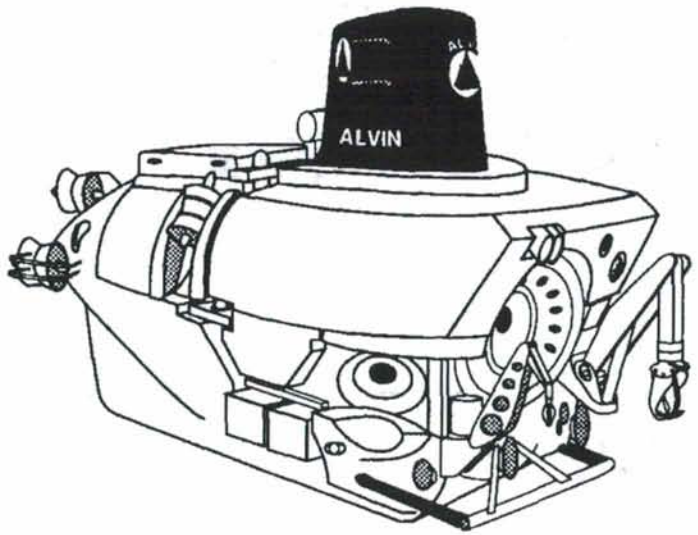

NDSF ROV Upgrades
Generic Tasks
Jun-99
Aug-99
Oct-99
Dec-99
Feb-00
Apr-00
Jun-00
Aug-00
Oct-00
Dec-00
Feb-01
Apr-01
Jun-01
Aug-01
Oct-01
DSL-120
Jason
SYSTEM STANDOWN

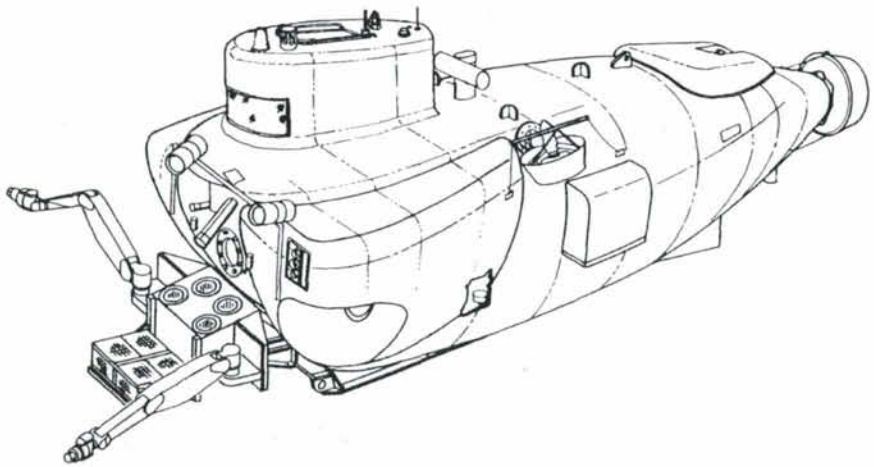
JASON II Design Overview



Appendix X

SEA CLIFF - ALVIN
Engineering Study





SEA CLIFF STATUS

- Moved from Otis ANG Base to WHOI
- SEA CLIFF / TURTLE spare parts transfer approved
- Sea Cliff equipment

Options being studied

- Improvements to 4500 meter Alvin
- Use of SEA CLIFF as is
- Basic conversion of Alvin to 6000 meter using SEA CLIFF components
- Frame up new design of 6000 meter vehicle

Current Status

- Completed survey of Alvin users
- Completed study of all other 6000 meter HOV's
- Developed specifications for improved Alvin

Left to do

- Complete costing of various upgrade options
- Submit final report

Appendix XI

COMPLETED 1999

ALVIN & ROV Operations

Deep Submergence Group

Woods Hole Oceanographic Institution

JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC

Alvin & ROV Operations on R/V *Atlantis*

VRIJENHOEK LUPTON *Alvin*	SINTON VAN DOVER *Alvin* DSL-120	KARSON *Alvin* Argo DSL-120	MULLINEAUX FISHER CAVANAUGH *Alvin*	CARY LUTHER LUTZ *Alvin*	MAINTENANCE	CARSON TORRES *Alvin*	STEVENS DUNCAN *Alvin*	LEVIN LONSDALE BROWN *Alvin*	FISHER CAVANAUGH *Alvin*	SEYFRIED BECKER KASTNER *Alvin*	SMITH *Alvin*	MAINTENANCE	LUTZ VAN DOVER *Alvin*	MANAHAN DEMING *Alvin*
Southern E.P.R.		*Hess Deep*	*Northern E.P.R.*			*S. Cal.-Oregon*	*Gulf of Alaska*		*Juan de Fuca*		*Cal. Coast*		*Northern E.P.R.*	

ROV Operations on Other Ships

BALLARD YOERGER *Jason* DSL-120	COWEN *Jason*	CHADWICK EMBLEY *Jason*	CHAVE *Jason*	
Northern Horizon	**R/V *Thompson***			
Med.	*Juan de Fuca*			

11/24/99
Betsey Doherty
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SCHEDULED 2000

ALVIN & *ROV* OPERATIONS

Deep Submergence Group

Woods Hole Oceanographic Institution

JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG

Alvin & ROV Operations on R/V *Atlantis*

CARY LUTHER REYSEN-BACH *Alvin*	COCHRAN FORNARI *Alvin*	TORRES *Alvin*	LUTZ *Alvin*	MANAHAN CARY FELBECK *Alvin*	DELANEY *Jason Alvin*	SEEWALD PLUMLEY van DOVER *Alvin*	CARSON KASTNER *Alvin*	MAINTENANCE	DELANEY WILCOCK *Alvin*	MacDONALD *Alvin*	BLACKMAN ARGO II DSL-120 *Alvin*
Guaymas	*E.P.R.*	*Calif.*	*Calif.*	*Northern E.P.R.*	*Juan de Fuca*	*JdF*	*JdF*		*JdF*	*Gulf of Mexico*	*Mid Atlantic Ridge*

ROV Operations on Other Ships

FORNARI Argo-II DSL-120	BALLARD DSL-120	LEVIN *Jason*	RONA *Jason*
R/V Melville	*Northern Horizon*	*Thompson*	
East Pacific Rise	*Black Sea*	*Eureka*	*JdF*

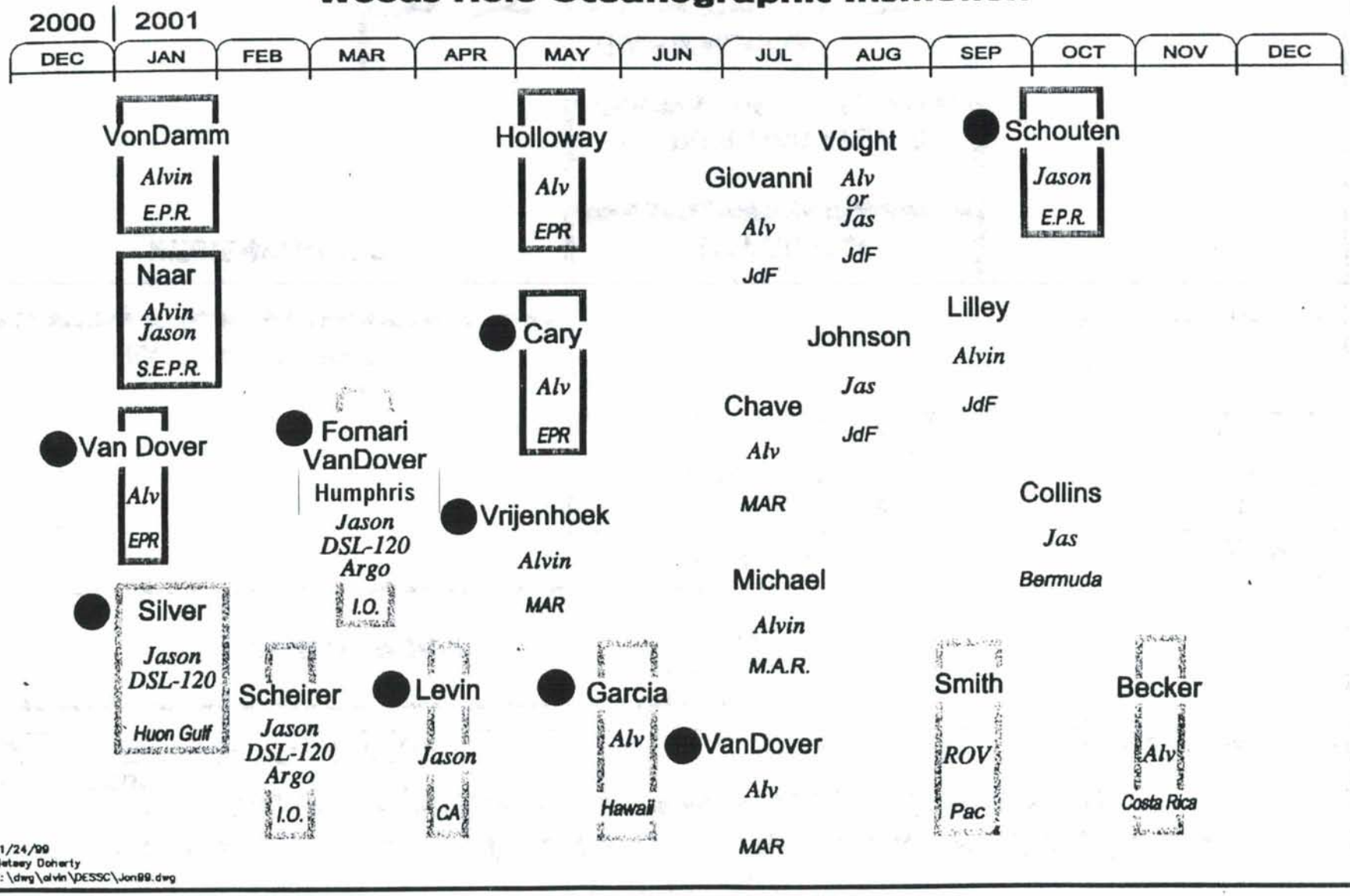
11/24/99
Betsey Doherty
d: \dwg \alvin \DESSC \Jan99.dwg

2001 REQUESTS

ALVIN & ROV Operations

Deep Submergence Group

Woods Hole Oceanographic Institution



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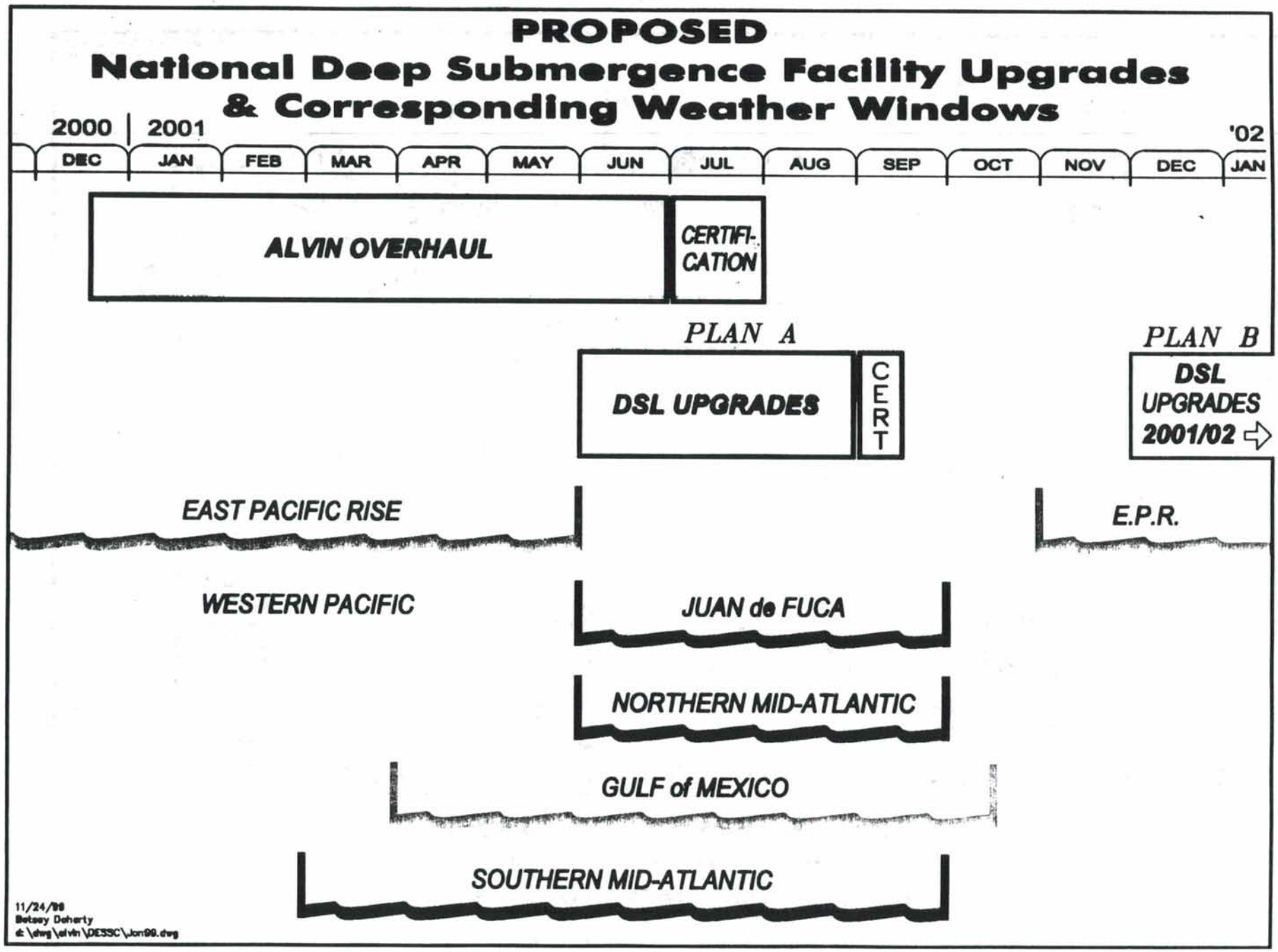
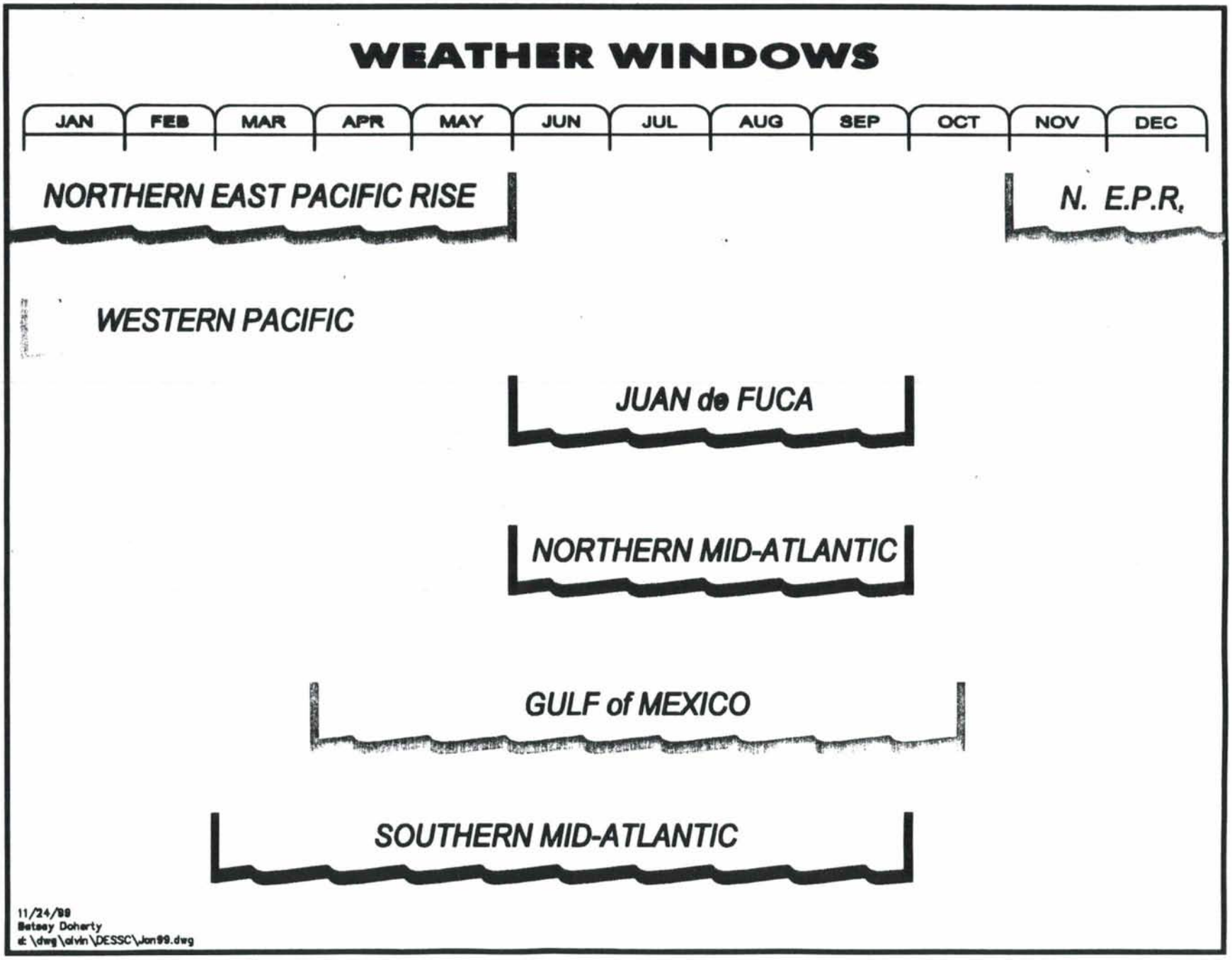
PROPOSED
National Deep Submergence Facility Upgrades & Corresponding Weather Windows



WEATHER WINDOWS



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