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**PRELIMINARY REPORT OF THE 1988 A2-88-NC GORDA RIDGE CRUISE**

Open File Report 94-711

Carol A. Reiss<sup>1</sup>

Robert A. Zierenberg<sup>1</sup>

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<sup>1</sup>U.S. Geological Survey, Menlo Park, California, 94025

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# PRELIMINARY REPORT OF THE A2-88-NC GORDA RIDGE CRUISE

By Carol A. Reiss and Robert A. Zierenberg

## INTRODUCTION

Presented here are the preliminary results of data collected during field operations at northern Escanaba Trough (NESCA), southern Gorda Ridge, aboard the RV *ATLANTIS II* and submersible DSV *Alvin* in June 1988. Figure 1 shows the site of Escanaba Trough as well as the location of volcanic edifices, the extent of sediment cover, and the uplifted terraces along the valley walls, and the NESCA study area. Large massive sulfide deposits discovered in 1986 (Zierenberg and others, 1991) and high heatflow areas (Abbot and others, 1986) were targeted for mapping and sampling during this dive operation. Figure 2 shows composite dive tracks for the area, along with detailed bathymetry of the NESCA area. Figures 3 through 12 show individual dive tracks, marked vents, sample locations, and interpreted geology, based on submersible observations, dive transcripts, samples, photographs, and videotape. A list of personnel appears in table 1 (see paragraph below). Appendix 1 contains the transcriptions of dive observers' comments, depth and heading information (when available), and descriptions of the external camera photographs (when available). A list of samples with descriptions appear in appendix 2. A total of 35 samples were collected during this dive operation. Samples were photographed and described on board, and are currently archived at the Branch of Pacific Marine Geology, USGS. Subsamples were taken for bulk chemical, sulfur isotope, and gold analyses. Bulk chemical analyses were conducted by Geological Survey of Canada. Pat Shanks of the USGS has analyzed samples for sulfur isotopes. The results are summarized in Morton and others (1994). Jim Allen (USBM, Salt Lake Research Center) processed selected samples for gold analyses. Doubly polished thin section (DPTS) analyses were conducted by Randy Koski, and are reported in Zierenberg and others (1993) and Morton and others (1994). Van Dover and others (1990) describe the biology of the vents.

## Personnel

The *Alvin* 1988 Juan de Fuca Ridge dive program A2-88-NC (USGS cruise designation) included participants from Massachusetts Institute of Technology, Woods Hole Oceanographic Institute, the U.S. Geological Survey, Geological Society of Canada, Scripps Institute of Oceanography, University of Tokyo, and Cornell University. See participant and affiliation list in table 1.

## Regional Setting

Escanaba Trough is located along the southern Gorda Ridge, approximately 300 km west of northern California. The northern study area (NESCA) lies approximately 30 nautical miles north of the Mendocino Fracture Zone. This is a slow-spreading (2.3 cm/yr) sediment-filled axial valley, characterized by volcanic edifices a few kilometers in diameter, and spaced between 5 and 15 km apart. Circular sediment hills are interpreted to be uplifted fault blocks above laccolitic intrusions emplaced above these igneous centers (Zierenberg and others, 1993). Massive sulfide deposits have been

identified on the peripheries of these hills; several deposits have surface exposures of greater than 100 m in at least one direction. The full extent of sulfide mineralization in the area has not been documented.

### Preveious studies

A brief summary of previous studies is presented in Reiss and others (1992). Morphology of the Gorda Ridge is summarized in Clague and Holmes (1987). Detailed studies of the geologic, hydrothermal, geochemical, and biologic processes are reported by numerous authors in Morton and others (1993). Zierenberg and others (1993) report on the genesis of massive sulfide deposits along Escanaba Trough.

### Navigation

The acoustic transponder net deployed in the NESCA area by the U.S.G.S. in 1985 was continuously maintained and utilized during this dive operation. X-Y coordinates on figures 3-12 correspond to the transponder net which was internally calibrated and geodetically tied to ship satellite positions during transponder deployments. Two additional transponders were deployed in the northern NESCA area for dives 2038 and 2039 (see dive summaries 2038 and 2039 for detailed navigation summary). Acoustic travel times were recorded on the *Atlantis II* navigation system ACNAV, then reformatted (Reiss, unpub. programs, 1989) and post-processed using Sonatech software. Benchmarks, or markers, referred to in transcripts, designate specific sites physically marked by deployment of identifiable flags on the sea floor. Locations of samples and benchmarks are listed in appendix 2.

## Dive 2033

Dive 2033 (fig. 3) was targeted on the large massive sulfide deposit discovered on DSV *Sea Cliff* dive 658 on the north flank of Central Hill. Small isolated sulfide chimneys were observed at a depth of 3,357 m in the flat sediment plain north of the Central Hill. The submersible traversed south and encountered extensive massive sulfide outcropping on the north flank of Central Hill at a depth of 3,250 m. The traverse continued up the hill with several stops to sample sulfide. Massive sulfide was observed nearly continuously up to a depth of 3,235 m. Blocky and slabby talus was abundant, but sulfide and sulfate chimneys formed in situ were observed in several areas. The submersible returned to the north and re-intersected massive sulfide at 3,276 m. A northward traverse up the hill again observed nearly continuous outcrop of massive sulfide up to a depth of 3,235 m. Bacterial mats were observed in a few small areas, but no hydrothermal discharge was observed. Samples of massive sulfide talus and barite chimneys were collected. Shells of vent-specific bivalves were collected at 3,249 m at the same location where marker 9V was deployed. The submersible then traversed east for several hundred meters crossing a sediment-covered area cut by numerous channels; some channels are more than 5 m deep. The submersible made a broad turn toward the north and traversed west for several hundred meters, again crossing an area of sediment-covered sea floor with irregular topography. No signs of hydrothermal activity were encountered until a mound of massive sulfide several meters high was encountered at a depth of 3,257 m on the northwestern edge of the upper part of the Central Hill. Several samples were collected and marker 6-dot was deployed. Although extensive outcrops of unweathered massive sulfide and shells from vent specific bivalves were observed, no live vent fauna or signs of active venting were located.

## Dive 2034

Dive 2034 (fig. 4) was targeted on the area where high heat flow was measured in 1985 (Abbot and others, 1986). The dive landed north of the known area of outcropping pillow lavas that form the eastern part of the Central Hill. The sea floor at the landing site (3,353 m) was young basaltic sheet flow with only thin sediment ponded in shallow depressions. The submersible traversed northeast until the west facing normal fault scarp that forms the eastern boundary of the inner graben was observed. The volcanic lava forms changed from dominantly sheet flows to dominantly lobate flows near the base of the scarp. Sediment cover increased abruptly as the scarp was approached. The scarp face itself was entirely sediment covered. The submersible then turned and headed towards the west, crossing again onto sheet flow basalt. The submersible then circled and headed northeast and once again traversed sheet flow basalt until we intersected the sediment-covered normal fault scarp. As before, lobate lavas were encountered near the fault scarp. The location of the scarp base is east of the change of slope shown on the bathymetric base map of the dive track because the scarp is steeper than indicated. We traversed up the steep scarp to a relatively flat sediment bench at 3,305 m. The entire scarp face was sediment covered and showed evidence of down-slope transport of sediment including small mass flow deposits that had moved a relatively short distance from the headwall scarp to the base of the scarp. The steep scarp was locally cut by channels incised into the sediment. We descended down the scarp face and traversed west to

northwest across an area of flat sediment-covered bottom. A small mound of basaltic rubble was encountered and sampled; this basalt may have been erupted through, or flowed into, the sediment. From here the submersible turned south and encountered an irregular hummocky sediment-covered bottom with small isolated exposures of sulfide and basalt. At one point, the submersible drove directly beneath the transponder that had been deployed the previous day. The submersible continued south for the purpose of intersecting the contact between sediment on the north face of the hill and pillow basalt. We encountered a waterlogged branch on the sea floor that was heavily colonized by small galatheid crabs and attached fauna. The log was recovered for biological study and box cores were collected from the sediment immediately adjacent to, and a few meters away, from the log. We continued the traverse south and encountered basaltic sheet flow at 3,335 m. After crossing a flat stretch of sheet flow and lobate sheet flow, the sea floor began to slope upward. Continuing up the slope of the Central Hill we passed from predominantly sheet flow to predominantly pillow lava. Lava drapes and lava tubes were observed down slope. There were no flow contacts, sediment cover changes, or other indications of multiple eruption units recognized. It appeared the pillow basalt hill was the eruptive center that fed the sheet flows that ponded north of the hill. One small area was encountered at 3,323 m (21:33 GMT ) where galatheid crabs were much more abundant than normal, but no other indications of hydrothermal activity were noted.

#### Dive 2035

Dive 2035 (fig. 5) was targeted to investigate morphologically young massive sulfide deposits imaged by bottom-towed camera at the base of the sedimented Southwest Hill in the area of the saddle between the Southwest Hill and the small hill to east southeast. The dive was plagued by navigational difficulties and never reached the target, spending most of the time north of the intended position. Massive sulfide was first encountered on this dive at the base of Southwest Hill at a depth of 3,304 m, approximately 75 m north of the known sulfide outcrops. The continuity of these deposits is not known. The deposits observed on the dive were predominantly sulfide talus; chimneys characteristic of the morphologically young deposits to the south were not observed. It is possible that the deposits visited on dive 2035 were displaced fragments of an older deposit imaged by the camera sled at a shallower depth on the flank of the Southwest Hill. Alternatively, the sulfide may have formed in place, but has been disrupted by sea floor weathering and slumping. Sulfide mineralization extended from 3,295 to 3,305 m; two samples were collected from this area. The dive then headed north for several hundred meters across a flat sediment-covered plain before turning back to the west. Massive sulfide was again encountered, at a depth of 3,300 to 3,304 m, when the submersible reached the base of the Southwest Hill. Samples were collected and the submersible traversed south obliquely rising up the scarp that forms the side of the hill. The scarp was generally sediment covered, but locally was covered by mudstone talus. Bedded sediment was exposed in some areas of the scarp and small debris flows were observed. The submersible continued a southward traverse across the top of the hill. A dredge track was crossed near the top of the scarp. The top of the hill was relatively flat and completely sediment covered. Box cores and push cores were collected at the end of the dive.

2036

The objective for dive 2036 (fig. 6) was to explore the area of massive sulfide mineralization discovered at the end of dive 2033. The submersible landed in a relatively flat sediment-covered area west of the Central Hill. The north-south scarp that forms the west flank of the Central Hill could be clearly seen on the CTFM (in-sub. foward-looking horizontal scanning sonar system) sonar. The submersible turned to the east and climbed to the top of the hill. Near the top of the hill an east-west trending scarp to the south could be seen on the CTFM sonar. A few disarticulated vent clam shells were observed on the slope. The submersible crossed over the crest of the ridge extending northward from the Central Hill and turned north to head back to the west. A CTFM sonar target led the submersible to a mound of massive sulfide venting shimmering water. Most of the remainder of the dive was spent sampling vent fluid, rocks, and biology from this mound. The sulfide mound is approximately 15-20 m long and 10 m wide with a base at 3,240 m and a top at 3,236 m. There were three areas of diffuse active venting; from a stubby, porous chimney that formed the top of the structure, from an area about 1.5 m lower where the base of the chimney flared out to form the mound, and from a ridge about 1 m lower that extended northwest from the chimney. All of these areas had diffuse venting of clear shimmering water. The venting structures were porous white sinters of anhydrite and barite. There was one large clump of tube worms near the intermediate level vent. The tube worms are thin and annulated and closely resemble those from the Southern Juan de Fuca Ridge vent site. Some tube worms were colonized by white anemones with red tentacles. Yellowish-colored palm worms were abundant near the vents. The rocks near the vents were covered with small white mollusks, mostly too small to be resolved from the view ports unless the window was very close to the bottom. Fluid samples were collected from the lower two vents. Measured temperatures for both vents were about 217°C. Sulfate sinter from the active vents and massive sulfide from the mounds was sampled. Marker 0 was deployed where tube worms were collected from the area around the middle vent; marker 6X was deployed at the lower vent. The end of the dive was spent in a quick reconnaissance of the area to locate other vents to be sampled on subsequent dives. Immediately to the south and slightly east of the sampled mound is the largest sulfide mound known in the area. The mound is built along the west slope of the hill and rises from 3,256 m to 3,225 m. One area on the side of the mound was covered by a field of tube worms several meters long. The mound was topped by inactive stubby sulfide chimneys. The hill top beyond the peak of the mound was shingled with slabs of lithified sediment. The submersible looped around to the west and several mounds of massive sulfide were observed, some of which were inhabited by vent fauna were seen to have diffuse venting of shimmering water. None of the mounds were venting fluid as vigorously as the sampled mound. The mounds were generally a few tens of meters in diameter and 4 to 8 m high. Small sediment-covered areas of the same size as the mounds separate one mound from the next. The mounds could well be interconnected in the subsurface. Massive sulfide mineralization was observed as deep as 3,260 m at the western extent of the traverse. One mound observed at 20:50 GMT, 3,254 m, appeared to both the pilot and the port side observer to resemble basalt rather than sulfide. The composition of this mound is unconfirmed; it was not photographed by the external camera, and a hand-held camera photo of this mound is too dark to be useful.

## Dive 2037

Dive 2037 (fig. 7) was a pilot-training dive and was intended to resample hydrothermal fluid from the vents discovered on dive 2036. Due to miscommunication and confusion over marker numbers, the dive landed at the inactive sulfide mound where marker 6-dot had been deployed on dive 2033. The submersible traversed around the area of the 6-dot mound searching for active hydrothermal venting and encountered several other mounds of massive sulfide. Numerous sulfide mounds west and south of the 6-dot mound include those observed at the end of dive 2036. Diffuse venting of 18°C hydrothermal fluid from a mound south of the 6-dot mound supported a thick cluster of tube worms and associated vent fauna. Some tube worms were collected and a fluid sample was taken from within the tube worm mass at 18:47 GMT, 3,250 m. The dive continued south passing more mounds of massive sulfide rising above the sediment-covered bottom, but none were observed to be actively venting. The sub circled west and then headed north encountering a large, but inactive sulfide mound at 19:30 GMT, 3,260 m. The dive headed back to the 6-dot mound and then turned north to explore for other mounds. A scarp or channel wall was encountered. Just past the top of the channel, a partially sediment-buried, poorly layered outcrop was passed that was tentatively identified as sheet flow basalt (20:06 GMT, 3,258 m). Just past that, several of the large inactive sulfide mounds seen on dive 2033 were encountered over the depth of 3,255 to 3,241 m. The dive then headed south-southwest back toward the area of the initial sampling site. A very large sulfide mound was encountered south of the 6-dot mound at approximately 21:00 GMT. The base of the mound is covered by sulfide talus and is at an approximate depth of 3,250 m. A large colony of tube worms was discovered toward the top of the sulfide mound at 3,235 m. Diffuse venting from within the tube worms (13.5°C) was sampled using the titanium bottles, and the plume sampler on the top of the sub was triggered. Two sulfide samples were collected from the area near the base of the mound a couple of meters below the tube worms. An attempt was made to collect a box core in the sediment that covers the base of the mound, but the closure mechanism was not activated, so the sediment washed out of the core.

## Dive 2038

Failure to locate high temperature (>300°C) venting in the NESCA area resulted in a decision by the chief scientist to explore the next volcanic edifice the north, which is located along the rift axis at approximately 41°03.5' N. latitude (fig. 8). At the time of the dive series, SeaBEAM bathymetry of the area was classified by the U.S. Navy and not released. In order to target areas likely to have massive sulfide mineralization, a bathymetric map of the area was constructed during the night before the dive using the 12 kHz echo sounder of the *Atlantis II*. Navigation was provided by two ACNAV (acoustic navigation) transponders positioned south of the hill which were roughly tied to the NESCA transponder net by acoustic ranging to the northernmost transponder of the NESCA net, which was occasionally within range. The dives in this area were also navigated with these two transponders, but the navigational control was poor due to insufficient calibration of the position of the transponders and difficulty of obtaining good fixes within this net. The resulting bathymetric map outlined the major hill associated with the volcanic edifice. Geologic analogy to areas of extensive massive

sulfide development in the southern Escanaba Trough (SESCA) and NESCA areas was used to target the first dive in this area. The dive was to traverse from south to north across the base of the steepest flank of the large on axis hill that defines the center of the volcanic edifice. Less than 15 minutes into the traverse the dive encountered massive sulfide mineralization (16:58) at a depth of approximately 3,260 m. As DSV *Alvin* continued up the slope two smaller mounds of massive sulfide were crossed. An area of extensive sulfide outcrop was encountered at approximately 3,253 m depth. Some mollusk shells were observed at the base of the sulfide outcrop. The dive then traversed over the top of the sediment-covered hill and encountered more massive sulfide on the north side at a depth of approximately 3,260 m. Several large to very large outcrops of sulfide were crossed as the sub moved east along the contour of the hill slope. The sub then turned south and began a westward traverse across the top of the hill. A small area of sulfide encountered at 3,264 m (18:15) was sampled, including attached biota. The sub continued its westward transect again passing massive sulfide at 18:25 GMT at 3,265 m. At approximately 18:45 GMT, an extensive area of massive sulfide was encountered at 3,265 m. At this point the sub turned to the south-southeast and re-encountered the large deposit crossed on the initial traverse. The sub then made a broad looping traverse that eventually took it north across the top of the hill. A small outcrop of sulfide at 3,260 m depth was encountered at 20:06 GMT. Moving further north, the sub again encountered substantial sulfide outcrops at 3,265 m depth. These outcrops were partially explored and two samples were collected. The sub then moved a few tens of meters east of the outcrop and took push core and box core samples before ending the dive. The poor navigational control and lack of observer documentation make reconstruction of this dive difficult. However, review of the video tapes and the dive notes allow several important observations. The sulfide outcrops encountered are quite old, highly weathered and partly sediment buried, but these are some of the larger outcrops observed in Escanaba Trough. The topography is clearly more complicated than is shown on the map. Many of the sulfide outcrops are along steep slopes, possibly fault scarps. CTFM images of twin linear reflectors and diver observations of parallel ridges of sulfide suggest the some mineralization may be developed along the walls of small grabens. Sulfide mineralization is clearly much more extensive than could be documented on a single dive, warranting further investigation as a center of extensive sulfide mineralization.

## Dive 2039

Dive 2039 (fig. 9) was targeted on the eastern flank of the sediment hill investigated on dive 2038. An improved bathymetric map was created during the night preceding the dive by continuation of the 12 kHz survey from the *Atlantis II*. A small steep-sided graben-like feature between the eastern rift-bounding fault and the east flank of the sediment hill was observed to have a flat floor that was a strong acoustic reflector. Exploration of this feature was the initial dive objective followed by a westward traverse up the hill slope towards the sulfide deposits encountered at the end of dive 2038. The dive started by traversing northward along the base of the eastern rift-bounding fault. Navigational errors related to a poorly calibrated net and the difficulty of acoustically imaging steep slopes result in a mismatch between the apparent slope shown on the dive track map and the observation that the sub was indeed traversing a flat sediment-covered terrain at the base of the fault scarp. No outcrops occur on the

flat sediment-covered floor, however isolated talus blocks from centimeter to meter size were observed. A small block of mudstone talus was collected at 17:23 GMT, 3,313 m. Most of the larger talus blocks observed were angular pieces of sheet flow basalt that were lightly sediment dusted and colonized by stalked animals. A push core was collected at 18:11 GMT, 3,308 m next to some blocks of basalt talus. The sub then move further north and up the slope of the fault scarp. Approximately 9 m above the floor of the flat sediment-covered bottom an area of outcropping basalt sheet flow was observed and sampled (18:25 GMT, 3,306 m). The basalt was best exposed along the steep slope of the scarp and the upper surface was partly sediment buried. After sampling the basalt, the sub began a long traverse to the west toward the outcrop of sulfide sampled at the end of dive 2038. No outcrops were observed as the sub traversed up the gentle slope of the hill. The terrain was gently undulating due to the presence of N-S ridges and Southwestales with a few meters relief. Near the top of a local hill at 3,254 m, small isolated outcrops of sulfide or sediment-covered sulfide talus were encountered. Most of the outcrops were only 1-2 m in diameter and were heavily oxidized and colonized by stalked animals. Several samples were collected from these isolated outcrops, including one sample that was composed of massive chalcopyrite-isocubanite. Two box cores and a second push core were collected from the sediment-covered area between the sulfide outcrops.

#### Dive 2040

The primary goal of dive 2040 (fig. 10) was to resample the hydrothermal vents discovered on dive 2036. The sub landed on the bottom approximately 200 m NW of the vent site. Unfortunately, an incorrect target was entered into the ACNAV navigation system, so the sub was vectored to a target approximately 1 km to the southeast of the intended target. Dive weights from dive 2033 were observed shortly after the start of the traverse. The sub traversed up the steep side of the Central Hill and crossed an area with an extensive field of dead clam shells, with minor amounts of sulfide talus and some outcropping sulfide (17:20, 3,241 m). Much of the area near the top of the hill was cut by channels a few meters deep and several meters wide. The sub continued across the top of the hill and encountered an extensive area of massive sulfide, including several very large sulfide mounds. The field of sulfide mounds was quickly explored from approximately 17:54 to 18:35. Sulfide mineralization occurs between the depths of 3,258 to 3,240 m, one sample was collected. Chimney-like structures are relatively common in this area, but no active vents were observed. However, the apparent presence of live clams in the sediment and areas of bacterial mat on massive sulfide suggest that the area is at least weakly hydrothermally active. Clam shells are much more abundant at this site than at the sulfide deposits to the north. The surface controller became aware of the navigational mistake and the sub was then redirected back to the north to sample the 6X vents, therefore this large field of massive sulfide remains very poorly explored, and the possibility for active vents occurring in this area is good. The sub rose up into the water column for the traverse back to the north in order to save time and battery power. The sub reacquired bottom contact just south of the southern limit of the large sulfide field investigated on dive 2033 and proceeded north. Large outcrops of massive sulfide were crossed as the sub looped to the west. After crossing a few steep sediment-covered scarps, the sub again encountered mounds of massive sulfide in the area investigated at the end of dive 2033 and during dive 2037, returning to near

where dive 2040 started. While looping further to the west to turn back to the 2036 vent site, the sub encountered another area of massive sulfide mineralization at about 19:30 GMT, 3,261 m. This area consisted of several mounds of massive sulfide including one colonized by a cluster of tubeworms and bacterial mat. The mounds are topped by barite chimneys. The 108°C vent fluids from the vent colonized by the tubeworms were sampled. Marker 3 was deployed and samples of barite and massive sulfide were collected. The sub then moved to the side of the mound, crossing an area with ripplemarks in the sediment, and collected two push cores and two box cores before dropping the weights at the end of the dive.

#### Dive 2041

Dive 2041 (fig. 11) was a second pilot-training dive. The primary objective was to resample the hydrothermal vents sampled on dive 2036. The dive landed on bottom about 100m NE of the 6X vent site and transited over a sediment-covered bottom to the sulfide mound. Almost the entire dive was spent in the vicinity of the 6X mound. Two water samples were collected and one sample of massive sulfide was collected. Multiple attempts, a few successful, were made to collect vent fauna. A box core was taken from the sediment-covered base of the mound. At the end of the dive the sub made a short transit to the south and climbed the side of the large mound with the extensive tubeworm field that was sampled at the end of dive 2037.

#### Dive 2042

The location and objectives of dive 2042 (fig. 12) were not announced prior to launch. Dive transcripts were not produced by either diver, so the information on this dive has been reconstructed entirely from the video tapes recorded during the dive. The dive reached bottom at 16:53 GMT, near the active hydrothermal mound on which markers 6X and 0 had been deployed. The submersible transited over this mound providing good views of the active vents at each of the markers. The sub proceeded to the southeast and climbed the large sulfide mound colonized by tubeworms that was sampled at the end of dive 2037. The dive then proceeded east across the top of the Central Hill. Several channels were crossed on the western slope. After crossing the flat top of the hill, the sub crossed a steep scarp on the east side and turned south to follow the base of the scarp. The scarp was near vertical and fairly continuously developed for several hundred meters. The floor was generally flat and sediment covered with locally derived blocks of mudstone talus slumped from the steep scarp. Locally, the flat floor was interrupted by steep slopes perpendicular to the major scarp. CTFM images show that the steep slope is one wall of a graben. The graben is typically 8 m deep and trends nearly N-S. The cross structures also occasionally showed on the CTFM as parallel reflectors trending perpendicular to the parallel reflectors from the walls of the graben. The graben is apparently offset or changes direction near 55,000 N on the transponder grid. At about this location, massive sulfide was encountered along the base of the west wall of the graben. Fairly continuous outcrops of massive sulfide occur for approximately 200m along the west wall of the graben. The base of the graben is generally at about 3,260 m. At one point, the submersible climbed up the wall of the graben to the top where a massive sulfide mound was sampled at 3,253m. This extensive area of massive sulfide lies immediately east of the field of massive sulfide mounds that were discovered during

dive 2040 and is almost certainly part of the same field. Several areas of extensive colonies of live clams and bacterial mat occur on the flat sediment-covered areas near the base of the massive sulfide exposed on the steep walls. Some clams and the underlying black sulfidic sediment were sampled by push core. Live tube worms were observed in an area of apparent low temperature venting (18:22, 3,248m), but vent temperatures were not measured and water samples were not taken. A few portions of the video tape of massive sulfide show shiny black botryoidal masses that could be hydrocarbon, but this could not be confirmed. Also, one of the external photos showed what could be a barnacle among the hydrothermal vent fauna, but again, this is only speculation based on the evidence available. The submersible continued its southward traverse. Beyond the southernmost exposure of massive sulfide was an area of sediment-covered bottom with less abundant clam shells on the sediment. The sub continued to follow the west wall of the graben until a very steep E-W trending sediment wall was reached which apparently marks the end of the graben. The sub climbed approximately 20m up out of the graben to a flat sediment-covered area, transited a few tens of meters west and then descended approximately 20m into what was apparently another graben, or an offset portion of main graben. The floor of this depression was flat and sediment covered except for local mudstone talus blocks shed from the step walls. Two box cores were collected and the dive was terminated.

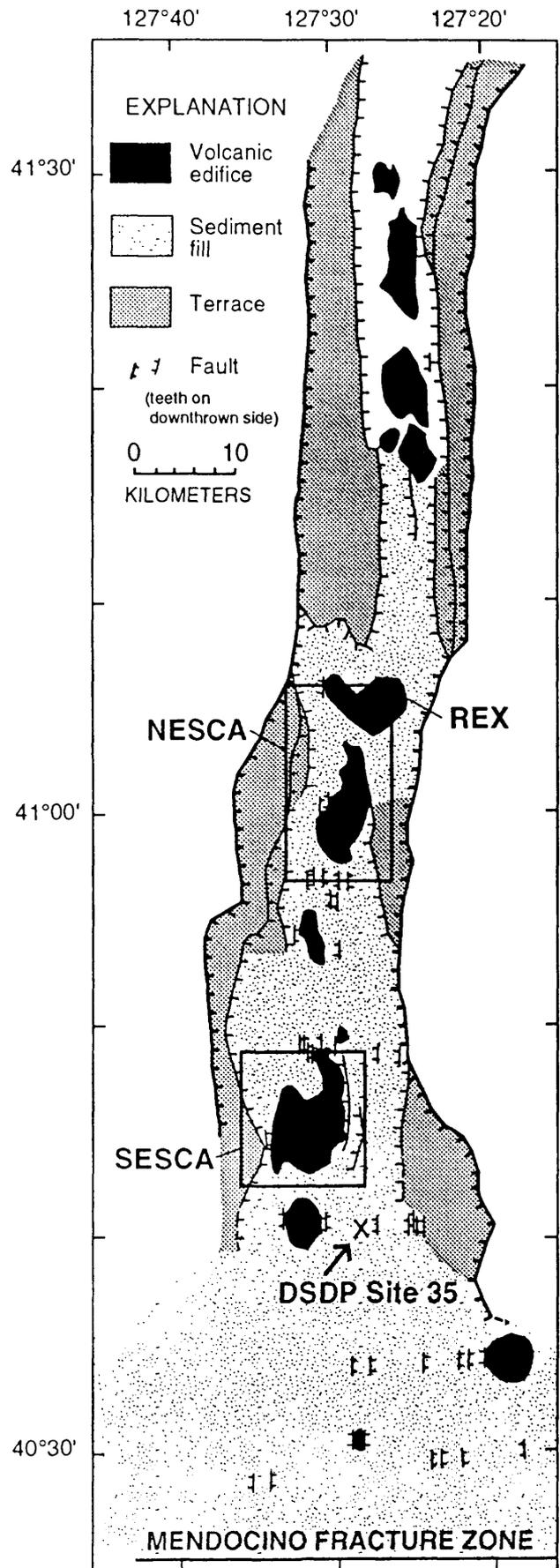
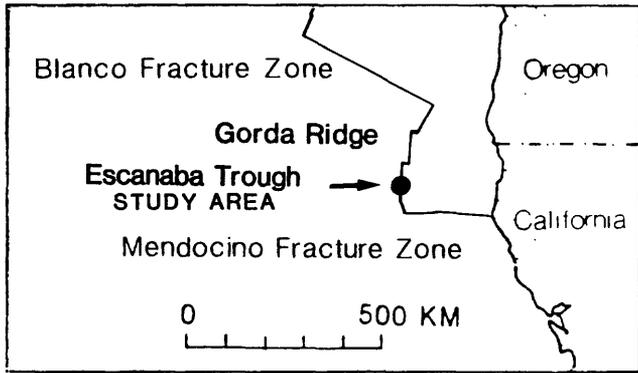


Fig. 1. Location map and general geology of the Gorda Ridge, showing volcanic edifices, terraces, sediment cover, faults and the NESCA study area of figure 2.

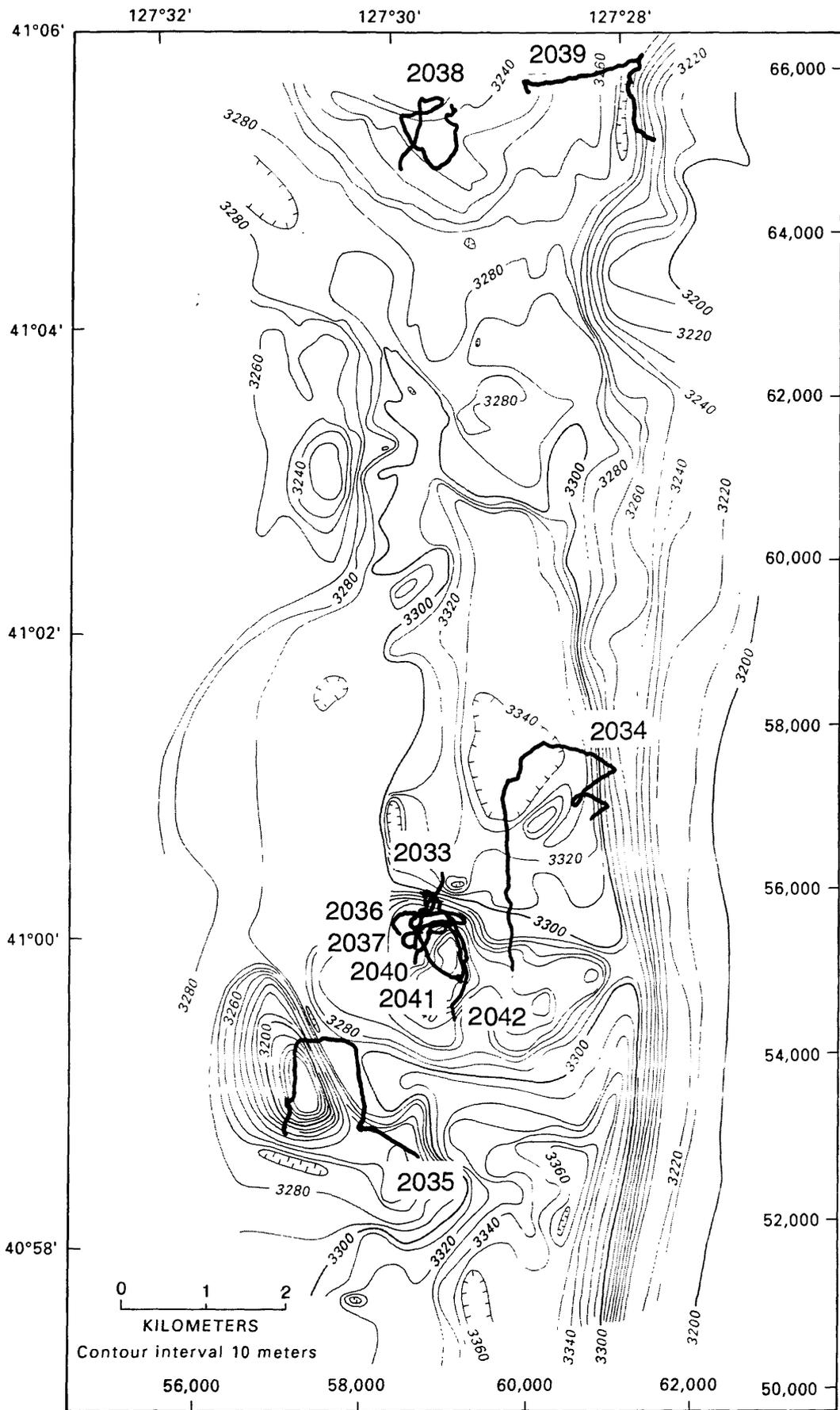


Fig. 2. Bathymetric map of NESCA showing 10 dive tracks, Southwest Hill, and Central Hill.

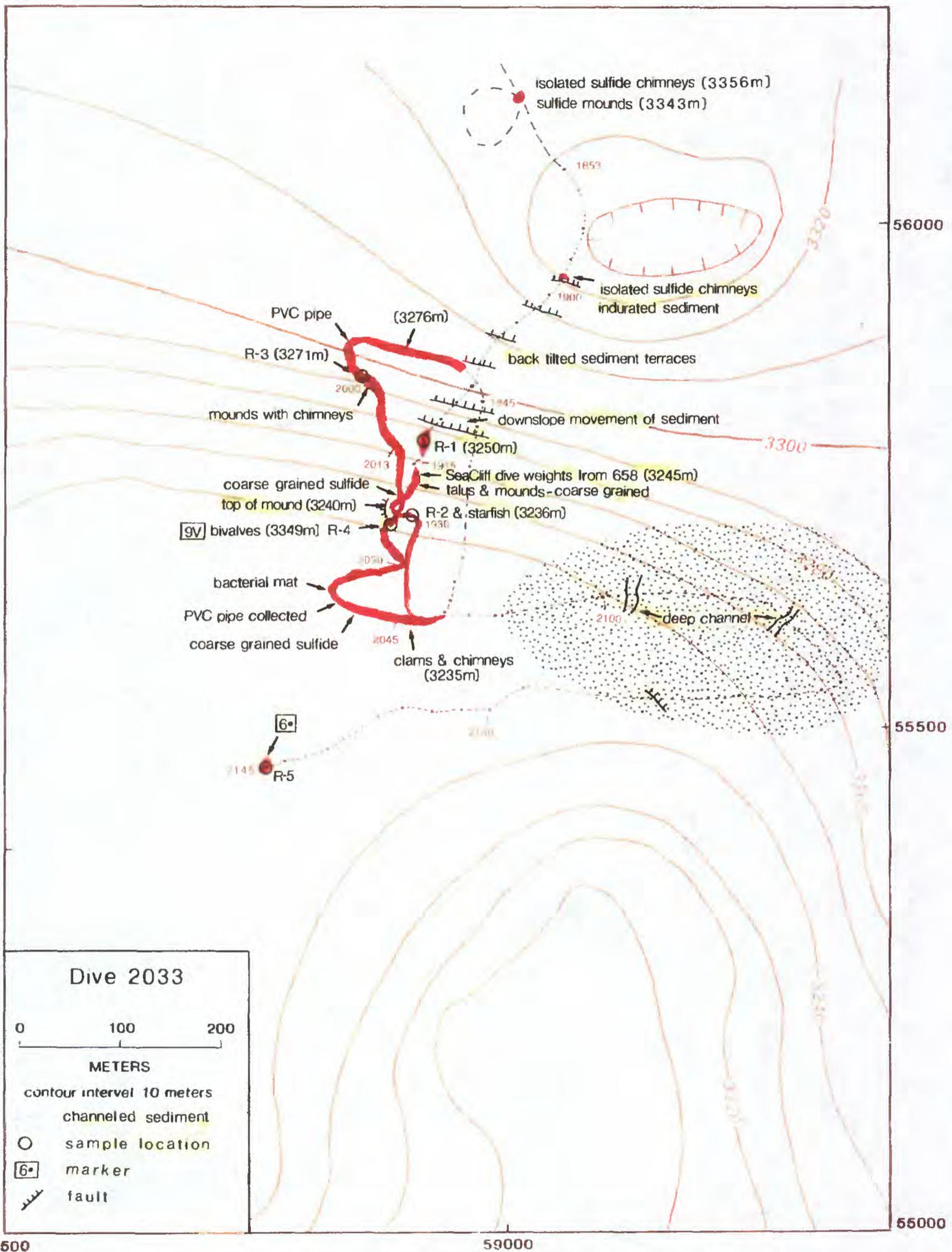


Fig. 3. Detailed bathymetry of the northern Central Hill, showing dive tracks and interpreted geology for dive 2033. Dots represent good positions obtained during dive, short dashes represent estimated track, long dashes represent poorly navigated areas, red indicates areas of sulfide mineralization.

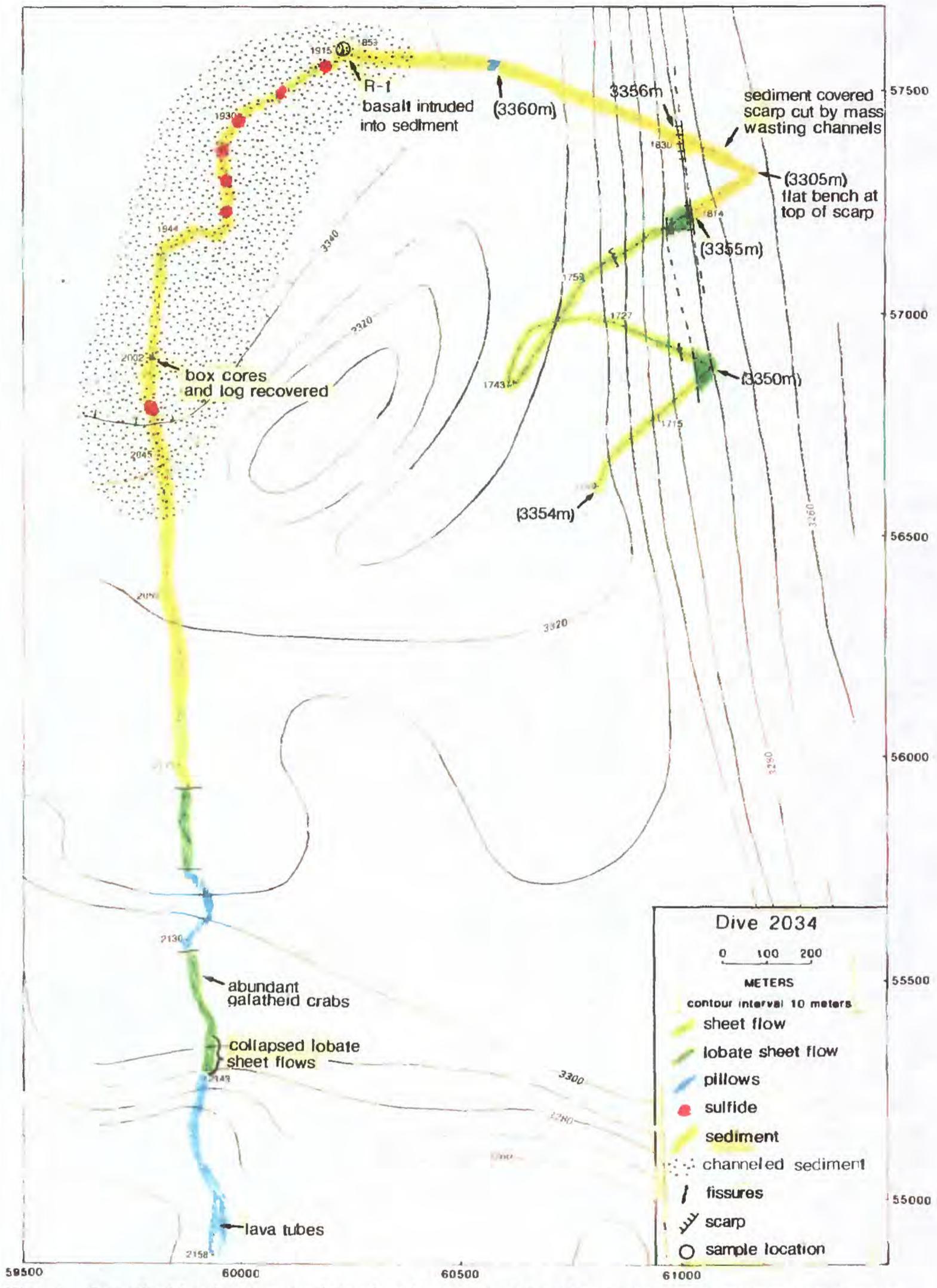


Fig. 4. Detailed bathymetry of the basin north of the Central Hill, showing dive tracks and interpreted geology for dive 2034. Dots represent good positions obtained during dive, and dashed line represents estimated track.

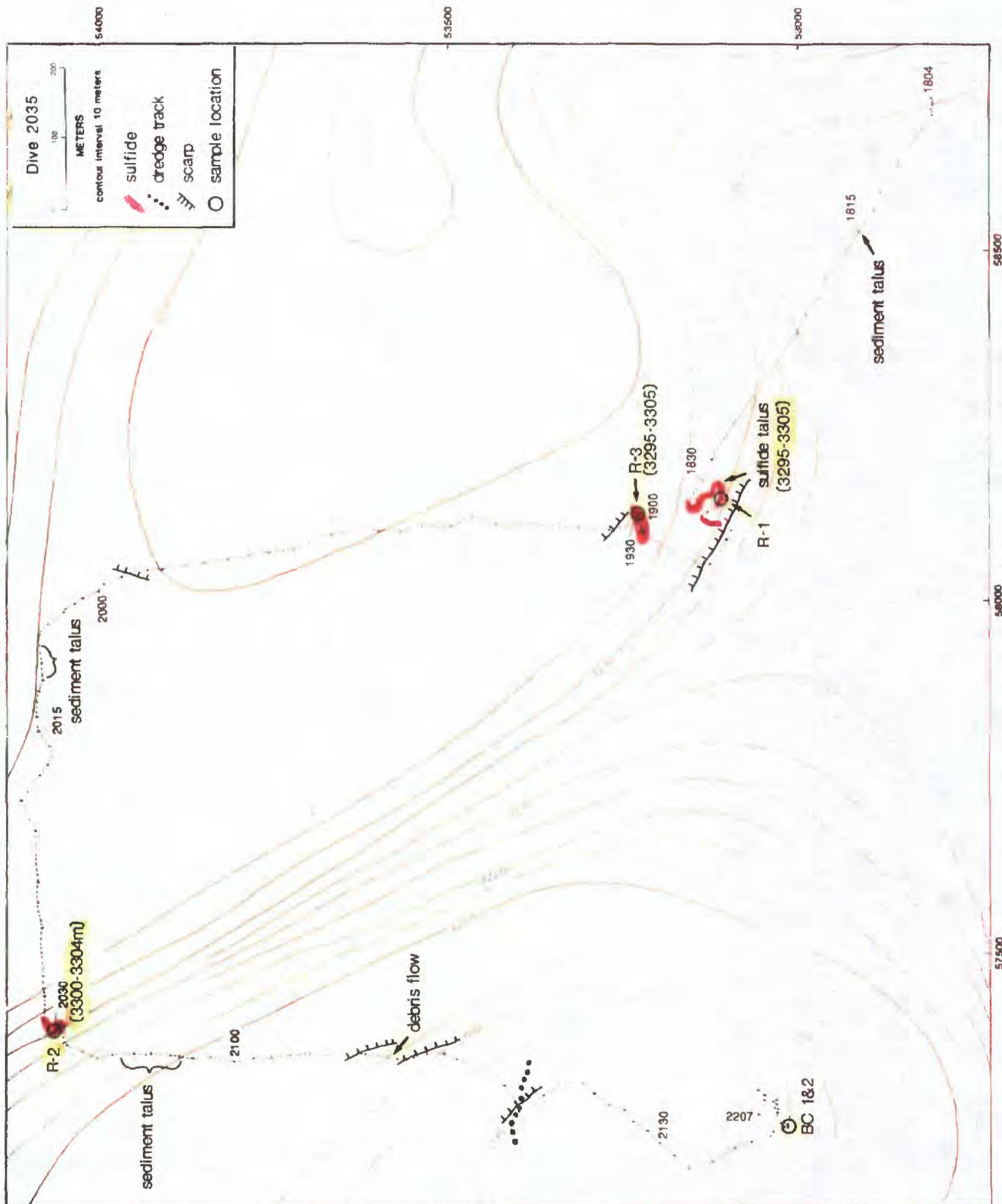


Fig. 5. Detailed bathymetry of the southeast portion of the Southwest Hill, showing dive tracks and geology for dive 2035. Dots represent good positions obtained during dive, and dashed line represents estimated track.

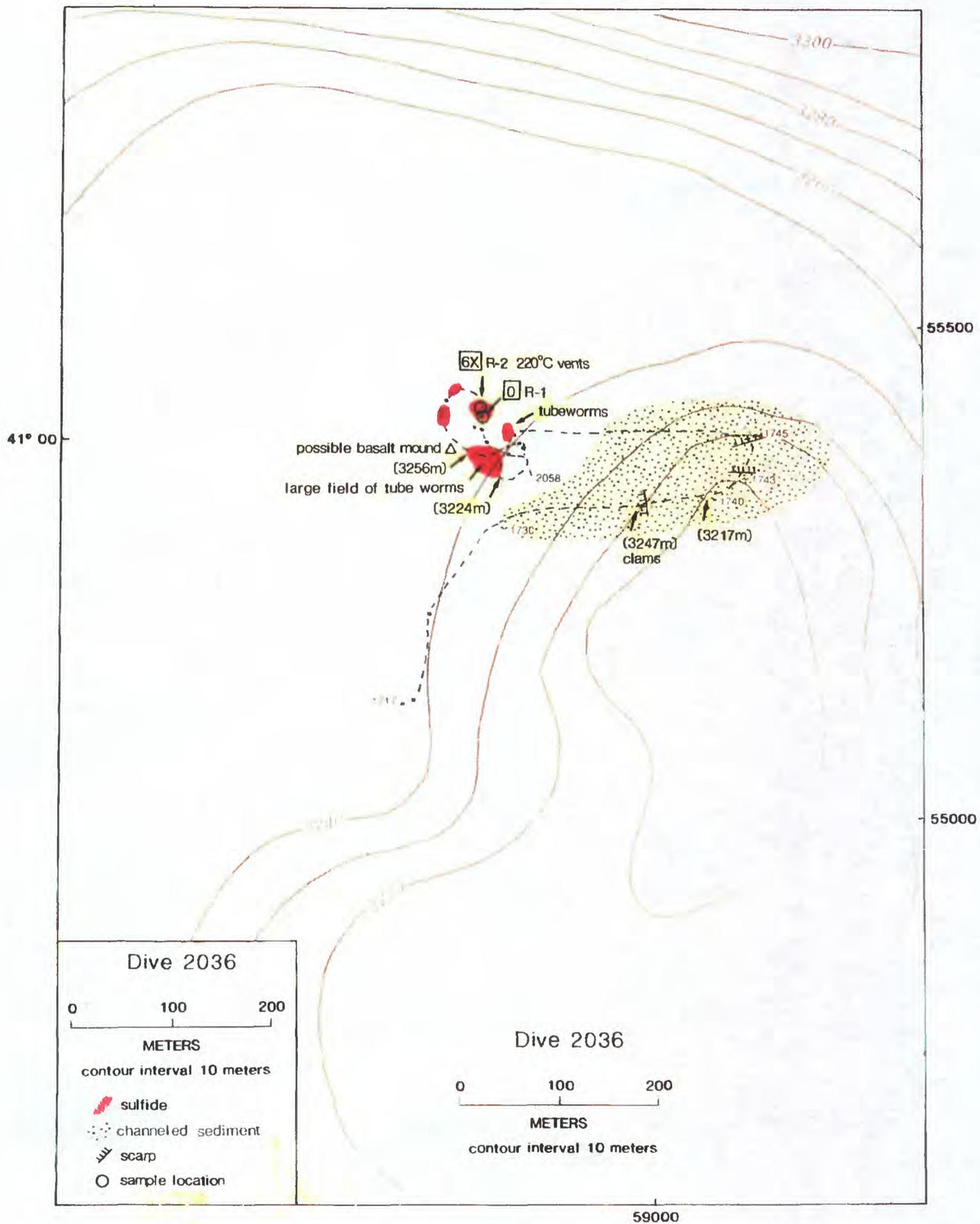


Fig. 6. Detailed bathymetry of the Central Hill, showing dive tracks and interpreted geology for dive 2036. Dots represent good positions obtained during dive, and dashed line represents estimated track. Numbers in boxes represent sea floor markers.

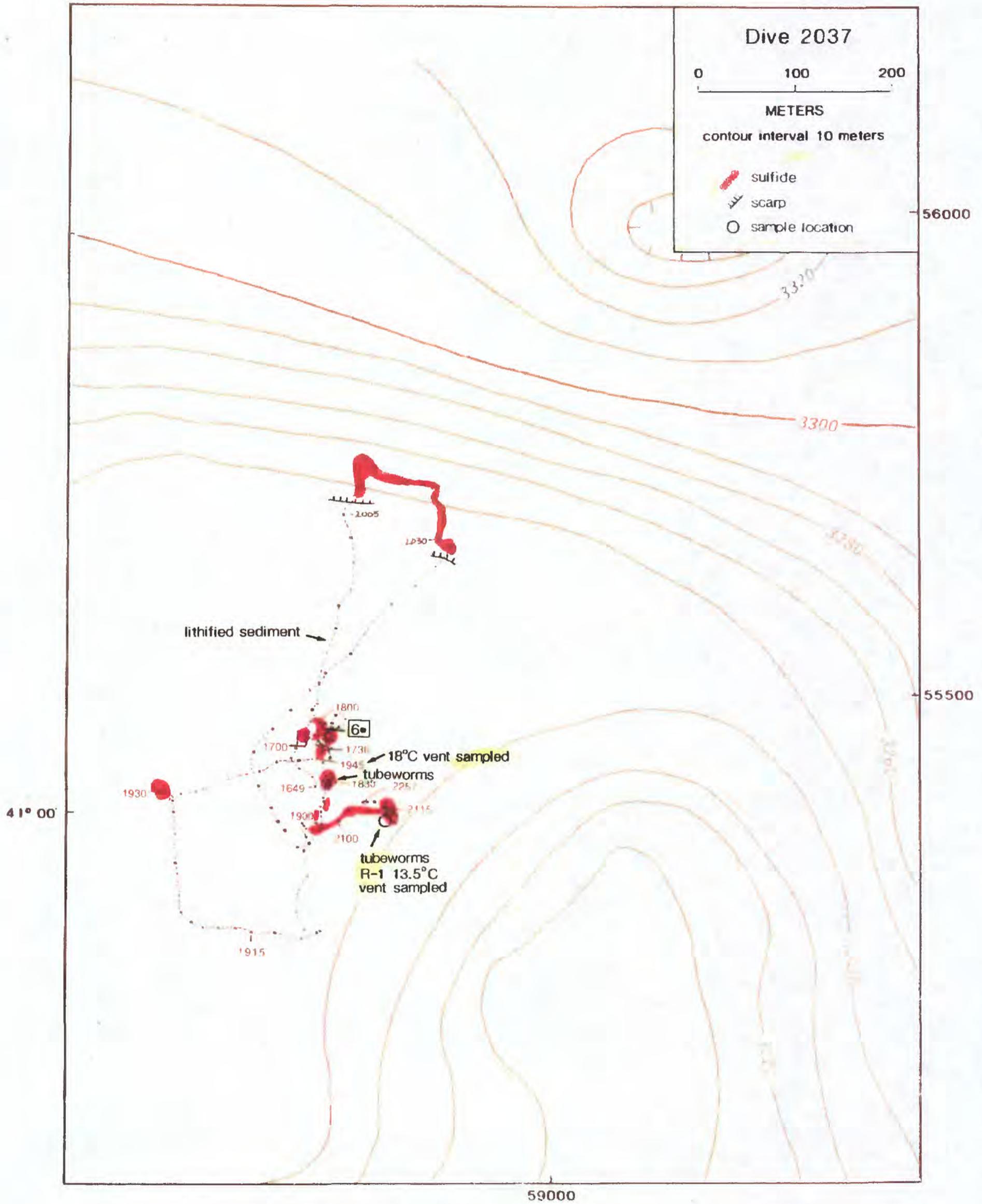


Fig. 7. Detailed bathymetry of the Central Hill, showing dive tracks and interpreted geology for dive 2037. Dots represent good positions obtained during dive, and dashed line represents estimated track. Numbers in boxes represent sea floor markers.

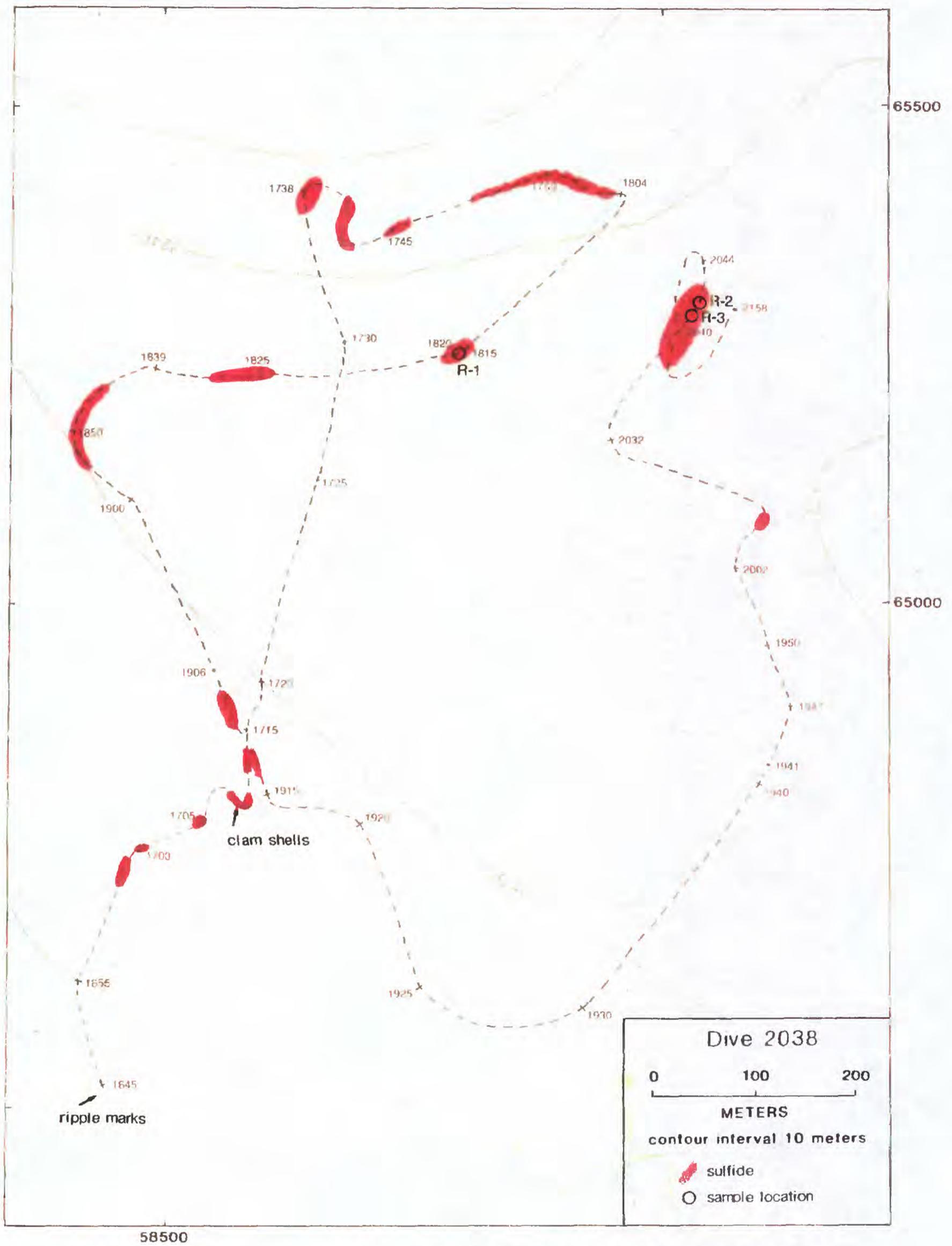


Fig. 8. Detailed bathymetry of the northern Nesca area, showing dive tracks and interpreted geology for dive 2038. Dots represent good positions obtained during dive, and long dashed line represents poorly navigated, estimated track.

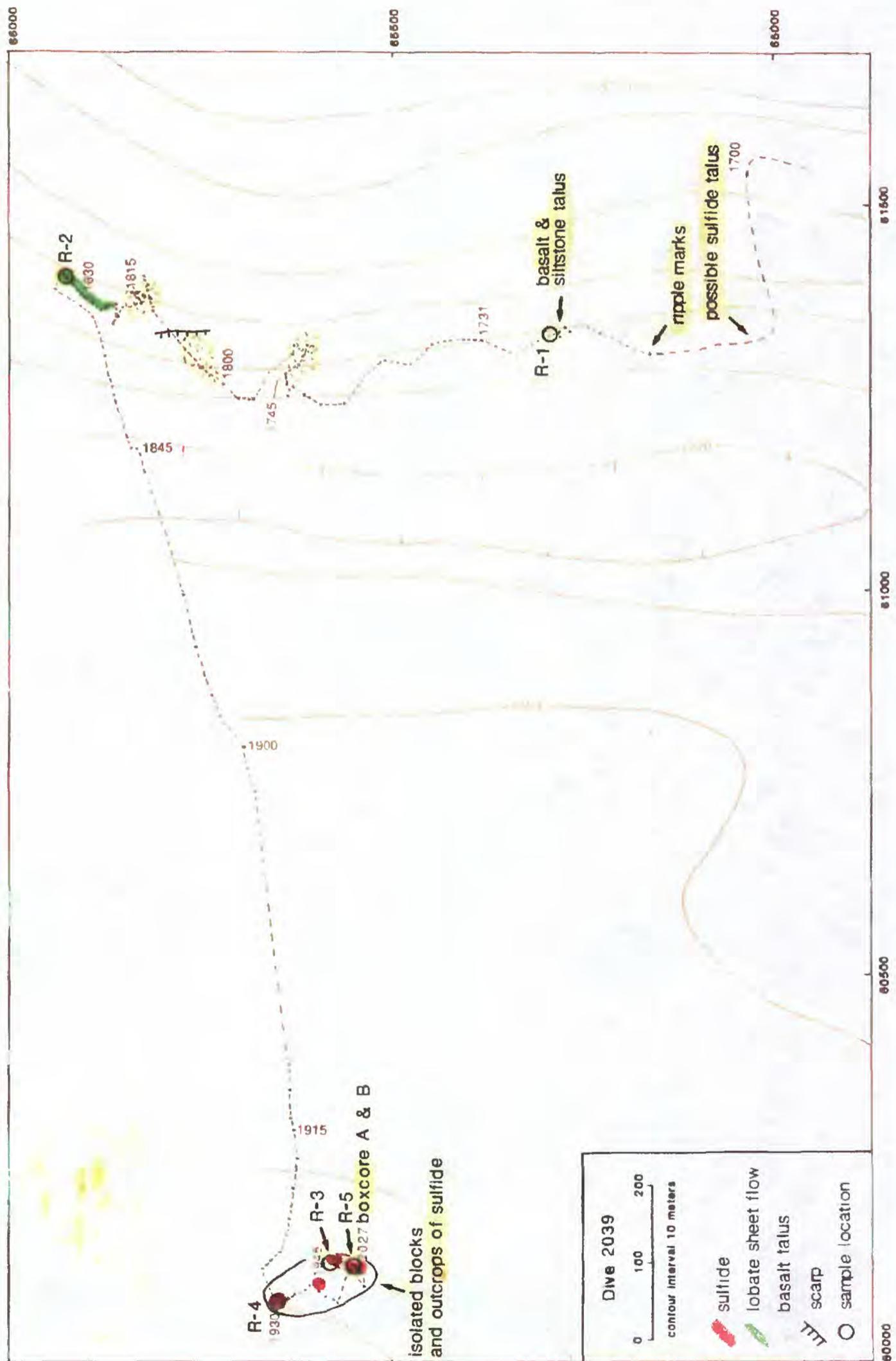


Fig. 9. Detailed bathymetry of the northern Nesca area, showing dive tracks and interpreted geology for dive 2039. Dots represent good positions obtained during dive, and dashed line represents estimated track.

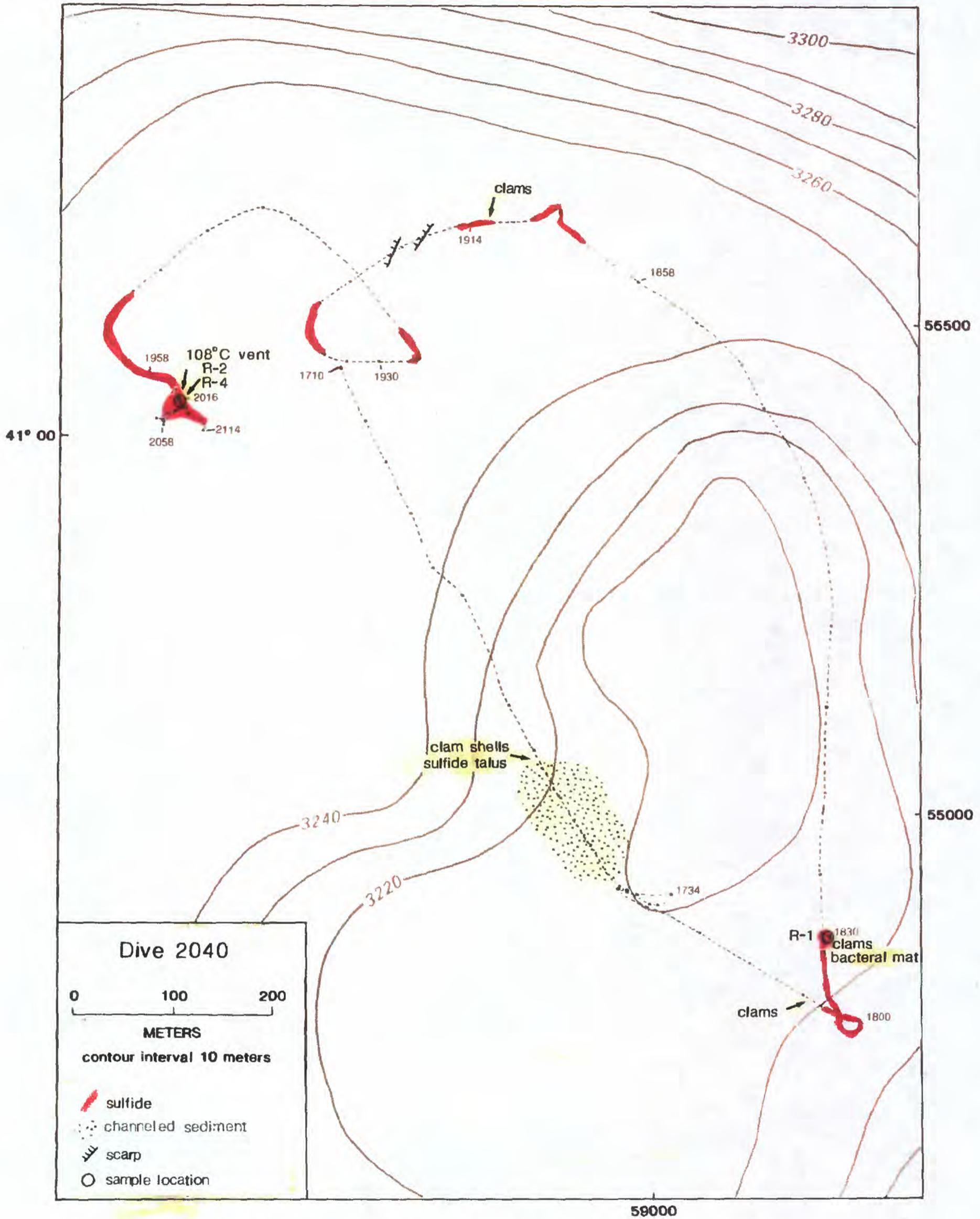


Fig. 10. Detailed bathymetry of the Central Hill, showing dive tracks and interpreted geology for dive 2040. Dots represent good positions obtained during dive, and dashed line represents estimated track.

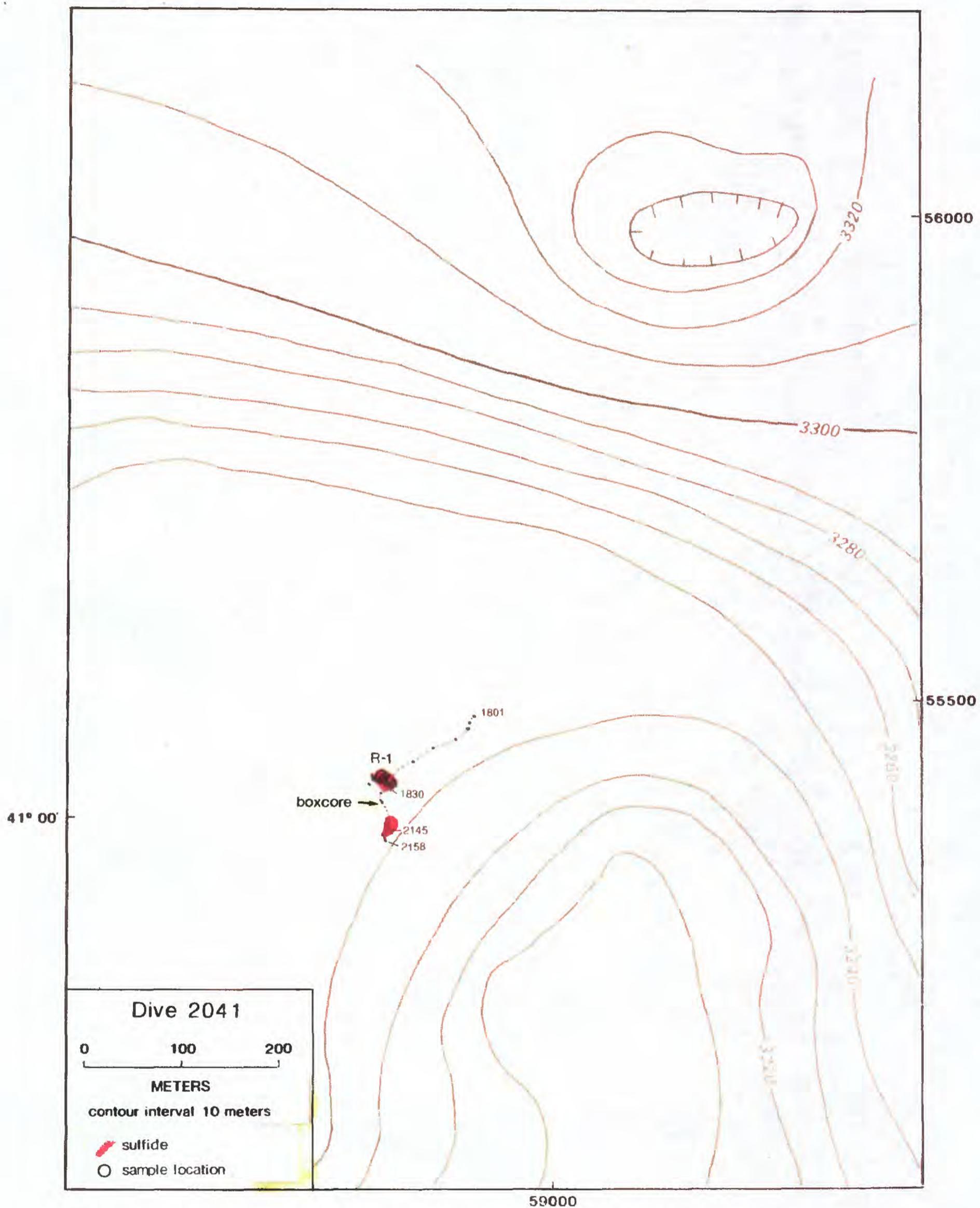


Fig. 11. Detailed bathymetry of the Central Hill, showing dive tracks and interpreted geology for dive 2041. Dots represent good positions obtained during dive, and dashed line represents estimated track.

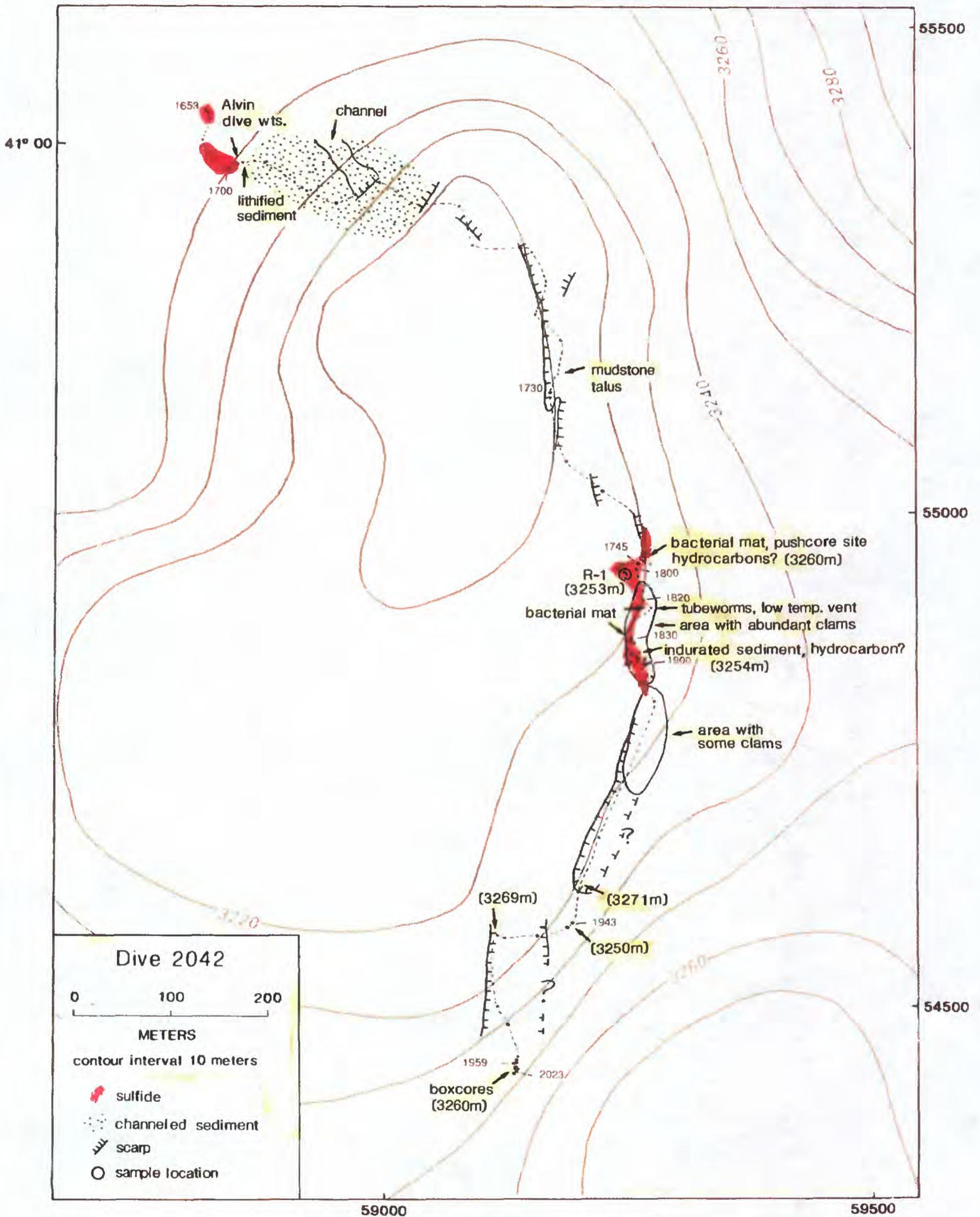


Fig. 12. Detailed bathymetry of the Central Hill, showing dive tracks and interpreted geology for dive 2042. Dots represent good positions obtained during dive, and dashed line represents estimated track.

**Gorda Ridge 1988 Cruise Participants of A2-88-NC**

**U.S.Geological Survey**

Wayne C. Shanks III  
John Slack  
Randy Koski  
Rob Zierenberg  
Chuck Heywood  
Stephanie Ross

**Massachusetts Institute of Technology**

John Edmond\*\*  
Andy Campbell  
Martin Palmer  
Chris German  
Rob Sherrell

**Woods Hole Oceanographic Institute**

Cindy Van Dover  
Fred Grassle\*

**Geological Society of Canada**

Bruce Taylor

**Scripps Institute of Oceanography**

Andy Magenheim

**University of Tokyo**

Yoshitaka Gamo

**Cornell**

William Sangray

\*\*Chief Scientist

\*Co-chief Scientist

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## DIVE TRANSCRIPT

Location: NESCA  
 Port observer: Edmond no transcript prepared  
 Starboard observer: Koski

Julian day: 155  
 Date: June 3, 1988  
 Pilot: Foster

Transcript of divers' voice recorders; Hdg = gyrocompass heading, Obs = observer (S; starboard, P; port, E; external photo description), comments in ( )'s are diver's comments, comments in [ ]'s are editors' clarification.

Time (GMT)	Depth (m)	Hdg°	Obs	Comments
16:55	1320		S	
17:30	2037		S	
18:00	2860		S	
18:05	3000		S	
18:11	3150		S	Landing lights are on. I see particulate matter floating past starboard window.
18:14	3199		S	Altitude 147 m.
18:25	3280		S	Still descending.
18:30	3330		S	Altitude 29 m.
18:35	3356		S	Begin driving. I see sediment-covered bottom. I see a holothurian, first creature of the day, another holothurian. The sediment is fairly smooth, but has numerous small bumps and furrows (tracks), looks well bioturbated.
18:37	3357		S	Flat area here.
18:40	3356		S	First still photographs of bottom features. Quite a bit of turbidity, material floating in water column including long, tubular detached organisms, mucus, floc. I see brittle stars, anemones (purple).
18:41	3357		S	Very close to bottom.
18:42		162	S	Water temperature is 1.601°C. Drive to south and west ~2 m above bottom, sediment in water column. While John is observing sulfide chimney out the port side, I see flat sediment-covered bottom with anemones, shrimp, large holothurians. We're beginning up slope now; I see more anemones attached to small stubby outcrops poking up through sediment. Pink and white anemones.
18:44	3353	167	S	Moving up slope now; slope gradual, much particulate material floating above the bottom. I see no more outcrops. Holothurians and tracks. I see brittle stars a few meters apart, anemones, some white objects, many shallow mounds to 0.5 m across, pale blue fish, small (~0.3 m), iridescent, a brisingid, more brittle stars. Time is now 18:46:30, going up slope. I see more fish, bioturbated sediment (numerous shallow mounds).
18:46:52	3343	222	S	To the right I see basket weights that Dudley [pilot] dropped earlier. Continuing drive up steeper slope, I

Time	Depth	Hdg °	Obs	Comments
18:46:52	3343	222	S	To the right I see basket weights that Dudley [pilot] dropped earlier. Continuing drive up steeper slope, I see in the distance a large fish ~1/2 m in length, stubby head. Not much evidence of mass wasting on the slope at this point. Organisms do not look disturbed. Some are floating just above the bottom. Moving more toward the southeast over sediment. Holothurians and brittle stars.
18:51	3325		S	Moving up slope over sediment. Picture #3 of brittle star. Now within 64 m of Target A.
18:52	3314		S	Picture of brisingid and holothurian. Crinoid. Very close to bottom. Sediment has many organisms including pink anemones. Going up slope to terrace with another steeper slope above and beyond. I see a venus fly trap anemone. Rising over terrace, a low area starboard side, numerous breaks in slope, we're in a bowl-shaped area that flattens out along edges. Up slope and southward drive. Another blue-colored fish. Rising out of bowl, flattening out.
18:55	3302	204	S	Going up slope. We are going southwest to find sulfide outcrop, slope uneven with numerous breaks. Flat areas or terraces. A shallow slope with numerous low bumps.
18:56			S	Fragments of indurated sediment on slope, numerous holothurians and other critters. Steeper now, I see rock outcrop, sediment with rubbly surface. A blue fish pointing up slope.
18:58	3305		S	Now on indurated sediment surface. Now another terrace. Picture #6 of stalked organism. Pink holothurian with spines.
18:59	3300		S	Rising up slope, sediment cover is thin over more consolidated material.
19:01	3274		S	Up slope, sediment covered. Purple and white anemones.
19:02			S	Another break in slope, brittle stars, large holothurians. To my right, a valley. Over a break in slope to terrace dipping back into hill. Same bottom fauna. Many lumps may be covered holothurians.
19:02:45	3270	215	E	Sediment-covered bottom.
19:04			S	Going up slope over sediment. A 1 m long fish with silvery appearance.
19:06	3260	214	S	Moving up slope. I see a sediment-covered ridge in distance. White anemones. Up against a steep wall of indurated sediment. Appears to be much down slope movement, grooves in the sediment. Outcropping mudstone here and there. Another break in slope. I see in the distance a ridge and valley topography, all sediment covered.
19:08:30	3250	215	E	Small ridge of partially sediment-buried sulfide.

Time	Depth	Hdg°	Obs	Comments
19:11	3250		S	We see angular blocks, talus or rubble poking out of sediment quite abruptly. Mossy-covered material, looks like cactus forms jutting out of sediment; looks like sulfide. Orange oxidation surfaces, definitely sulfide here (put data frame on video to mark this site). OK, we've stopped to sample sulfide deposit, low-lying (~1/2 m above sea floor). Appears to be extinct sulfide mounds, low with rubbly chimneys and some saguaro-shaped chimneys. Organisms: galatheid crabs (sparse), a few anemones. Dudley is sampling sulfide.
19:14:45	3248	201	E	Sediment-covered bottom.
19:15	3248	193	S	Dudley has captured sulfide sample [2033-R-1], we are continuing up slope. We see more low rubbly sulfide mound with reddish-brown oxidized surfaces. Probably pyrrhotite-rich composition because of appearance of oxidation. A large fish in background.
19:15:30	3247	190	E	<i>Sea Cliff</i> dive weights in sediment.
19:17	3245		S	Now above area of sulfide and into sediment-covered terrain. Now we see on slope a number of rectangular markers and sulfide deposits on starboard side as a small ridge. Steel plates on bottom, partly buried ( <i>Sea Cliff</i> dive weights).
19:17:30	3245	245	E	Base of sulfide mound.
19:17:45	3245	239	E	Massive sulfide talus.
19:18:45	3242	209	E	Massive sulfide breccia with local Fe oxide weathering.
	3241		S	Straight ahead we see quite large blocks of sulfide with large cleavage surfaces reflecting in sub lights. Very large talus pile, many starfish attached to blocks. 6-7 m high boulder pile. Blocks are angular and weathered, but many have fresh sulfide on surface. About half way up sulfide outcrop.
	3240		S	On top of large sulfide outcrop, I am looking at very steep slope below me, at least 20 m dropoff. Massive sulfide and talus to the bottom.
19:19:45	3240	229	E	Water column.
19:20	3242	098	S	Now looking at more sulfide outcrop, a sulfide ledge with variable oxidation.
19:20:30	3241	101	E	Partially sediment-buried sulfide.
19:21	3241		S	A flatter slope underlain by sulfide. Now, an enormous fish. At top of terrace of massive sulfide with thin sediment cover. Three pictures of fish. Up slope again, more sulfide, sulfide ledges. We have been moving up slope steadily, even though not always indicated by water depth. Outcrop of massive sulfide with thin sediment cover, no vent specific organisms, but numerous anemones and brittle stars. Up slope, more massive sulfide, quite steep, a ledge and slope topography. Numerous rubbly exposures.

## Appendix 1

Dive 2033

Time	Depth	Hdg°	Obs	Comments
19:21:15	3244	128	E	Subhorizontal ledges of massive sulfide, partially sediment covered.
19:21:30	3245	138	E	Large fish over ledges of massive sulfide.
19:25	3236		S	Trying to sample organisms. Our plan is to continue up slope, go to west a little, then back to east in search of tube worms.
19:30			S	Biological sample in critter basket [with small sulfide fragment; sample 2033-R-2]. Moving above sulfide outcrop with numerous galatheid crabs. Sulfide is variably oxidized with small irregular chimneys. Coming up against a large prominent massive sulfide edifice covered with massive sulfide talus, rises above sub. Large number of galatheid crabs on sulfide and sediment.
19:32	3234	180	S	Low rubbly massive sulfide outcrop with small sulfide spines poking out through sediment. Up above bottom now, but can still see sulfide pinnacles with galatheid crabs. Some chimneys rising abruptly from massive sulfide pinnacle, none active. Massive sulfide slabs on slope.
19:32:00	3235	210	E	White patch in sediment at the base of a massive sulfide mound.
19:33:30	3235	186	E	0.5 m chimneys in area of sediment-covered sulfide.
19:34:30	3235	195	E	Water column.
19:36	3242		S	We are swinging around to drive over slope again.
19:36:30	3242	325	E	Sediment-covered slope.
19:37	3237	003	S	Sediment-covered sea floor, some indurated sediment outcrops. Undulating sediment-covered surface, approaching slope, sediment fragments and outcrop.
19:39			S	Undulating bowl-shaped area. A galatheid crab.
19:41			S	Only see sediment with benthic organisms.
19:43	3247	003	S	Gently rounded sediment-covered area. Turning west now. Sediment-covered area. A sea pen.
19:46	3260		S	John sees sulfide out port side, but I am looking down at sediment-covered sea floor. Turning to S, ledges of sulfide exposed, also now, pinnacles of massive sulfide
19:47:30	3272	269	E	Sulfide talus in sediment
19:48:30	3276	271	E	30 cm high sulfide chimneys in sediment
19:49	3276		S	Chimneys and massive sulfide ledges; some very well shaped tubular chimneys preserved. Massive sulfide mounds with chimneys on top.
19:49:30	3278	271	E	PVC pipe on sediment-covered bottom.
19:50	3260	270	S	Now looking at sediment-covered sea floor again.
19:50:30	3278	158	E	Anemone attached to PVC pipe.
19:51			S	Saw PVC pipe. Massive sulfide talus and low mounds against the slope. I have taken 30 photographs.
19:51:30	3273	126	E	Sulfide breccia at the base of a sulfide mound.
19:52:00	3272	137	E	Ledges of massive sulfide on slope of mound.

Time	Depth	Hdg°	Obs	Comments
19:52:30	3271	159	E	Chimneys on slope of sulfide mound.
19:53:00	3270	181	E	Tunicates on sulfide-sulfate chimneys.
19:53:30	3269	193	E	Anemone with very long tentacles and brisingid on top of chimneys.
19:54:00	3269	198	E	Anemone with very long tentacles and brisingid on top of chimneys.
19:54:30	3270	181	E	Tunicates on sulfide-sulfate chimneys.
19:55	3271		S	Dudley is sampling sulfide from large pinnacle.
19:55:30	3271	206	E	Sampling barite chimney.
19:59:00	3271	186	E	Freshly broken base of barite chimney, top seen in distance.
20:04	3271		S	Dudley has recovered two chimney pieces [samples 2033-R-3A and 2033-R-3B].
20:07	3271		S	Picture 30 of brisingid on massive sulfide mound. Pictures 31, 32 of sulfide with organisms.
20:07:00	3272	228	E	Fresh breaks from sampling barite chimney
20:08:00	3271	200	E	Large sulfide talus block at base of barite chimney.
20:09:00	3270	197	E	Anemone with long tentacles on sulfide.
20:10	3269	165	S	Moving up slope again. Up partly buried massive sulfide Pink anemone on sulfide. End of side 1 [audio tape]; begin side 2.
20:10:00	3270	192	E	Start of traverse up steep slope covered with sulfide.
20:18	3250	108	S	Continuing drive up slope. We should be coming to point where we originally found massive sulfide. I see slabby massive sulfide outcrop. This is very large massive sulfide deposit with thin sediment cover in places. Large blocks of sulfide above. Crystalline massive sulfide reflecting in lights of sub. Anemones, starfish.
		209	S	Now, angular low ridges of sulfide with sediment in between.
20:19:00	3250	192	E	Massive sulfide crusts buckled upward through sediment due to displacement caused by growth of sulfide.
20:19:30	3249	193	E	Coarse blocks and slabs of sulfide near edge of sulfide deposit.
20:20	3240		S	Mostly sediment covered down slope to starboard. We've come across area with scattered clam shells. We will deploy marker <b>9V</b> [sample 2033-R-4].
20:21:30	3248	199	E	Sediment covered ridge.
20:22	3249		S	Change hand held camera film at 20:20 to roll #2. Marker <b>9V</b> deployed, on site where bivalve organism collected. Roll #2: first 2 frames show <b>9V</b> .
20:23:30	3249	185	E	Open Calyptogena shells on sediment covered bottom.
20:32	3248		S	We will look around this area for a few minutes and then drive east. The bivalves are large and elongate, very white on external video.

Time	Depth	Hdg <sup>o</sup>	Obs	Comments
20:35			S	Beginning to drive or turn to east. The sediment exposed where scraped by sub has a gray color in contrast to orange at the surface. Somewhat greenish in color also. I have changed video tapes (to tape 2).
20:35:18	3245	118	E	Iron stained and hydrothermally altered white sediment(?)
20:35:48	3244	145	E	Iron stained bacterial mat(?), altered sediment(?), at base of sulfide mound.
20:40	3244	172	S	Off to west, a steep slope with several ledges of hydrothermal material, yellow and orange in color. Some have yellowish coating or crust.
20:42			S	Dudley has collected PVC pipe and put in basket. I can see large sulfide fragments with scattered anemones and starfish. Evidence for down slope movement of large fragments. Surfaces are yellow to orange in places, dark in others. Thin sediment cover locally.
20:44:15	3234	158	E	Top of steep massive sulfide mound.
20:45	3235		S	We will begin to move east now. Massive sulfide fragments have large flashy cleavages. Numerous crabs and starfish. Fringing hairy or filamentous organisms on some sulfide surfaces.
20:46:30	3236	192	E	Dark coarse sediment on mud near sulfide mound, probably mass wasting of sulfide mound.
20:47			S	Sediment with massive sulfide poking through. White patches in sediment may be organic. Ahead I see large slabs of massive sulfide, the top of which is brown underlain by more deeply eroded yellow-orange material, possibly sediment. Went over area with 1 to 2 m tall spires of massive sulfide, well preserved.
20:49:00	3233	098	E	Water column.
20:51:30	3237	088	E	Sediment-covered bottom.
20:52		022	S	Moving somewhat up slope (heading 002 <sup>o</sup> ), will drive to east. Sediment-covered slope here, some rubble (massive sulfide?) coming down slope. Driving over channel, up slope. I see only sediment, heading 022 <sup>o</sup> . Over low, linear channel with only a few outcrops of indurated sediment. Purple anemones.
20:52:30	3241	092	E	Small channel in sediment, start of traverse over sediment-covered channeled terrain.
20:54			S	Moving over sediment.
20:55	3241	090	S	Over sediment-covered sea floor, ridge and channel terrain. Here and there a patch of lighter-colored sediment around mounds (burrows). Lighter in color than brownish surface sediment.
	3240	090	S	On sediment-covered terrain. Usual organism including a few stalked critters.

Time	Depth	Hdg°	Obs	Comments
20:59		132	S	Over sediment-covered sea floor, numerous holothurians. Some outcrop of pale-colored sediment.
21:01			S	We are over steep slope into another channel about 10 m deep.
21:03			S	Continue over sediment-covered bottom with very rounded features related to mass wasting. Minor indurated sediment outcrops.
21:04			S	A large fish.
21:05	3255	090	S	Heading over sediment. Photo #8 is of indurated sediment exposure.
21:11	3270	240	S	We've gone as far east as we can before returning to sulfide area. Will turn and drive to southwest. Over sediment with small fragments of harder material. Shrimp critters, brittle stars, holothurians, etc. Moving up slope, fragments of sediment with movement tracks above - mass wasting in action.
21:16	3250		S	Larger outcrop of blocky indurated sediment. Crossing over 5-10 m deep channel with slabs and blocks of indurated sediment on slopes. Now, a very steep slope with thin unconsolidated material moving down from above.
21:16:20	3258	242	E	Subcropping mudstone on edge of small channel.
21:20	3244		S	Still climbing on sediment-covered rounded topography. Bottom drops away occasionally.
21:22	3245	272	S	All sediment covered. Now, a flat-lying surface with a low scarp rising above that exposes indurated sediment. Running low on battery power according to Dudley.
21:30	3244	250	S	Upslope drive, on sediment.
21:31			S	Galatheid crabs.
21:35		156?	S	A scarp with exposure of light-colored sediment rock. No obvious bedding. Debris apron(?) at bottom of slope, in channel.
21:39	3259		S	Moving southwest over sediment.
21:40	3255		S	Sulfide outcrop, then sulfide talus. Battery power very low. We will try to sample as much sulfide as we can before leaving bottom.
21:40:30	3258	240	E	Large blocks of massive sulfide at base of mound.
21:41:00	3258	209	E	Large blocks of massive sulfide at base of mound.
21:43			S	Sampling continues. Picture 15 of sulfide. Dudley will deploy marker <b>6 dot</b> . Sulfide material is very soft, sulfide rich, numerous particles in water column.
21:50	3257		S	Marker <b>6 dot</b> deployed, 3 chunks of sulfide collected [sample 2033-R-5].
21:50:30	3257	232	E	Marker <b>6 dot</b> on massive sulfide colonized by brisingids, end of dive.
21:51			S	Off bottom, heading to surface.
21:53			S	Drop weights.
23:52			S	Surface.

## DIVE TRANSCRIPT

Location: NESCA  
 Port observer: Campbell  
 Starboard observer: Zierenberg

Julian day: 156  
 Date: June 4, 1988  
 Pilot: Hollis

Transcript of divers' voice recorders; Hdg = gyrocompass heading, Obs = observer (S; starboard, P; port, E; external photo description), comments in ( )'s are diver's comments, comments in [ ]'s are editors clarification.

Time (GMT)(m)	Depth	Hdg°	Obs	Comments
15:00	surface			
15:30	0622		P	
16:07	1700		P	Current set to N.
17:06	3353	360	P	Arrive on bottom. Sheet flow with sediment dust. Rough terrain current from south gullies/channels in high spot. Many holothurians, temperature 1.6° C.
17:06	3353	350	S	Just made bottom contact on folded sheet flow terrain. No shiny glass, some sediment cover, estimate sediment cover at 20%. A few sponges, asteroids, anemones, a large stalked and branching sea pen. Irregular flow folded terrain with 5-10 m of relief, dropping away to the starboard side, our heading 350°.
17:07	3354	359	E	Broken sheet flow.
17:07:41	3354	352	S	On flow-older sheet flow, I can see a little bit of glassy crust on the basalt. Bottom is dropping away in front of us, our heading is 352°. Coming into what might be a collapse pit. There is a brisingid, several small sponges, but not heavily colonized. There is a current from the south. We just moved over a small depression in the sheet flow, there is a lot more sediment cover here, approximately 90%, just a little bit of flow-folded sheet flow coming up through the sediment. There are a few holothurians, mostly the purple variety, one with the spikey legs. I can see a nice collapsed roof on a lava lake, the collapse is about 2 m deep.
17:11	3351		S	We are going to head 045° to the eastern bounding scarp. We are about 3 m off the bottom which drops off to the starboard, flow-folded broken rubble sheet flow. I've seen one collapse pit. Sediment cover outside of the collapse pit is about 10% or less. Not much in the way of glassy surfaces. Now coming over another collapse pit.
17:12	3353		S	Still over folded sheet flow terrain, thin sediment cover. Rugged bottom topography with 5 m or more of relief. We're now coming over a fairly deep collapse pit off to the starboard, about 3 m deep. The bottom of the

Time	Depth	Hdg°	Obs	Comments
17:13			S	collapse pit is nearly 100% sediment covered. There are a few holothurians and brisingids on the basalt. Still traversing sheet flow basalt. There is a large whitish fish, not a rattail, about 75 cm long. There are a few brisingids, and a few brittle stars, but not a lot of life here.
17:15	3354	052	P	Collapse pits, brittle stars, large bottom fish, holothurian.
17:15	3352	050	S	We're coming to a large sediment-covered ridge, coming out of the broken sheet flow. There is a large fish sitting on the bottom. This is just a mound of sediment, but the sediment cover is increasing as we move on a heading of 050°, heading for the east scarp. There is about 30% sediment cover now. Still a very rugged topography, lots of blocky broken sheet flow.
17:16	3351		S	Still over sheet flow and broken sheet flow. Still a very rough topography with 1 x 2 m elliptical piles and mounds of sheet flow.
17:17			S	Just changed to lobate sheet flow, large lobes, some quite elongate. Lava flowed down the slope we're driving up. Still about 20% or more sediment cover and not fresh glass.
17:17	3350		S	Still over large lobate and elongate pillows, becoming more pillow-like than sheet flow-like now. I can see a little bit of reflection from them. They are about 1-2 m across, several meters long. Some of them have an expanded bread-crust texture. Sparsely populated with biota, just a few brisingids, rare stalked sea pens and brittle stars, and a few sponges.
17:19	3349	052	S	Back over broken sheet flow, out of the more lobate sheet flow that occurs on the more irregular slopes, as opposed to the smoother slope that had the sheet flow. A lot of whitish mud, especially on the undersides of some of the pillows, it almost looks like bacterial mat, there is no indication of the flow of any water, there is just the whitish fluff under some of the pillows. There is a galatheid crab here.
17:20			P	New heading 280°, 200 m to target. CFTM hung-up.
17:20	3350		S	Changing heading to 280° to head back to the high heat flow area.
17:22	3351		S	Over variably broken sheet flow and some lobate pillows, elongate down slope, somewhat collapsed. There are several sponges, some brittle stars.
17:22	3348	283	S	Increasing sediment cover to about 80%, I can still see exposed rubble, a holothurian, some asteroids. Our heading is 283°, we're going back towards the high heat flow site based on surface navigation.
17:22:00	5551	283	E	Partially sediment-covered broken sheet flow.

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Time	Depth	Hdg°	Obs	Comments
17:23	3348	284	S	Over very large lobate pillows now, 2 m across, sediment dusted, but I can still see some glass occasionally. They are expanded, good expansion cracks. Moving down a slight slope heading 280°. As we move down the slope we see more lobate flows with lobes elongate down the slope. Now crossing a slight fissure, only 1 m or so deep, it does not extend very far. Another fissure coming up. Some good striations to the pillows.
17:24	3353	280	S	We are coming down a slight slope. The terrain is large, flattened lobate sheet flow. As the relief on that goes down, the amount of sediment cover goes up.
17:23			P	Galatheid crab, pillows, sheet flows.
17:25		283	P	Rattails, starfish, anemones, very rough terrain. Sediment ponds in collapse pits, holothurians up to 6 in. [inches]
17:25	3356		S	Picture taken of a fan-like sea pen on lobate sheet flow. We are over a collapse pit 2-3 m across and 1 m deep now. The bottom is sediment covered, there is a galatheid crab on the bottom. Climbing up over broken rubbly sheet flow.
17:26	3355	283	S	Still over broken sheet flow. There are occasional piles of sediment and occasional blocks of mudstone just sitting on bottom here, clearly material that has flowed down off the scarp and been deposited here. There is a small fish below me about 20 cm long. We just passed a ridge with a lot of brisingids on it. There is a large rough outcrop of basalt with several brisingids and sponges. Taking a picture of that.
17:27	3357		S	Still broken sheet flow with some heavy sediment cover in pockets, almost completely sediment covered in the low spots. Some holothurians down in those areas, mostly asteroids, brisingids and a few sponges in the areas that are not heavily sediment covered. I can still occasionally see a block of mudstone which has flowed down the hill.
17:28	3357		S	Over a sediment-covered pocket, I can still see broken sheet flow out in the distance, sediment cover is increasing, not too much bioturbation. There are a few anemones in the sediment and a few holothurians.
17:29	3358		S	Over low relief flat sheet flow now. It looks heavily sediment covered, but it has very low relief, there is some nice flow folding of the crust, it is a flat smooth terrain.
17:30	3356	261	S	We're heading to the heat flow target. Just passed over a smooth folded sheet flow terrain and now we're over a totally sediment-covered bottom, which is dropping off slightly to starboard. I can just barely see some folded sheet flow below it, it is not well colonized

Time	Depth	Hdg°	Obs	Comments
				by animals, but there are a few holothurians, some brittle stars and some anemones, and sponges on the outcropping sheet flow.
17:31	3358	262	P	Sediment-covered area, cross small ridge, large shark, collapse pit.
17:31	3359		S	Just passed over a spiked holothurian, this one, as opposed to most of spiked holothurians, was a light purple and not a white one. Most of the holothurians I see on this flat sediment-covered bottom are the flat, dark purple holothurians; there are several in the field of view.
17:32	3360		S	Over very low relief sheet flow, almost totally covered by sediment here, in fact now totally covered by sediment, sparsely populated.
17:32:30	3360		S	There is some flow folded sheet flow outcropping now with a galatheid crab on it, some small cascade folds formed as it flowed down a small slope, some of the crust is broken up and platey. There are some sponges and sea pens, some asteroids and another galatheid crab. There is a large fish in the water, about 50 cm across.
17:33	3359		S	Just passed over a ridge of broken, folded sheet flow and now back over smooth sediment. Heat flow target 260°, 130 m. We are coming over another area of broken, folded sheet flow. The low areas between these ridges of broken folded sheet flow is ponded sediment. There is sediment which looks like it has been sloughed off on to here from the scarp on the east, not just pelagic sediment, but blocks of mudstone.
17:33:00	3359	261	E	Sediment-free broken sheet flow.
17:35	3359		S	Going back and forth between folded sheet flow and sediment-buried folded sheet flow. A little bit of a fissure here, a crust of collapsed sheet flow, exposes a bit of sediment as it fell off, a nice ridge of folded sheet flow. A few holothurians, not much in the way of stalked animals.
17:36		239	P	Sheet flow (target ~100 m away). Not a good area for heat flow.
17:36	3360		S	Coming up over another small hill a few meters high of flat and platey sheet flow sticking up slightly above sediment-buried sheet flow.
17:37	3360		S	Now over sediment pocket, I can just see some sheet flow in the distance. A very large white non-rattail fish on the bottom here about 1 m long.
17:38		202	P	Sheet flow, ropy, dusting of sediment. White crust on sediment. Heat flow target area.
17:38	3359		S	We are over an area with a lot of lobate and flat sheet flow going into a steeper slope that is covered with

Time	Depth	Hdg°	Obs	Comments
				broken and folded sheet flow talus, fairly rugged topography right here, and therefore thinner sediment cover.
17:38:00	3360	203	E	Folded sheet flow.
17:39	3356	198	S	Still over broken sheet flow with local areas of ponded sediment, no thick sediment cover. I see 3-4 galatheids at the moment. Now over a sediment ridge on sheet flow, the sediment is thicker as we move this way.
17:40	3355	196	S	We are over increasing sediment cover on buried folded sheet flow. The surface reports that we are at the site of the high heat flow measurement.
17:40:00	3355	193	E	Predominantly sediment with sheet flow.
17:41	3356		S	There is irregular mounded relief, all sediment covered. Steeper slopes have some mudstone talus on them.
17:41:00	3353	166	E	Hummocky sediment-covered bottom.
17:42	3352		S	Folded broken sheet flow crust, partly sediment covered. I've seen a nice wine goblet glass sponge.
17:42:00	3352	061	E	Bright white "organic" patches on sediment.
17:43			P	Thin sediment cover over sheet flows.
17:44:00	3355	213	E	Ring of bright white "organic" material in sediment, some basalt(?) showing through sediment with asteroids and tunicates.
17:45:00	3356	188	E	Slabby sheet flow in sediment with bright white patches.
17:46	3555		P	"Crust" is only debris on surface of sediment.
17:47:30	3356		S	We are over a little white circle of small fine pebble-sized fragments, they almost look like they are shell fragments. We thought it might be hydrothermal activity, but there are no signs that it is either bacterial mat or any hydrothermal sediment. It is sitting on top of the other sediment, it has been dropped there by something. I took one picture of it with the hand held [camera].
17:47	3353	030	S	From the heat flow site we are going to transit over the high heat flow area toward the eastern scarp.
17:48	3354		S	Took a picture of a large white fish on the bottom. There is an even larger fish similar to it up in the water column, which probably won't be in the picture. The fish was almost 1 m long, but had a very white reflective head, more reflective than the rest of the body. We are over a rough, flow-folded and fractured sheet flow terrain with mounds and piles of flow-folded sheet flow. There is quite a bit of relief. There is a small shelf of white material between two sheet flows. Rather odd, it looked like indurated sediment, I see a little bit of glassy shine on some of this sheet flow.
17:49	3350	031	P	Head for scarp.

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Time	Depth	Hdg°	Obs	Comments
17:49	3355		S	Still over broken rugged sheet flow with pockets of sediment in between, some crabs, a few sponges and some starfish, a few brisingid, but not heavily colonized.
17:50	3357		S	Over flow-folded sheet flow, very rugged broken surface, pretty rugged topography with mounds of a few meters of relief.
17:51	3359		S	Still over flow folded sheet flow. Right now we're over a sediment pocket, the relief is a little lower, and the sheet flow is a little flatter here, but generally over rugged terrain.
17:53:00	3360	030	E	Folded sheet flow.
17:53:30	3359	030	S	Moving over folded sheet flow with intermittent ponds of sediment in between in the low spots.
17:54:47	3358		S	Over sediment -covered sheet flow. There is a large fish right below me about 50 cm long, a couple galatheid crabs back there, a few holothurians, not well colonized.
17:55	3360	032	P	Sheet flow terrain. Occasional pictures for Cindy and Fred. Talus/fissured dome.
17:56:00	3360	030	E	Folded sheet flow.
17:57	3360		S	Over sediment-covered bottom now, just passed over some exposed flow-folded sheet flow, but now over totally sediment-covered bottom. A few meters of relief, rather moundy, but relief is getting a bit smoother as we head northeast.
17:57:00	3360	032	E	Flat sediment covered bottom.
17:57:41	3360		S	Moving out of the sediment-covered pond back into exposed flow-folded sheet flow again, fairly low relief, slabby, slightly broken, nice pahoehoe like sheet flow, trying the hand-held video.
17:59	3358		S	Over a sediment-covered pond between flow-folded sheet flow.
18:00	3355		S	Changing heading to 060° to head more to the east to climb up this scarp to take a look up there. We are moving over a sediment-covered area right now.
18:01	3355	063	S	We are over a totally sediment-covered bottom now which is sloping up to the starboard side.
18:02	3356		S	Coming up a slope of about 10° which steepens up ahead of us. It is shingled with thin sheet flow basalt, but nearly totally sediment-covered due to the low relief of the basalt.
18:02:00	3357	061	E	Sediment-dusted slabs of sheet flow.
18:04	3355		S	We are over fissured thick basalt flows with a thin sediment cover. Taking several pictures. Very extensive set of fissures, 50 cm wide, a bit of whitish material in them, but no real signs of hydrothermal activity or bacterial mat, but a good set of fissures going through the basalt here.

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Time	Depth	Hdg°	Obs	Comments
18:05	3357		S	Still coming over broken sheet flow with a lot of surface cracks and some white staining, there may have been a little water coming up here at one time, it is not real obvious, nothing clearly hydrothermal and no animals. Taking a picture of fractured and slightly stained basalt.
18:06			S	Just came over a dome, the area of the fractured basalt had an almost vertical side. It was about 3 m high and came down into a sediment-covered plain. It may have just been a uncollapsed lava tube, but how it chilled its' sides is beyond me.
18:07	3363		S	Over a sediment-covered area, but there is shingled sheet flow coming down the slope to the port. We're moving slowly up slope here. There is a 50 cm fish out there.
18:08:00	3363	061	E	Sediment-buried folded sheet flow.
18:09	3359		S	Still over sheet flow with a lot of sediment cover, occasional tubular pillows, just passed over a sea fan, a real sea fan, not a fan like sea pen. There are a couple of the spiked holothurians down on the sediment-covered bottom. Now we are coming over some elongate pillows, no glass seen here.
18:10			P	Alternating sheet flow/pillows. Sediment in lows.
18:11	3358		S	Just came across some basalt talus and we are moving up a sediment-covered slope. A few legged holothurians and a purple urchin on it.
18:11:00	3358	062	E	Sediment-covered bottom.
18:12	3360		S	Over a broadly hummocky terrain, just passed a very large creature in the water the size and shape of a holothurian, but with a lot of little appendages, swimming along off the bottom, it was light pink in color, it was about 15-20 cm long, swimming a couple of meters off the bottom.
18:13	3355		S	Just passed several large holothurians, took a picture of a purple holothurian that was trumpeting with some appendage on one end.
18:13	3351		S	We are coming up a very steep, completely sediment-covered slope, with furrows from down slope movement of sediment cut through it. The furrows are only a few cm deep. We are still climbing up this slope, it is a slope of about 80°.
18:14			P	Large amount of debris in water column, going up sediment-covered hill.
18:14:30	3343	061	S	Still coming up this completely sediment-covered scarp with small channels and grooves cut by debris coming down, no real talus deposit at the bottom.
18:15			P	Arrive at scarp, all sediment covered, slope becoming steeper uphill (70°), water murky, current from the south.

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Time	Depth	Hdg°	Obs	Comments
18:15	3336		S	Some larger channels. Now I can see channels that are several meters to almost 10 m across and several meters deep cut through by mass-wasting processes going down this steep scarp.
18:16	3329		S	Still coming up a scarp, it has flattened off a little here, but there are some deep channels with steep sides with a bit of exposed mudstone, and some mudstone talus.
18:16:44	3328	062	E	Narrow ridge or fissure in sediment, slight uplift of semi-indurated sediment.
18:17	3321		S	Still coming up a steep scarp, but all sediment covered. The scarp here is about 70°.
18:17:30	3324	062	E	Sediment-transport lineations down steep slope.
18:17:45	3318	063	E	Top of sediment scarp.
18:18:44	3312		S	The slope has flattened down to about 20°, still sediment covered, we appear to be about at the top of the scarp. There is some bioturbation.
18:19:45	3307		S	On a sediment-covered slope. Just passed two nice purple pyramid urchins. They were within a few centimeters of each other, they were about 15-20 cm across.
18:20	3306		P	Reached bench on slope, 50 m up slope, whole slope is sediment covered.
18:21	3305		S	Changing heading to 280° to head to the top of the small hill with transponder 6 on it, heading for target C which is about 1200 m away. The slope here is gentle, about 10°, all sediment covered, sparsely populated with animals. We are about to start heading down scarp.
18:22	3309	283	S	We are about 4 m off bottom. The bottom is dropping away in front of us as we drop off the scarp. Some slight steps, but the slope is only about 20° here and steepening as we go down.
18:23	3337		S	Just re-established bottom contact off the scarp, there are intersecting steps on the scarp, the main one is heading perpendicular to our heading of 280°, but another one is trending at 45° to that, it is just a small bench that drops off on the main scarp, which runs north-south with a slope of about 30°, all sediment covered.
18:27	3343		S	Still moving along the scarp. I can see a small debris slide which has moved about 4-5 m down this 30° slope, a little talus apron right in front of it, a little slump. The flow stopped on a flat bench in the sediment. Our altitude is 10 m.
18:28	3351		S	We are about 6 m off the bottom, smooth flat sediment covered, a couple of holothurians on it, a couple of brittle stars, and a few stalked sea pen-like animals.

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Time	Depth	Hdg°	Obs	Comments
18:29	3356		S	We are near bottom, smooth flat sediment covered. A few lighter patches where bioturbation has brought up lighter, less oxidized sediment. Some holothurians and brittle stars, but poorly colonized. Somewhat hummocky topography, but mainly gentle swales.
18:31	3357		S	Hummocky sediment-covered bottom sparsely populated by the normal biota.
18:32:30	3359		S	Flat hummocky sediment-covered bottom with the normal biota.
18:33 to 18:54			S	Data not logged on voice tape; observing through the forward port-hole.
18:33	3356		P	Bottom of scarp, head for hill with transponder
18:41			P	Holothurians, starfish, crinoids, lobate pillows, "No nontronites though".
18:44:00	3361	275	E	Sediment covered sheet flow.
18:45	3360	263	P	Pillows, collapse pits; still camera set on 1-2/min for most of dive.
18:50	3361		P	Traverse to hill, sediment-covered area, occasional areas of possible hydrothermal staining (but may just be weathering). Water is quite murky.
18:55	3354		P	Old weathered sulfide deposit, thick sediment cover.
18:55	3354		S	Looks like we are in an area with a large and old sulfide deposit here. I haven't gotten a good look at it yet. We are going to try to sample it.
18:55	3353		S	We drove through an area of hummocky sediment-covered terrain. We have a lot of outcropping massive sulfide, old weathered material. It is brownish, there is a large mound off to the starboard side. There is not much iron oxide weathering on this stuff, it looks rather odd.
18:55:45	3353	291	E	Semi-indurated mudstone talus on edge of sediment channel.
18:56	3353		P	Sulfides protrude through sediment, stop to pick-up "sulfides", blocky material, switch on Osprey [camera]
18:56:45	3353	283	E	Altered(?) baked(?) indurated sediment at top of channel margin.
18:57	3353		S	We are on the bottom, just took a picture of a stalked anemone.
18:59			P	No footage previously as side arm not operating. Sampled 3 small pieces from a larger piece of basalt "with some sulfide", all on video. Ralph [pilot] rearranged water-sampler in basket.
18:59	3353.5		S	We are sampling massive sulfide (actually basalt). I can see sparkly sulfide in the water (probably mica flakes from turbidite stuck to basalt) being stirred up by our sampling attempts.
19:02	3354		S	Just taken a sample of basalt which is covered with sulfide. I can see sediment with sulfide in it here.

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Time	Depth	Hdg°	Obs	Comments
19:04	3356		S	Sampling, we grabbed a large piece of basalt which was covered with sulfide, and broken off several pieces; Two grapefruit -sized pieces are in basket 6 and small orange-sized piece may be in basket 10 [sample 2034-R-1]. We are in a fairly large sulfide field, I saw it as we came in, it goes uphill to starboard, down hill to port side. It goes several meters up hill. It is very odd looking, it does not look like what I've seen before, it is browner and finer grained, it almost looks like basalt talus, but there is plenty of sulfide around. Up the hill is a massive mound with some projections. We are going to try to work around to the other side of this mound and come up to the top of it and take a look at what is up there.
19:07	3354		S	We are lifting off from the sampling site and are going to traverse around here. There is a lot of sediment on the outcrop. It is white, but it does not look hydrothermally altered, it looks like mudstone. There is a small orange shrimp, some crinoids and brisingids, starfish. Most of what I can see immediately below me looks like altered basalt, but there is clearly plenty of sulfide around here as well.
19:08	3353		S	We are making a big turn and should come back up the ridge which is only a few meters above us at this point. We are in a little sediment-covered swale which is between massive sulfide on either side of us as we make the turn. I see mostly talus, it looks like a mound about 4 m high at most, maybe 3 m high. There is a lot of rubbly material on the surface, we are going to go look at the top of it.
19:09:00	3353	023	E	Basalt breccia in sediment.
19:10	3353		S	Still looking at this talus, it still looks like a ridge of altered basalt with some sulfide on it. I'll take a few pictures here as we try to look at the top of this ridge.
19:13	3356		S	Waiting for the water to clear.
19:16	3351		S	We are going to make a pass by the top of this sulfide mound, I'll try to take several pictures. It has a lot of sediment on it. I can see the tracks where the sub was sitting. Fairly irregular toward the top, it looks rather weathered and rounded, and knobby. I don't see the basalt that we saw before, it looks like mostly sulfide up here now. Out in the distance in the swale between the two mounds, I can see truncated pillows and broken sheet flow. Right below me is a projection about 1 m high. It looks like flow-folded sheet flow that just has a surface coating of alteration on it. Right in the sediment-covered swale there is a fissure going through, sediment covered, it could be just a collapse, but a bit of a rift through there. Another peak coming

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Time	Depth	Hdg°	Obs	Comments
				up here. A very steep side to this construction, which is about 3-4 m high. It is not clear how much of it is basalt and how much is sulfide.
19:19	3357		S	We are going to head 235° about 300 m to the target at the top of the hill. Still in the area of this sulfide construction. The base of it is a mounded sediment terrain. Completely sediment covered, the sides of it are very steep, rubbly looking.
19:20		240	P	Gully to port as make way uphill.
19:20	3358	239	S	Moving up across another part of a pinnacle on this constructional mound, it looks like a bunch of slabby sulfide, weathered back, somewhat weathered out. Now we are coming over what looks like a big deep collapse pit that is completely sediment covered, or a channel of some sort. A bit of mudstone exposed in the sides. In the distance is a large galatheid. Hummocky sediment-covered terrain with occasional small protrusions of what looks like sulfide, and out in the distance, some more sheet flow. Still over this sulfide field, but there is some sheet flow exposed as well. When you get real close you can see there are some very small chimneys, several cm high at most, sticking up through the sediment. A lot of sediment cover now, we're starting to lose the outcrop. Well out in the distance I can see more exposed rock, but it is too far away to identify. We are going to move toward the target, because this is old stuff and we don't see any signs of hot water here.
19:21:00	3357	239	E	Hummocky sediment-covered bottom.
19:22	3357		S	Well off to the starboard at the edge of my field of view is another low mound of sulfide with very steep slopes; I assume it is sulfide, it is rubbly, it is off the edge of my field of view and is hard to identify. The terrain here looks very similar to the terrain seen on [ <i>Sea Cliff</i> ] dive 659.
19:23	3359		S	We are dropping down as we head for the target, coming off this edifice which had several smaller mounds on top of it. The slope is flattening out a bit. It is mud covered with a bit of mudstone talus sticking out here and there. A few holothurians and a few anemones.
19:23	3363		S	There are a few isolated little chimneys coming up out of the sediment again, rather old, pretty much sediment buried, just barely sticking up through, mostly a hummocky sediment-covered bottom.
19:24	3366		S	Transiting along smooth sediment-covered bottom, somewhat hummocky, we still have a current from the south to the north. Small jellyfish in the water, just

Time	Depth	Hdg°	Obs	Comments
19:26	3364		S	passed a rattail fish. There is a bit of exposed mudstone on some of these mounds, but not much.
19:27	3365		S	I'm on a sediment-covered bottom, there are some rocky outcrops coming up on the left.
19:27	3362		S	Just passed a little area of broken sheet flow on my side, some pillows on the other side, still mostly sediment covered.
19:27	3362		S	Coming up a steep sediment slope with some down-slope movement and grooves on it.
19:28			P	Approaching steep slope, Ralph "bored" with "all this active sediment", whole area sediment covered to port.
19:29	3351		S	Sediment-covered bottom, very highly channeled, now coming up on some outcropping sulfide. This is rubbly sulfide, very old and weathered. I see some iron oxide underneath it. Let's keep cruising because this is old stuff. Above the sulfide was some mudstone talus. There was a venus fly trap on there and some other anemones. It was not too large a mound, I saw a few little dead chimney-like projections, rather weathered back.
19:30	3356		S	Very hummocky and channeled sediment-covered terrain, a couple of brisingids on it, some bioturbation, a fairly deep channel, deeper than I could see to bottom, probably on the order of 8 m, I can't quite see the other side. Rather irregular, rough topography here (for being) totally sediment covered.
19:32	3355		S	Still in sediment cover, there is a little scarp below me, about 1 m high, it leads down to another, more rounded channel. I can see mudstone talus around, there is a small outcropping of something with a big venus fly trap on it. This could all be mudstone talus.
19:33	3356		S	Moving up on a ridge which bounds a channel. On the edge of the ridge I can see again what appeared to be outcropping sulfide, although it was under the sub, just a small outcrop of old stuff. Most of what I see on the other ridge which is coming into view is sediment talus. There is a nice orange shrimp right outside the window. At the end of this ridge there is a lot of outcropping rock. Too far away to see, there has been down slope movement of it. Some of it is mudstone talus, maybe all of it is.
19:35	3358		S	Channeled terrain with a series of ridges, very steep sides, I can just barely see outcropping rock on the other side. There is pushed up mudstone underneath me. Mostly sediment covered, but occasional outcrops of what appears to be old weathered sulfide.
19:37	3361		S	A very complex ridged terrain around here.
19:38	3363		P	Top of hill? Very old sulfide outcrops.

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Time	Depth	Hdg°	Obs	Comments
19:38	3365		S	Still on this complex channeled terrain, still sediment covered. We just passed something on the bottom that was very white, flat, it looked like flower petals. It was not clam shells, I was close to it and got a good look at it, it looked like paper thin white material, presumably biological.
19:40	3361	211	S	Moving up hill a little bit on a heading of 211°. I can see some debris slides, some material coming off this hill on the steeper slopes. It is not heavily colonized. There are some stalked sea pens, some anemones and some holothurians.
19:42:33	3358		S	Ridged terrain with exposed mudstone. We might touch down here; no, we are going to clear. Coming up a steep slope to starboard, one of these channels with mudstone talus exposed at the edge.
19:43	3345		P	Still not at top of hill, continuing up hill, found no outcropping of sulfide
19:44	3355		S	Still moving up irregular sediment-covered terrain.
19:45	3355	225	S	Still moving over irregular channeled terrain, some exposed mudstone, no sign of sulfide at this elevation.
19:45:23	3355	233	E	Abandoned sediment channel?
19:45:44	3354.7		S	Looking at the transponder weight, I'm taking a picture.
			S	Some comments not recorded, due to leader at end of tape.
19:46	3352	275	P	Right at transponder.
	3357	180	P	Head due south.
19:48	3351		S	We are going to head 180° and head back toward the volcanic dome hoping for sulfide. We just passed an eel-like fish which swam off rapidly after we alarmed it.
19:50	3356	180	S	Over hummocky sediment-covered terrain.
19:51	3360		S	Coming across sediment-covered bottom with some mudstone talus. Some venus fly trap anemones, on the mudstone. No signs of hydrothermal material in the talus.
19:54	3365		S	Sitting on the bottom. We are going to take a couple of box cores for Fred [Grassle]. Right out to the starboard was a 1.5 m long slug-like creature (a log) that was covered by small 1-2 cm long crabs, a very odd creature.
20:02			S	I've just taken several pictures of a log with several small crabs on it, which we are going to try to collect. We will collect a box core right next to it and a box core a few meters away from it.
20:05			P	Sampling near log. Translucent small holothurian flies through water column, like a shrimp, head looks somewhat like a slug with feelers on stalks, row of legs down each side, then neck, round mouth (Like a sucker with leg-like appendages surrounding it).

## Appendix 1

Dive 2034

Time	Depth	Hdg°	Obs	Comments
20:07	3366.5		S	We've just taken box core A which was taken right next to the log [sample 2034-BC-A]. In addition to the crabs on the log, I just saw a 2 cm long shrimp swimming around next to the log. Out the front port hole I can see two large holothurians, about 50 cm. They are both purple, but they have distinct morphology. One is fat and smooth, the other is thinner and has lots of small projections. They should show up in some of the front-looking camera shots. Still sampling the log where we took the first box core. The holothurian that was next to it just swam off. There is a fish which has come to watch this operation, he is sitting beside the sub watching. I took a picture of him, but he left when we made some noise. Picture of a purple holothurian, there is a crab next to it at the log sampling site.
20:16:04	3367	191	E	Sediment -covered bottom with <i>Alvin</i> tracks, holothurian and log in bottom right corner.
20:19			S	Just sampled the log [sample 2034]. Several of the crabs have jumped off, but there are still several still sitting on it as we jostle around with it.
20:21:00	3366	202	E	Log in manipulator.
20:29	3366.6		S	We are taking box core B about 3 meters away, slightly up hill from box core A.
20:35	3367		S	We are about to head 180° bacbc-k towards the volcanic hill. We have just taken box core B about 3 m uphill from box core A [sample 2034-BC-B].
20:37	3362	177	P	Heading south after sampling log. Box core A next to log. Box core B ~3 m away.
			P	Initially covered by sediment. Progressed across series of steps in sediment, eventually got out of sediment-covered area, progressed across lobate pillows, sheet flows then much larger pillows (no times recorded as I was driving sub).
20:37	3363	175	S	We are heading up a slight slope, sediment covered, there is some white material on Andy's side. Off in the distance I can see a whole field of venus fly trap anemones, some very nice ones. There is a little bit of outcropping rock, I can't tell if it is mudstone or not. No, there is some sulfide out here. Some old sediment buried sulfide in this area. Lots of venus fly trap anemones out in the distance, too far out to take a picture. Quite a bit of barely outcropping, small sulfide out in the distance.
20:39:30	3356	178	S	Sediment-covered bottom with some holothurians, some sponge-like round porous balls, some type of creature (xenophyophorians), some brisingids off in the distance, there are some purple anemones and a brittle star. We just passed a sea spider.
20:42	3351		S	Lots of swimming bristle worms in the water.

## Appendix 1

Dive 2034

Time	Depth	Hdg°	Obs	Comments
20:43	3349		S	Coming up on a 20° sediment-covered slope.
20:44	3345		S	Still over a sediment-covered bottom, but it looks like there is a bit of dark very fine talus on it. It is too far away to see clearly what it is.
20:46	3343	177	S	Sediment-covered bottom with some channels. The channels are 8-9 m wide and a few meters deep with rounded sides.
20:48	3339		S	Still over sediment-covered bottom with some channeling.
20:50	3337		S	Still transiting over a sediment-covered bottom with some ridges and swales. Not too much biology, just the normal bottom creatures.
20:52	3335		S	Continuing up a 5° sediment-covered slope with a few holothurians and a couple of fish.
20:54	3334		S	Picture of a rather large holothurian.
20:55	3334		S	Continuing up a slight slope with sediment cover.
20:56	3334		S	Coming up a slight sediment-covered slope.
20:59	3332		S	Over a sediment-covered bottom, coming slightly up hill.
20:59	3332		S	Sediment-covered bottom. I just got a good look at one of the white things that looks like paper, It was cone shaped and like a limpet shell that had dissolved away leaving a white inner lining.
21:03	3332		S	Still over sediment-covered bottom.
21:04	3332		S	Still sediment-covered bottom. This area has a lot of the little brown spongy mud balls (xenophyophorians) on it, several holothurians.
21:05	3332		S	Picture of a purple holothurian.
21:08	3335		S	Still heading to the south, going up a smooth slope which is stepped, it comes up and then drops back down. Our depth has not changed much in the last several hundred meters.
21:10	3335		S	Octopus sighted, no picture.
21:12	3335		S	Still sediment-covered bottom. Several holothurians, occasional fish, rarely stalked crinoids, and one or two galatheids here and there.
21:12	3335		S	Low, lobate sheet flows just coming up through the sediment. Some crinoids and sea pens on them.
21:13	3335		S	Low relief, flat and occasionally flow-folded sheet flow, and lobate sheet flow, 95% or more sediment covered, barely exposed through the sediment. Very low relief so the sediment cover is fairly thin.
21:14	3334		S	Picture of a large fish, not a rattail, about 1.5 m long.
21:14			S	Over sheet flow terrain, a lot more stalked animals. A few anemones, several sea pens, including some of the fan-like sea pens. Still high sediment cover with plenty of holothurians and asteroids on the bottom as well.

## Appendix 1

Dive 2034

Time	Depth	Hdg°	Obs	Comments
21:14:30	3334	177	E	Close-up of gorgonian on basalt in sediment, possibly sulfide crust rather than basalt.
21:15			S	I just took two pictures of a creature I've seen on previous <i>Sea Cliff</i> dives. It is difficult to describe, it looks like a bunch of ribs coming up from one stalk that lays horizontal. We are in a sheet flow terrain with some cracks in it. A lobate surface in many places. There are some nice fissures which are open only a few cm and are not too deep. I can see some glass, quite a bit of glass, but still sediment covered.
21:16:00	3335	176	E	Lobate lava in sediment.
21:17	3335		S	Picture taken of the lobate sheet flow, sediment covered, but some shiny surfaces on it. Very large flattened lobes with some fissures. Picture taken of a large, beautiful glass sponge.
21:17:00	3335	177	E	Lobate sheet flow.
21:18	3335		S	More robust lobate forms now, almost pillowed, fairly glassy, some orange shrimp, some nice glass sponges, a few holothurians, some of the fan like sea pens. There is more biota now that we have more hard substrate. (Range and Bearing from surface: 150°, 700 m)
21:19	3335		S	Some nice fissures in this lobate terrain, I'm seeing more glassy reflections now. Big robust lobes, but still highly sediment covered.
21:20	3335		S	Picture of lobate sheet flow with some white staining on it which was probably biological. It was shiny white, I couldn't tell what it was. We are still in low relief lobate sheet flow with a bit of collapse, but not much, occasional fissure.
21:22	3334		S	Lobate sheet flow, flattened lobes several meters wide.
21:23:44	3334		S	Still over lobate sheet flow with a dusting of sediment.
21:24	3334		S	Relief is getting a little steeper and there are pillows rather than lobate sheet flow. They are large, robust pillows often several meters across with cracked bread-crust texture, very typical of the pillows seen on top of the volcanic hill, toothpaste striations, elongate down slope, a few meters across, no fresh glassy surfaces can be seen here.
21:26	3331		S	Very large pillow, meters across and several meters long where you can see that far. Very robust, sediment covered, a few sponges, a few brittle stars, not too many stalked animals here.
21:28	3326		S	Still over large robust pillows. The amount of sediment cover seems to be decreasing, no glassy surfaces. Picture taken of a fish over the pillows.
21:29	3326		S	Still over pillowed to lobate flows. The slope has flattened a little.
21:32	3324		S	Still over flattened lobate flow.

## Appendix 1

Dive 2034

Time	Depth	Hdg°	Obs	Comments
21:33	3323		S	Folded sheet flow talus ridge. There are more galatheid crabs. There are a couple of galatheids on the starboard and a little more life than we've been seeing. Ralph reports from the port side that there are abundant galatheids.
21:35	3324		S	Picking up more sediment cover on the pillows, but I can see a little bit of glassy shine to them here, but fairly thick sediment cover, moderate relief, lobate to pillowed flows.
21:37	3322		S	We are in an area of flattened, but still bulbous, pillows, meters across, some toothpaste striations, and occasional trap door break-outs. Sediment cover decreasing, but relief on the pillows is increasing.
21:39	3320		S	Some large collapsed lobes, but the collapse is only 25 to 50 cm, leaving an outer shell of lobate surface. Other than that there are large, robust, bulbous pillows. Sediment cover is variable, it is thin here, but there are pockets that are thicker.
21:41	3319		S	Large flattened pillow lobes, some thick pockets of sediment between them now, but not much cover on the pillows themselves. Some sponges, for awhile there has not been too much biota on the pillows, now there are some sponges, sea pens, star fish.
21:40	3316		S	In an area of sheet flow, there is a collapse pit about 3 to 4 m across, 1.5 m deep. Still an occasional lobe sticking up above the collapsed sheet flow. There are some glassy surfaces, but the sediment cover is rather extensive.
21:42	3314		S	There is another collapse pit about 2 to 3 m across, but only half a meter deep. It is just a collapsed flow lobe.
21:44	3313		S	There are lava channels or lava tubes coming down through the pillow terrain, but they have mostly collapsed leaving sheet flow rubble between the lobes.
21:46	3311		S	Below us is a lobate terrain with some 5-6 m long, 2-3 m wide pillows, large feeder tubes.
21:48	3309		S	Lobate sheet flow, some sponges, some sea pens.
21:48	3309		S	We just passed an area with some orange iron-oxide staining between the pillows. It was very light staining, clearly an old hydrothermal effect, but nothing that was extensive.
21:51:30	3308		S	Large robust bulbous pillows with expansionary cracks. Some spalled crusts, occasionally you can see some glass buds still attached.
21:53	3303		S	Very large and elongate pillows now, the slope is increasing a little bit.
21:54	3298		S	Still large pillows.
21:56:30	3298		S	Still large pillows. You can see more glass now. Often there are small projections and buds that are totally

**Appendix 1****Dive 2034**

<u>Time</u>	<u>Depth</u>	<u>Hdg°</u>	<u>Obs</u>	<u>Comments</u>
21:59	3295		S	glass still left on these pillows, even though they are 70% or more sediment covered. Still coming across large elongate pillows and lava tubes, occasionally some of the lava tubes are collapsed, but mostly they are expansionary.
21:59:00	3295	176	E	Pillow lavas
22:00			S	Terminated dive on the pillowed volcanic hill.

## DIVE TRANSCRIPT

Location: NESCA  
 Port observer: Shanks-no transcript provided  
 Starboard observer: Palmer

Julian day: 157  
 Date: June 5, 1988  
 Pilot: Foster

Transcript of divers' voice recorders; Hdg = gyrocompass heading, Obs = observer (S; starboard, P; port, E; external photo description), comments in ( )'s are diver's comments, comments in [ ]'s are editors clarification.

Time (GMT)	Depth (m)	Hdg°	Obs	Comments
17:57	3290		S	Arrive on bottom. Sediment covered. Abundant organisms; anemones, sea cucumbers, sea pens, brittle stars. Heavily bioturbated.
18:00	3300	280	S	Flat sedimented bottom, as above.
18:01	3304	270	S	Bottom as above.
18:02	3303	269	S	Bottom as above.
18:05	3304	242	S	Bottom as above.
18:07	3301	265	S	Bottom as above, but becoming more undulating.
18:08	3304	303	S	Bottom as above.
18:08:30	3305	302	E	Sediment-covered bottom.
18:09	3305	302	S	Bottom as above.
18:10	3303	302	S	Bottom as above with 0.5 m high ridges lying perpendicular to path.
18:11	3303	302	S	Bottom as above; ridges disappeared.
18:12:45	3299	301	E	Albino pyramid urchin
18:13	3297	302	S	Bottom as above.
18:15	3294	303	S	Bottom as above.
18:15	3288	303	S	Small sediment debris slides 1-2 m across on same bottom as above.
18:16	3283	302	S	Debris slides gone. Bottom as above.
18:16:15	3283	302	E	Large starfish with webbed legs.
18:17	3283	302	S	0.5 m high ridges, ~5 m wavelength, perpendicular to path. Otherwise bottom as above.
18:18	3283	302	S	Bottom as above.
18:19:45	3284	302	E	Sediment-covered bottom, gap in photos.
18:20	3285	303	S	Bottom as above.
18:21	3283	302	S	Bottom as above with gentle slope dropping off to right of sub.
18:22	3287	303	S	Several meters off same bottom as above.
18:24	3293	301	S	Bottom as above.
18:26	3289	301	S	Bottom as above with slope steepening to right of sub.
18:27	3289	303	S	Moving over 1 m high ridge dropping off steeply to right, otherwise same bottom as above.
18:29	3290	302	S	Bottom as above with 0.5 m high ridge of outcropping siltstone.
18:30	3295	303	S	Several meters above same bottom as above without siltstone.

## Appendix 1

Dive 2035

Time	Depth	Hdg°	Obs	Comments
18:31	3300	303	S	Passing over outcrop of blocky dark brown material several meters below.
18:32	3304	262	S	On gentle, sedimented slope with some sulfide debris. Blocks up to 1 m square and 0.5 m thick. Heavily colonized with diverse biota; crabs, anemones, sea pens, sea cucumbers. Sulfide heavily covered with sediment. Sediment constitutes about 90-95% of visible bottom.
18:33	3303	168	S	Bottom as above.
18:34	3303	133	S	Bottom as above.
18:35	3301	120	S	Bottom as above.
18:36	3298	189	S	Bottom as above.
18:37	3295	166	S	Sulfide blocks becoming sparser, otherwise as above.
18:38	3292	049	S	Sulfide gone. Flat sedimented bottom covered with same characteristics and biota as described above.
18:39	3296	346	S	Lost sight of bottom.
18:40	3299	250	S	Bottom just in sight. Sulfide rubble up to 0.5 m blocks, heavily sedimented, abundant biota; crabs, shrimps, sea pens, anemones.
18:41	3304	263	S	Moving off sulfide onto totally sediment-covered bottom.
18:43	3304	188	S	Sediment-covered bottom as described above.
18:43	3303	174	S	Slope ahead steepening. Bottom as above.
18:44	3297	261	S	Bottom as above.
18:45	3291	140	S	Bottom as above.
18:46	3290	099	S	Bottom as above.
18:47	3290	180	S	Bottom as above with density of biota decreasing.
18:48	3290	326	S	Bottom dropping off steeply to right.
18:50	3297	359	S	Sediment-covered bottom dropping off steeply to right.
18:51	3302	042	S	Moving over sediment-covered bottom.
18:52	3304	023	S	Coming onto blocky sulfide outcrop. Blocks up to 0.5 m square, most 20 cm square. Bottom still heavily sedimented. Sulfide is less than 10% of outcrop. Heavily colonized with starfish and anemones.
18:54	3298	051	S	Stopping to collect sulfide sample [sample 2035-1].
18:56			S	On station.
19:11	3296	107	S	Leaving station, moving over field of sulfide debris, still heavily sedimented.
19:12	3295	042	S	Sulfide coverage diminishing and blocks becoming smaller [20 cm square and less].
19:13	3296	086	S	Moving into area of greater sulfide cover [up to 20%]. Blocks up to 0.5 m square. Heavily dusted [0.5 cm] with sediment.
19:15	3299	127	S	Stopped to sample sulfide. Glittering crystals exposed during sampling.
19:19	3298	175	S	Moving to sample different portion of outcrop. Sulfide very friable. Captured sea cucumber [sample 2035-3A].
19:24	3298	178	S	Leaving station.

## Appendix 1

Dive 2035

Time	Depth	Hdg°	Obs	Comments
19:25	3297	199	S	Heading up slope covered [up to 20%] with sulfide blocks up to 1 m across. Blocks covered with 0.5 cm of sediment in places.
19:26	3295	241	S	Bottom as above.
19:27	3295		S	Stopped to capture tunicate attached to small [20 cm square] block of sulfide [sample 2035-3B].
19:31	3295	207	S	Leaving station. Bottom as above.
19:31	3295	353	S	Several meters off bottom. Appears to be sediment covered.
19:32	3300	353	S	Sediment-covered slope several meters below.
19:33	3300	352	S	Same as above.
19:36	3316	351	S	Close to bottom again. Sediment-covered bottom with same biota and character as seen throughout dive.
19:37	3319	350	S	Same as above.
19:38	3321	350	S	Same as above.
19:40	3324	350	S	Same as above.
19:43	3329	350	S	Same as above.
19:44	3320	350	S	Same as above.
19:45	3325	350	S	Moving over series of small ridge [1 m high, wavelength 5 m] lying perpendicular to sub.
19:47	3327	350	S	Flat sedimented bottom as above.
19:49	3326	349	S	As above.
19:51	3325	350	S	As above.
19:53	3323	348	S	As above.
19:55	3319	348	S	As above.
19:57	3315	347	S	As above with steep slope dropping away to right of sub.
19:58	3315	345	S	As above.
20:00	3316	344	S	Slope flattening to right and steepening ahead.
20:06	3314	260	S	Sediment appears to contain fragments [slabs up to 30 cm square and few cm thick] of sediment breccia.
20:07	3312	261	S	Strongly brecciated sediment with blocks up to several meters across. Very little biota.
20:08	3309	271	S	Several meters above sediment-covered bottom.
20:08	3310	251	S	Sediment-covered bottom sloping off to right. Only a few galatheid crabs, no other biota.
20:10	3312	263	S	Lost sight of bottom.
20:12	3317	265	S	Sediment-covered bottom as above.
20:17	3314	263	S	As above.
20:23	3314	259	S	As above.
20:26	3305	260	S	As above.
20:28	3303	260	S	Sediment becoming more lithified. Large sulfide outcrop [several meters across] that appears to have been uncovered by slumping sediment. Mixture of sediment breccia with blocks up to 1 m across and sulfide blocks up to 50 cm across. Sulfide heavily stained with iron oxide. Loose sulfide blocks on surface appear to be underlain by more solid sulfide

## Appendix 1

Dive 2035

Time	Depth	Hdg°	Obs	Comments
				substrate. Sampled second sulfide at this site [sample 2035-2].
20:29:45	3304		E	Large massive sulfide mound.
20:30:00	3304	004	E	Steep sediment slope behind sulfide mound.
20:31:45	3301	145	E	Jagged sulfide projecting from sediment.
20:32:30	3302	119	E	Sediment-covered bottom.
20:33:00	3303	239	E	Sulfide sub-cropping on near vertical sediment-covered slope.
20:35:00	3302	204	E	Massive sulfide mound surrounded by sediment with small sulfide protrusions.
20:35:45	3302	209	E	Sampling weathered sulfide mound.
20:45	3300	273	S	Leaving station.
20:47:45	3300	243	E	Edge of sulfide deposit.
20:48	3300	243	S	Heading over sediment-covered bottom with usual characteristics.
20:48:00	3300	236	E	Sediment-covered bottom.
20:49	3297	197	S	Sediment debris slide coming in from the left.
20:49:15	3297	197	E	Blocks of semi-indurated siltstone.
20:51	3293	170	S	Sediment debris contains blocks up to 0.5 m long.
20:51:00	3295	181	E	Large blocks of semi-indurated siltstone.
20:53	3295	180	S	Sediment-covered bottom.
20:54	3295	180	S	As above.
20:56	3295	181	S	As above.
20:57	3297	181	S	As above.
20:59	3291	181	S	As above.
21:00	3286	182	S	As above with small [20 cm] blocks of sediment breccia.
21:03	3285	180	S	Same as above without breccia.
21:07	3270	182	S	As above.
21:08	3265	181	S	Climbing up steep slope of sediment breccia.
21:09	3259	182	S	As above, with "sand" in sediment giving reflections off crystal faces.
21:10:00	3252	181	E	Large sediment talus blocks
21:11	3249	182	S	Large sediment debris flow with blocks up to several meters across.
21:12	3239	181	S	Debris flow covering 30% of visible bottom.
21:12:00	3234	180	E	Outcropping indurated sediment on slump scarp
21:13	3221	183	S	As above.
21:15	3215	234	S	As above.
21:17	3211	236	S	Breccia becoming smaller with blocks now 10 cm square.
21:18	3188	231	S	Breccia becoming sparser, but underlying sediment appears lithified.
21:19	3179	235	S	Bottom as before. Crossing dredge track.
21:19:30	3178	267	E	Dredge track at top of hill.
21:20	3178	234	S	Followed dredge track to top of slope through consolidated sediment.
21:20:00	3178	258	E	Chain bag tracks in sediment.
21:21	3178	165	S	Following ridge south over consolidated sediment.

**Appendix 1****Dive 2035**

<u>Time</u>	<u>Depth</u>	<u>Hdg°</u>	<u>Obs</u>	<u>Comments</u>
21:23	3180	160	S	As above.
21:25	3167	196	S	As above.
21:31	3170	216	S	As above.
21:36	3180	162	S	Stopped to take box cores, push cores and trip water samplers [samples 2035-PC-1, 2035-PC-2, 2035-BC-AB].
22:03:32	3179	198	E	Flat sediment-covered bottom.
22:07	3179		S	Dropped weights and left bottom.

## DIVE TRANSCRIPT

Location: NESCA  
 Port observer: Zierenberg  
 Starboard observer: Van Dover

Julian day: 158  
 Date: June 6, 1988  
 Pilot: Hollis

Transcript of divers' voice recorders; Hdg = gyrocompass heading, Obs = observer (S; starboard, P; port, E; external photo description), comments in ( )'s are diver's comments, comments in [ ]'s are editors clarification.

Time (GMT)	Depth (m)	Hdg°	Obs	Comments
17:17:26	3259		P	About 3 m off bottom, smooth, flat, sediment covered. We are about 40 to 50 meters from the scarp on the west side of the 3210 m hill. We are going to get trim on the bottom and look for some sulfide.
	3259		S	On bottom, sedimented area. West of N-S scarp, heading north.
17:18	3260		S	Sediment-covered area, lots of bioturbation. Seastars, several species of holothurian, xenophyophores cover the sea floor. Started first video for this dive.
17:19	3261	070	P	On bottom. The video is recording the sonar, the sub is heading approximately 070° and the scarp is shown on the 500 m scale. Actually, the reflection does not look like the scarp, but may be an isolated sulfide structure. On the 50 m scale now.
17:20	3262		S	Sedimented rise (3 m) in front of us. Osprey video camera will be used throughout the dive.
17:21:54	3262		P	On the bottom. We are recording on the Osprey camera. Smooth, flat sediment-covered bottom. Probably a bit less habitation than I am used to seeing here. There are a couple of anemones, some of the mud balls (xenophyophores), who's name I can't pronounce, and a few holothurians.
17:26	3260	000	P	Flat sediment-covered bottom with a linear drop off which is trending a bit west of north, it drops down about one meter. Smooth sediment-covered bottom which is sparsely colonized. There is a stalked crinoid, some anemones, an orange holothurian, some mud balls, a purple holothurian is swimming by in the water column.
17:26	3259	005	S	Moving along N-S ridge. Brittle stars abundant, xenophyophores, large urchin, pycnogonid, anemones. Holothurian feeding on a squid(?).
17:28	3259		S	Still on soft sediment.
17:28:31	3259		P	Coming up to a small sediment-covered scarp. Setting the external camera rate on 30 seconds because we are on a fairly flat smooth sediment-covered bottom.
17:29:41	3257		P	Flat sediment-covered bottom, a few holothurians, a couple of brittle stars, and one anemone.

## Appendix 1

Dive 2036

Time	Depth	Hdg°	Obs	Comments
17:30	3256		P	We are on a flat sediment-covered bottom with a series of low ridges and channels. A lot of them are parallel to the north-south sediment scarp, but some of them curve around. We are now crossing one that runs east-west. It looks like a debris flow channel cut into the sediment.
17:30	3256		S	Shallow dips in the sediment; looks like dunes.
17:31		090	S	Change heading to east. Brisingids lying in sediment with arms straight out; one specimen with two arms buried beneath the sediment. On hard substrates, brisingids sit with their arms reaching up, forming a cup.
17:32	3256	054	P	Moving over channeled sediment-covered bottom. There is a rattail fish on the bottom. There are gentle swales and channels here, probably sediment erosion channels, that are 1-2 m deep at the most. There is not much mudstone exposed by the channels. You can see that they are sinuous, are curved in places, they all most seem to be meandering, although it is hard to see that on the side scan [sonar].
17:32	3255	056	P	We are starting to come up a slight hill as we have changed our heading to 056°. We are heading for the small scarp that is to the east of us, which we will climb up. We are still going over small ridges and channels. Several holothurians here, but other than that the bottom population is rather sparse.
17:32			S	Beer bottle.
17:33			S	Continuing over sedimented area with 1 m or less undulations.
17:33:00	3256	056	E	Sediment covered bottom.
17:34	3253		S	Sediment.
17:35	3252		S	White clam shells.
17:36	3247	056	P	There is some thing below me I can't identify, it is very long, it almost looks like a stick laying in the sediment, partially sediment covered. There are some clam shells over here although we are on a smooth sediment-covered bottom. We will keep our eyes open and hope.
17:36	3247		S	Altitude 11-12 m; 30-40 clam shells. Looks like they're empty, lying on the surface of the mud. Holothurians also present. On a steep rise. Galatheids up the slope. Sediment is mottled.
17:37	3240		P	We are at the east scarp, it has a slope of about 30°, smooth and sediment covered, some evidence of down-slope movement on it.
17:37	3237			
17:38			S	Near top of slope.

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Time	Depth	Hdg°	Obs	Comments
17:39	3227	065	P	The ridge changes direction here and runs east-west. Coming up the scarp, it is smooth and sediment covered, somewhat inhabited.
17:40	3218		S	On top of rise.
17:41	3217		P	Changing heading to 020° and we will head for target B which was the sulfide mound at the end of dive 2033. Over smooth sediment-covered bottom, it is dropping off gently to the port side. Not too much biologic activity, a few brittle stars and some holothurians, a little bit of burrowing.
17:41	3217	020	S	Change heading, toward target "B".
17:42	3219		S	Shallow depressions in sediment surface.
17:42:30	3218	020	P	Flat sediment-covered bottom, some very gentle channeling in it. There is a galatheid crab out to the side, a small rattail fish. I see the other side of the channel now. The channel is about 4 m wide and only 1-2 m deep. The side we are headed toward is actually about 3-4 m high, so the channel is highly asymmetric. The wall actually appears to be curved. A little bit of subcropping mudstone, it does not actually outcrop on the channel wall, but is completely sedimented over.
17:43	3216.5		P	Coming over a near vertical scarp, about 80°, dropping straight off to our heading at 020°, all smooth and sediment covered. I can't see the bottom of the scarp. I can barely see one white animal way down there. I can't read the altimeter at the moment, but it looks like it is about a 6 m drop. Our depth is 3216.5.
17:43	3216		S	Large steep slope down.
17:43:30	3216	019	E	Drop-off, sedimented bottom.
17:44		020	S	Heading down slope.
17:45	3222		P	We are swinging around to the west to look at a side scan target which looks slightly different than the ridges we have been seeing on the CTFM. I'm going to switch the video back to the Osprey. The scarp we are coming down is stepped, it had a steep top, about 80°, it then leveled off to about a 20° slope, and then it drops off again. It is cut into by some channels which trend down perpendicular to it. Smooth sediment covered and not well colonized.
17:45	3224	270	S	Begin chase to CTFM target to west. Has sonar image distinct from local terrain.
17:47	3229	270	P	We are over a rather deep channel right now which comes down the scarp.
17:48	3230	350	S	
	3334	262	P	Coming over a sediment-covered channel again. Heading towards a sonar reflector.
17:50	3226		P	There is some outcropping sulfide. Ralph [pilot] sees a chimney in front of us.

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Time	Depth	Hdg°	Obs	Comments
17:51			S	Sulfide mound.
17:51	3236		S	Top of sulfide mound.
17:51:30	3236	243	E	White material on edge of hydrothermal mound.
17:52	3235		P	We are at the base of a sulfide mound. I can just barely see bottom on my side. There is a report of warm water, and I couldn't be more pleased.
17:52			S	Shimmering water; white discolored substrate. No animals, barren. On lip of hill. Down below, chimneys.
			S	Benthos and hand-held photos as we move over the bottom. Numerous white gastropods (limpets?) on sulfides. Galatheid crabs, tube worms, anemones present.
17:53	3238		P	We are coming down on a sulfide edifice. I can just barely see out my side some large blocks, they look rather sediment covered and eroded. There are a lot of white creatures colonizing it, I can't really see them. They could be tunicates, I see some galatheids. Taking pictures, I see shimmering water coming up and tube worms. It looks like anhydrite. Some nice tube worms here, anemones, some limpets in with the tube worms. Bottom temperature is still 1.6°C.
17:53:00	3237	247	E	Massive sulfide mound.
17:54:00	3238	261	E	Tube worms on massive sulfide mound.
17:55	3235		P	Looking over a large mound structure. It is about 4-5 m high, it has several chimneys, only one of which I saw was active, most of which are plugged. (To pilot: I don't see any shimmering water below me. You are going to come into view of it, but it is going to be down several meters, it may be too low for you to see. It is going to be hard to sample that one. There is diffuse flow out of the top of the chimney, there is no smoke, just shimmering water. I'll try to take a look below you to make sure there is nothing hot down there.)
			P	I've got a good view of the bottom now. There are several tube worms, most of them at my level are dead. In front of us is an active chimney. Shimmering water is coming out, but not smoke. There are live tube worms above that. I see several galatheid crabs, some tunicates or something which looks similar to tunicates. There is a little bit of shimmering water coming up out in the distance seeping out of the mound. I'm going to put the data frame on the Osprey for a minute.
17:55	3235		S	Working the sulfide area. 5-6 shots on benthos camera, 3-4 shots on hand-held [camera] of small area of tube worms with shimmering water.
17:57			S	Back up on mound. More benthos shots. Jumbled, fractured sulfides. Sea star, venus flytrap, tube worms. Polychaetes stirred up into water column by the props.

Time	Depth	Hdg°	Obs	Comments
				Ralph's working the smoker. Tubeworms out fore and port. Temperature probe in vent.
17:57:22	3235	182	E	Chimney at top of mound.
17:58:08	3239	178	E	Active vent on the flank of the mound.
17:59	3238		P	We are sitting on the side of a large sulfide edifice with mostly dead tube worms at my level, but live tube worms at the top where the shimmering water is. In the distance there is a bit of leaking shimmering water. The surface is iron-oxide coated, actually looks very white, most of it looks like barite, it is rather porous.
18:01	3239	180	P	We are on bottom and are preparing to take some temperature measurements on some shimmering water. My hand held camera setting is on 17. Most of the pictures have been shot in rapid succession, some without waiting for the strobe to recharge. The sulfide deposit is rather porous at the level I can see with mostly dead tube worms and white porous material which I believe to be barite. There is some iron staining. A lot of what we came over as we came into this area was darker and looked like sphalerite or pyrrhotite. There were several areas where shimmering water was leaking out. A few rather porous chimney tops leaking shimmering water. Beautiful shot on the Osprey of shimmering water coming out of a chimney top.
18:04	3239		P	Still taking temperature measurements. As I look forward toward the active part of the chimney, which rises up above us, the color goes from a white porous barite to darker material which I believe to be sulfide. There is some iron staining on some of that sulfide. As we drove in, around one of the orifices which was emitting hot water there was very white material which I am almost sure is anhydrite and not barite. It looked different, very clean and white, and had very hot water coming out of it. The animals I see are predominantly tube worms and some thing that is similar to a tunicate, if not a tunicate, some kind of flow-through material. There are some anemones on the cooler part of the chimney, and some things that look like sponges, although they may not be. Out in the distance is some shimmering water coming up about 2 m away. I'll take a picture of that, which should be frame 18 or 19.
18:06	3239		P	Taking temperature measurements, they average somewhere between 80° and 90°[C]. Rather diffuse flow out of the top of the chimney. We are going to poke around a bit a see what the range of temperatures is. Temperature readings are as high as 115°, now they're dropping down to 105°, 115°[C] was about as high as I saw. As we stuck the temperature

Time	Depth	Hdg°	Obs	Comments
				probe into the chimney we picked up a little black smoke, it could have just been particulate, knocked off the chimney, yes, it is just particulate.
18:06			S	Temperature probe on Osprey. 214° C, 220°C.
18:09			P	Temperature reading of 220°, which is steady.
18:11			P	Last picture taken looking down on a slab of what is clearly sulfide. It has broken off and fallen down on top of the mound, which appears to be barite. There are some little barite chimneys. The slab has fallen on the tube worms, which are all dead at this level. On top of the slab are what could be snails, they could be limpets, but they look more like snails to me, an anemone, and what I am fairly sure is a sponge and not a tunicate.
18:11	3239		S	First sampling site. Setting up to sample 220°C water [sample 2036-R-1A]. Orifice is not part of a "classic" chimney structure; it is more like a hole in a shelf on the slope of the sulfide mound. Starboard side: a few scattered, small clumps of tube worms. Port side: tube worms heavily fouled by polychaetes. Sponges and anemones as well. Sulfide samples on Osprey video from mouth of 220° C vent. Samples removed to facilitate water sampling.
18:12			P	A small piece of rock has been collected from the chimney and will be placed in basket 1 next to the box core, it came from the chimney with 220° water.
18:15	3239		P	I just saw a bristle worm swimming by, about 2 cm long.
18:23			P	Rock #3 was a triangular shaped rock which came from the 220° vent, placed in basket #6.
18:24			S	Setting up for water sample. Shimmering water beneath starboard porthole. Sponges fouling tube worms. Orange fossilized? tube worms form a large part of local substrate in starboard area. (Similar material sampled on a later dive proved to be colonized by aplacophorans, ampharetids, folliculinids, limpets.)
18:26			P	We are setting up for water sampling at the 220° vent. As we moved off a little I could see more of the mound, it is pretty high with a lot of sulfide talus on it, most of what I can see is inactive. I see a large galatheid sitting on top, about 10 cm across, a few little sponges here and there, a lot of little white things which I think are snails, but they are too far away to see, I've seen a few bristle worms swim by. Not much that is active. Out the front now I can see shimmering water feeding live tube worms. They are Juan de Fuca-type tube worms. They have nice red plumes, annulations, they are a few millimeters across.

Time	Depth	Hdg°	Obs	Comments
18:30	3239		P	Still sampling the 220° vent. I see a lot of dead talus at this level which is down slope from the sulfides. Most of it looks like sulfides, but with an iron-oxide coating. I think it is probably pyrrhotite from the way it looks and how it weathers. I can't see the type of coarse-grained material that I could see to the north on <i>Sea Cliff</i> dive 658, but I can see individual crystals sparkling, fine-grained individual crystals. Out to the port is a projection on the talus, it looks like barite which has grown late, forming on the sulfide itself. There may be a little shimmering water coming out of it, but it is too far away to tell. Looking down the other side, just barely out in the distance several meters away, I can see one of the huge white fish, I can just barely make it out because of its white cheeks. It looks like is one meter long or more, I can't really tell because it is too far away. If it wasn't for the white cheeks, I wouldn't be able to see it. About the only active things I see at this stage are galatheids, I see two galatheids. There are a couple of anemones which are still alive and lots of dead tube worms. Some small white things which are probably snails, but can't be seen clearly, some sponges or sponge-like creatures which siphon water. Floating up from the bottom now is something orange, it is too far away too really see it, I assume it is a shrimp, but I can't see it well enough to really tell and I can't get a picture of it.
18:30				Up to frame 9, hand-held [camera]: fossilized worm tubes with some vestimentiferans as markers.
18:33	3239		P	Looking out the front port hole at the active part of the chimney. It is completely covered with white tube worms of the Juan de Fuca-type with red plumes. In among them I see orange colors which I can't identify. Some small orange creature which I can't identify, some small orange creature, may be like the palm worms. Above the chimney is a massive atacamite-colored green material, including atacamite-colored green tube worms. Check the comments about the atacamite, it may have been a strange lighting effect, but I can't see well enough to tell. I'll have to check on the way out from this site. Two pictures of a fish similar to the white-cheeked fish, but only about 50 cm long, swimming over the vent area, swimming slowly over the dead part. Down in the distance, I can see a white-cheeked fish of the same type that is at least 1 m long if not more, just sitting rather still, too far away for a picture.
18:34			S	Tube worms in photos may be different species? They look like they might be in cooler water and they don't

Time	Depth	Hdg°	Obs	Comments
				seem to have the annulations that are present on tubes of animals living adjacent to 220° C water. Water column is clear; very few copepod-sized organisms.
18:38			P	Correction to the earlier comment. I think the green coloration reported looking through the front viewport is a refraction effect caused by looking through the high curvature portion of the window, and is a refraction of the thallium-oxide lights and therefore is not the real color. There is an anemone-like creature on the rock, it is white bodied and it has bright red tentacles coming out of it, very similar to the colors of tube worm plumes, but the animal itself is not a tube worm. I tried to take a picture of it, but I probably did not get it. I'll try to keep an eye on it and get a picture if I can.
18:44			P	Flushing water samplers.
18:44:05			P	Tripping samplers, they are both drawing, the bottles are shimmering.
18:45			S	More pictures of starboard view; some tube worms and substrates; outside lights off, series of f-stops and focus.
18:46			P	Both bottles fully extended, still in the orifice.
18:46:42			P	Both bottles are still flushing, closed the bottles at 18:46:47. First hot water samples in bottle pair #4 [sample 2036-W1]. Bottle pair #4 has been placed in bin #6. Taking second bottle pair in the same orifice as bottle pair 2, in the same vent that measured 220° before we opened it up. The temperature was measured about 10 cm over to the left in the smaller vent. Ralph opened up a hole in the other vent to take the water samples, and we will try to take a temperature measurement in that before we leave.
18:49:00	3239	108	E	Active vent, tube worms and 75 cm-long fish in background
18:51			P	Two pictures of a small jellyfish, it is only about 1 cm high and 1 cm wide. I can't see it too well, it is purple or brown colored. Second bottle pair is in the orifice and appears to be venting. Second bottle pair is pair #3 and it is venting.
18:52:37			P	We've tripped the bottles and are taking the second samples in pair #3. The bottles are shimmering, at least one of the bottles is shimmering, the other is shielded from view.
18:53:36			P	Both arms are fully extended. Second pair closed at 18:55. We are going to try to take a temperature in the enlarged vent where both pair #4 and pair #3 water samples were taken. Temperature probe is in the same vent that was sampled by pairs #4 and #3, the

Time	Depth	Hdg°	Obs	Comments
				temperature is up to 212°, 217° and stable. The probe is about six inches in to the throat of the vent. We moved the temperature probe case out of the vents, the temperature reading was stable at 217°, but peaked at 219°.
18:56			S	Finished sampling hot water. Total of two pairs (#3 and #4) of water samples collected from 217°C orifice to right of 220° C orifice. Total of five sulfide samples collected from this area. Looking out forward porthole. Hot water flows up against a wall. No animals where it is very hot, then tube worms up 1.5 m. Definite azoic zone (at least in terms of mega- macrofauna). Water temperature: 217° C deep (6") in throat of vent that was sampled (different from 220° C vent). Water sample taken 1: into throat of orifice. [Clarification: there are two orifices adjacent to one another; one at 220°C, the other at 217°C. 217° C vent was sampled for water.]
19:06			S	Maneuvering to collect tube worms overhanging 217°C vent. One benthos shot as we moved. Vent sampled was on a small step on steep slope down.
19:06:49			P	We are moving to try to sample another vent. The barite chimney I could see in the distance was leaking hot water. I can see the bottom now, it is all sediment covered around us. This mound is a good 4 m high. I can see another mound out in the distance with sulfide talus coming off of it. When we finish sampling here we might go over to investigate that one. Our heading is 208°, the other mound is just off the port side and a bit forward. Looking down the slope here, I see very large talus blocks, 2-3 m on a side, and then a ridge, which could be either a very large talus block or a ridge, it is about 4 m. The mound is about 5 m high or so, may be more. I see several galatheids, several white things attached to the rock which are too far away to be resolved here. Not a lot of life on the dead part of the mound below the vents.
19:10			S	Osprey coverage of tube worms in vicinity of 220°C vents. We're facing 211°. Flow from vent flows in same direction, up slope. Fields of shimmering water visible.
19:10:47			P	Taking close-up Osprey pictures of the tube worms at the second site we've sampled. We took two water bottles and moved over about 2 m.
19:12			P	We've just saw a nice scan of the this chimney and we're going to move over a few meters and try to sample this second little chimney outlet.
19:14			P	Putting a sample of tube worms into the critter box. The tube worms came from the second vent we visited,

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Time	Depth	Hdg°	Obs	Comments
				the one we are going to try to sample now for temperature and water.
19:16			P	Just changed to the second video tape, I'm going to superimpose the data frame.
19:16			S	End of first videotape. Good Osprey footage of tube worms and 220°C vent. Still working at same site. Marker 0 deployed. Placed next to tube worms just above the vents. Marker is white, USGS type: syntactic foam, polypro lines and lead weight.
19:17:00	3238	198	E	Tube worms in foreground, possible 1-2 cm spheres of black hydrocarbon, blocky massive sulfide in background.
19:18			P	Another picture of the small 1 cm x 1 cm brown derby-type jellyfish.
19:20			P	Second handful of tube worms collected at the same site as the first, just placed in the critter box [sample 2036-B1]. Marker 0 deployed at 19:21 at the tube worm sampling site. The vent sampled for hot water is just out the starboard port. The tube worms are just above the water sampling site, and marker 0 is going in the same place.
19:24:00	3237	216	E	Marker 0 on massive sulfide
19:25			S	Leaving first vent site.
			S	Passing over sulfides; benthos camera shots.
			S	Alignment of mound is N-S. Continuing benthos shots, over tube worms. Shimmering water. Granular surface, tube worms along edge; just a few meters (4) north of previous site.
19:26			P	The alignment of the mound is north-south. We are heading just about south trying to sample a little porous barite chimney on the northern end of it. I'm looking at the base of the mound here, I can see an asteroid down on the sediment that is covering the base of the mound, and a galatheid crab. We are going to try to take a temperature measurement at the second vent which is roughly 4 m away from the first vent. It is on the northern extreme of this mound which has a north-south orientation. Taking some pictures of the rubble at the base of the mound, some anemones and a galatheid crab in the pictures.
19:26:00	3269	182	E	Lower vent site before sampling.
19:27:00	3240	218	E	Close-up of lower vent.
19:29	3240		S	Second sampling site. Temperature 217°C. Tube worms out starboard side look like grass.
			S	Hand-held [camera] photos: up to #22. Looking out over slope with bumpy sulfides. Ralph's trying to sample water. Starboard side: venting water devoid of animals; tube worms are down slope about .5 m.

Time	Depth	Hdg°	Obs	Comments
19:30:16	3240		P	Taking temperatures in the second orifice, up to 209°C. I've just finished shooting roll one. We are going to have to pull the probe out and stick it in again. We had a reading of 209° before we pulled it out. The probe is inserted in the vent again, reading climbing to 214°, 215°, a fairly stable reading of 216°, still climbing slowly. Stable at 216.5 now, it is just sitting there.
19:38	3240	260	P	We're sitting at the base of a sulfide mound just below a chimney. We just took a temperature of 216°. Out my window I've got sulfide talus, lots of white material on it that I can't identify, there are some anemones, but in addition to that there is some white material that is like tunicates or sponges with an opening orifice for the flow through of water. There is no hydrothermal activity down at this level. The talus is weathered brown with some white coating that apparently barite. There is a lot of white sediment around as well. Talus block are up to 2-3 m, in the distance I see some 4 m high talus blocks. Very large blocky talus. Some crystal faces showing, but mostly weathered surfaces.
19:40			P	All of the former temperature measurement were made with temperature probe 2. We are going to try to switch to temperature probe 1, due to a ground leak in 2.
19:46			P	We are excavating what appears to be a barite chimney which is porous and rubbly. A lot of shimmering water coming out, we have measured a temperature of 216°, but the flow is very diffuse coming up through the rubble and we have not found an orifice to sample yet.
19:55			S	Sulfide samples. Total of 7 pieces sampled at this site as Ralph works to open orifice of vent. Palm worms visible, hanging out in substrate; branchiae waving in the water column.
19:56			P	A grapefruit-sized piece of sulfate from the porous shimmering vent put in basket 2 [sample 2036-R-2].
20:05			P	We are going to try to swing the sub around to the other side of the porous white vent. It does not look like we will be able to get a water sample out of this one because there is too much rubble and not a large enough opening. We will try another spot.
20:06			P	We are back at the same porous vent trying to open up a space large enough to sample in.
20:10			S	End of film, 1st roll. Lots of shots of same thing at end of roll.
20:16			S	Sampling water.
20:16:44			P	We have a pair of water bottles in the rubble vent. The nozzles are stuck into the rubble up to the first bend and we are flushing the bottles now.
20:18:25			P	Triggered the bottles.

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Time	Depth	Hdg°	Obs	Comments
20:19			S	Not a good sample (Pair #2) [sample 2036-W2].
20:19:05			P	The plungers apparently are not retracting.
20:20:30			P	Pulling out the third water sample from the porous vent [sample 2036-W3]. The pistons apparently did not come back. OK, one bottle may have triggered. Ralph says the quality of the sample is probably not good. The third sample was reported as bottle pair 3, but I think that the second pair was actually 3.
20:24			P	Attempting to flush bottle pair 1 from bin 8. The nozzles are sticking into the rubble.
20:24			S	Sampling water (Pair #1). Palm worms stretch far out of their tubes. Shimmering water surrounds them. Numerous small invertebrates in rubble.
20:25			P	Bottle pair 1 from bin 8 triggered, both cylinders coming back [sample 2036-W4]. The second sampling site with the porous chimney is just about 4 m below the highest peak. The first sampling site is just below the peak. It is about 5 m north of the site.
20:26:50			P	Bottles closed.
20:29			S	Deploying marker 6X. Placed on top of mound, 1 M north of orifice. Not many tube worms at this hot water vent site. Limpets, anemones, galatheids. Begin reconnaissance of area. Heading N over field of sponges.
20:29:30	3239		P	Marker 6X is going to be deployed just above the porous vent where the third and fourth water samples were taken. It was a porous barite chimney, we excavated it and stuck the sample bottles in the rubble to sample. We had a stable temperature of 217°C, and we deployed 6X 1 m south of the vent.
20:30			P	Heading south on the east side of the edifice. We are going to take a slow photo traverse around the mound. There is a mound to port. Camera rate set on 4 seconds. We are coming up a high edifice. We were facing south, so this is to the east of the other vent. I see a lot of debris and rubble at this level, some galatheids on it. Taking some pictures. There is some mass wasting going on here. There are some tube worms up ahead. I can see tube worms on the video. There are some large talus blocks. There are some live tube worms down here, even in the talus. Galatheids, big talus blocks, there is some bacterial mat between some of the blocks. There are some more galatheids. There is mostly rubble on my side, the active part is ahead. We have not seen hot water yet, but there are live tube worms.
20:30		180	S	Coming up on another edifice; larger tube worms. Luxuriant clumps of tube worms. Anemones on worms. Climbing up. No hot water.

Time	Depth	Hdg°	Obs	Comments
20:30:04	3239	203	E	Tube worms and sulfide talus at base of mound.
20:30:37	3239	179	E	Large (70 cm) sulfide talus on sediment at base of mound.
20:31:08	3240	191	E	Base of sulfide mound adjacent to active mound.
20:32:16	3234	182	E	Thick clump of tube worms with anemones on sulfide talus.
20:32:32	3232	175	E	Blue filamentous bacteria(?) on massive sulfide with tube worms.
20:33	3228		P	Coming up a large mound, but we don't see warm water at the top. There is some biota at the top. I see mostly rubble, I see some tube worms, I see some bacteria. There are a couple of dead chimneys at the top. Taking some pictures. Depth at the top is 3224 [m]. We are real close on the port, we might just touch down. There is an other edifice ahead on the port which I think you can see. On this dead chimney there are some large anemones, including one venus fly trap. I'll take a picture of that. We are heading east. An other shot of this dead chimney, you might touch down on the stern here, no, we cleared. Sloping up to the port side there are some nice slabs of sulfide, lots of asteroids, some sponges and anemones, some bacterial mat, and I did see a few live tube worms. I see some broken chimneys on the rubble.
20:33	3225		S	At the top of the mound. Dead chimney, live tube worms.
20:33:08	3227	153	E	Bacterial mat towards top of mound.
20:33:32	3224	185	E	Top of mound?
20:34	3227	090	S	Sloping up into sediment terrain. Sedimented ridge.
		270	S	Back into active area. Galatheids.
20:35	3235		P	East of the tall sulfide mounds there is a sediment-covered slope, which I can't see. I am looking at one of the edifices, this one has a lot more iron oxide on it, very large rubble pieces, colonized by sponges. Taking pictures. The mound we sampled is down slope and west of here. There are some tube worms that are dead. There is a big patch of tube worms below me, I think they are all dead, but they are still white, I don't see any shimmering water, they are about 3 m below me. Ralph reports there are three mounds ahead of us to the west, one of which should be the one we sampled. I could see 3 very large patches of tube worms down there, but I couldn't tell if they were active, and I couldn't see hot water, but there were very large patches of tube worms on this side of that last edifice.
20:35:00	3226	125	E	Small sulfide chimneys and ledges on sediment-covered slope.

## Appendix 1

Dive 2036

Time	Depth	Hdg°	Obs	Comments
20:35:12	3226	093	E	Lithified surface sediment 1 meter up hill from small sulfide chimneys.
20:35:24	3225	082	E	Sediment covered bottom.
20:35:36	3224	032	E	Base of sulfide mound.
20:35:58	3225	032	E	Massive sulfide mound with sulfide talus.
20:36	3226		S	Sampling sites downslope and west of this site.
		300	S	3 edifices in front. Heading west. Marker. Pinnacle with tube worms down the slope. We think we're back to original sampling site (6X), but number on marker is not confirmed. Viewed from starboard porthole.
20:37	3232	357	P	We are off the bottom on my side, there is a big mound off to starboard.
20:37:28	3235	359	E	Massive sulfide.
20:38	3240	NW	P	We're going by the mound we sampled.
20:38	3242	298	S	Heading for additional targets. 3220 M = top of mound; bottom of mound = 3257 M.
	3249		P	Right now we are at 3249, the depth at the top was about 3224. The mound we are looking at now is inactive with rubble, there is some sheet-like sulfide which is exposed by mass wasting, breaking away of the slabs. There are some galatheids on it.
20:38:48	3247	248	E	Massive sulfide.
20:39:24	3252	290	E	Massive sulfide.
20:40	3257		P	We are over a little sediment pond between the mounds. Pictures taken. Turning to the left, we're heading north away from the tallest one which is next to the active mound.
20:40	3257		S	Galatheid, small sulfide outcrop.
20:40:37	3245	012	E	Small dome of sulfide with layering parallel to surface.
20:40:45	3257	357	E	Sulfide in sediment.
20:41			S	Sediment with talus from slope.
20:41:16	3257	349	E	Sediment covered bottom.
20:41:32	3259	282	E	Octopus on sediment-covered bottom.
20:41:48	3260	267	E	Sulfide and semi-lithified sediment
20:42	3259		P	Coming up another sulfide mound, big blocks of talus, almost 1 m, in fact up to 2 m, with red iron oxide. I can see a big sediment drop-off in front of us. I'll put the data frame on the video.
20:42	3260		S	At base of pair of mounds with saddle. Lots of talus, galatheids. Marker in sight. Unidentified number.
20:42:24	3258	248	E	Coarse sulfide talus.
20:44		180	S	Climbing up a rise.
			S	Mound to starboard. Looks inactive. 20 m. Lots of rubble.
20:44:32	3259	145	E	Sediment cover at base of sulfide mound.
20:47	3250		P	Coming by another sulfide mound on the port side, just changed to roll three on my camera. There is a very large chimney out to my side with some pagoda-like

Time	Depth	Hdg°	Obs	Comments
				extensions. It is about 3 m high. Ralph reports some warm water.
20:47			S	Tubeworms. South of first two sampling sites. Shimmering water. Galatheids, anemones on tube worms.
20:47:16	3250	231	E	Large field of tube worms with anemones and bacterial mat.
20:47:32	3249	222	E	Tube worms and massive sulfide covered by thick bacterial mat.
20:48		240	S	Hand-held photos of worms?
			P	We just passed a very large inactive chimney. We are south of our original sampling site, we have an active chimney with warm water and live tube worms. Coming up on my side I can see a large edifice 2-3 m across and 4-5 m high, I'll take a picture of that. Another dead mound in front of the submarine with a sediment-covered area between the mounds.
20:48:16	3250	191	E	Large sulfide spire.
20:49	3254	180	S	Inactive mound.
20:50	3257	090	S	Close to south wall. End of benthos camera photos.
	3254		P	That last mound we passed over was rubbly and looked like basalt instead of sulfide, it was about the same height, but it looked basaltic. I took a few hand-held [still camera] pictures and there were several external camera pictures, but it was hard to tell if it was basalt. There are brittle stars down in the sediment in the valley between these mounds. We are heading east, there is a wall showing on the CTFM to the south of us. We are going to head east, we have targets ahead of us, we are moving close to the south wall. Coming up another steep talus slope. It looks like sulfide, yes, it is sulfide, shingled sulfide, lots of sediment cover on this.
20:50:56	3256	098	E	Sediment covered bottom.
20:51	3251		P	A lot of sediment cover on this talus that were passing by.
20:51			S	Sulfide slope. Galatheids, seastars, abundant sponges.
20:51:08	3256	080	E	Sulfide in sediment.
20:51:48	3252	089	E	Massive sulfide.
20:52	3241		S	Hand-held [still camera shots] of sponges on chunks of sulfide rubble, S and E of original sites. Still climbing. Sponges; long tube worms on port side. No sign of hot water. Chimneys (inactive).
20:52:32	3248	095	E	Large sulfide talus blocks.
20:53	3243		P	We are coming up a very tall mound, we've come up at least 8 m now, I think more than that, but I'll have to confirm that when I transcribe the tape, still not at the top yet, there is an other tall mound off to the port. Lots

Time	Depth	Hdg°	Obs	Comments
				of sediment on the talus, some very coarse-grained sulfide, very large blocks of sulfides. Depth now is 3239.
	3235		P	Still climbing up, I've got tube worms, a big mass of tube worms out to the port side here, they are well off in the distance. I can't see if they're live or dead. There is a whole wall of tube worms here. I don't see any hot water, superimposing the data frame. Taking pictures. Very large tube worms, bigger than most I've seen, these are a good 1.5 m long or so, but still the thin Juan de Fuca type. I don't see any red plumes, but they are still white, I can't tell if they are live or dead.
20:54:32	3231	102	E	Large field of tube worms in distance.
20:55	3225	145	S	Still climbing.
	3228		P	We are still climbing up this hill, this edifice, mostly rubbly sulfide, fairly old looking, but there are big clusters of tube worms. I see some bacterial mat now near the top. I [see] the top in the video, and it seems to be inactive. It is still going up to port, picture taken. On the port side I'm looking down at a sediment-filled valley between mounds. We are coming directly over a mound, again inactive. I see an other wall of sediment-covered sulfide in front of us to port, 3225 m. We have at least 30 m of relief. The sediment I see here is shingled, it has been lithified. It is cropping out in little shingles, there is something that is cementing it together. I don't see any sulfide, but there is something crusty in it. We are going to go to the top of this ridge of sediment, which is partially lithified with some shingling. There is a large white-cheeked fish, taking a picture of that, there is an other fish I'll take a picture of. The time is...I'll superimpose the data frame.
20:55:16	3228	126	E	Tube worms and bacterial mat.
20:56:08	3224	140	E	Top of 32 m high mound of massive sulfide.
20:56:32	3225	126	E	Sediment-covered bottom, possibly underlain by crust of lithified sediment.
20:57:35	3222	156	P	Half the weights are away. We are leaving the bottom. Our heading is 156°, we've got both weights away, and we are on our way up.
20:57:40	3222	153	E	Sediment-covered bottom; end of usable photos.
20:58	3227		S	Top of mound. Weights away.

## DIVE TRANSCRIPT

Location: NESCA  
 Port observer: Taylor  
 Starboard observer: Hickey

Julian day: 159  
 Date: June 7, 1988  
 Pilot: Etchemendy

Transcript of divers' voice recorders; Hdg = gyrocompass heading, Obs = observer (S; starboard, P; port, E; external photo description), comments in ( )'s are diver's comments, comments in [ ]'s are notes added during transcription of audio tape.

Abbreviations: EXT = exterior 35 mm stereo camera (only port side used this dive. Total # frames = 371); R = rate of auto exposure indicated on panel (4, 8, etc. seconds between frames); VC = vertically-downlooking camera; INT = interior 35 mm camera on port side.

\*\*...\*\* = data from data logger added during transcription: D=depth; H=heading.

Initial target was end station on dive 2036

Note: this was a scheduled training dive.

[35 mm photography: ASA200 shot at 1/60, f4 with camera set for ASA400; film to be "push processed" @ ASA400]

Note: No external photos were described because the data frame was not working, so no times were recorded on the frames.

Time (GMT)	Depth (m)	Hdg°	Obs	Comments
16:48			P	Bottom in sight; ambient temperature, 1.57°C
16:51	3258	326	P	On bottom; on target. Mud covered bottom, slopes away; SIT camera on video (Osprey color video camera not functioning); driving in search of hot vent from dive 2036. Bottom slopes away to port side.
		323	P	Large white-headed fish, crab visible.
			P	At base of sulfide mound, possibly mound at last station from dive 2036; base of mound is traversed in search of vent. Video on SIT camera. Slope is up from port perspective, all sulfide in view. Moving to starboard. Water is becoming murky due to mud raised by sub.
			P	White starfish noted every 3-4 m. Starfish prevalent along base of sulfide mound. External camera off, pilot checking for electrical short on battery meter panel.
17:03	3259	103	P	External camera on; now in valley (saddle) between two sulfide mounds. Shots of sulfide mound taken through port window. VC fired for biology, sulfide mound slopes up to port side. Spot marker 6-dot from dive 2036; VC fired; still trying to find vent sampled on 2036. Sparkle of fresh sulfide visible out port side. Yellow-ochre coating on mud around edges of larger blocks of sulfide, slight mud covering upper sides of sulfide blocks. Steering mechanism not functioning, mud is stirred up as we maneuver. Water murky out port side. Pilot observes long "jellyfish"-like organism (can't see from port). Down-looking camera fired.
			P	[NOTE: there were two no. 6 markers previously deployed: a no. 6-dot, and a no.6 X. We did not realize this. We landed

Time	Depth	Hdg°	Obs	Comments
				on target assigned from <i>Atlantis II</i> , but this turned out to be the last dive station of dive 2033, and NOT the hot-water station of dive 2036. All comments in tape referring to 'marker 6' have been changed to read 'marker 6-dot'. Therefore, reference to last station of 2036, or marker 6 from 2036, are in error since the dive weights and marker were those from dive 2033; this explains why we could not find the hot water vent, despite careful searching.]
17:13	3253	103	P	At depth 3251 m, ambient temp. = 1.58°; Checked SIT camera, lots of noise; still no luck with Osprey.
17:14	3253	221	P	Murky out window. Titanium light turned on for running light. Sulfides on right side of video monitor. Sulfide pinnacle in view (monitor). Moving to lower right of image, looking for hot vent of 2036 sitting on top of dive marker 6-dot. Below: rusty sulfide with 3 small starfish-like animals.
17:18	3255	272	P	INT shots taken: sulfide mound viewed from port side. Maneuvering down slope to mound base to find hot vents from dive 2036. Base of mound has talus-like appearance, with block 1+ m across, with smaller ones in between. Some mud on upper surfaces of most blocks [though not much]. Crabs and starfish visible.
17:21	3259	305	P	INT, several shots. Depth 3261 m in between several large blocks of sulfide, at base of mound. Mud-covered surface beneath. INT shots of starfish and anemone-like animals. Pilot spots marker 6-dot straight ahead, I do not see any signs of a vent out port side. No tube worms visible. No shimmering water seen. Pilot looking directly at sulfide mound rising up before him. Will cruise base of sulfide mound to starboard. Sulfide with some yellow-ochre oxidation; silvery matting covering boulders/blocks in places, looks organic; clear, reflective minerals on surfaces [a sulfate?] See marker 6-dot from 2036 again. Dive weights from [dive] 2036 seen from port side. Mud stirred up, clouded up port view. Holothurian on mud surface at base of sulfide mound (hill). 3 white crabs, one every 4-5 m apart. Mound rises sharply, pinnacle on top. Lots of interference on SIT camera (monitor). Mud-covered surface visible from port, sulfide visible out starboard. White-colored block seen in lower right corner of video. See marker 6-dot out port window, water murky [greatly stirred up by sub]. Can't see much out window [I suspect now that white block may have been remnant of sulfate chimney from hot vent]. Sulfide pinnacle ahead on video.
17:37	3259	313	P	Talking to surface. Requesting position of vent relative to marker 6-q;dot. No shimmering water seen. Will go on bearing of 180° from marker, trying to find something new. [No specific guidance from <i>Atlantis II</i> regarding location of vent relative to marker]. Very murky out port side. Sulfide seen out port side, with white precipitate on some of the

Time	Depth	Hdg°	Obs	Comments
				blocks, INT of starfish; passing by marker 6-dot one more time. Cruising over top of a sulfide mound, then over muddy bottom with couple of holothurian. Pilot spots dive weights from 2033, skid mark. Reposition, looking at outcrop (protrusion) at base of mound.
17:46	3258	167	P	Marker is in upper right corner on video monitor; view looks like what I remember seeing in video from dive 2036. Pilot does not see any hot water coming from blocky outcrop. Crab and anemone on sulfide blocks. Slowly scanning slope just below marker trying to find the hot vent from dive 2036 (one last attempt). Dive weights visible out port side. Heading close to due south. Cruise up and over mound, heading south.
17:49	3256	163	P	On top of sulfide mound [the one with marker 6-dot]; mud stirred up; slopes away on port side; one sea pen observed, water very murky, back reflection from exterior lights. Marker 6-dot directly out port side, about 2 m away. VC fired, passing over dive weights, water murky. EXT has been off due to murkiness in water. Manipulator on port side is leaking oil. Holding, waiting for mud to settle, sitting in saddle between two major sulfide mounds. Not much activity on bottom for photography. Still getting noise on SIT camera.
18:00	3257	104*	P	Using sonar in search of other reflectors. Still parked, waiting for mud to settle so we can move on. Then moved off to south, heading 100°. Large sulfide mound ahead. On top of mound, looking down. Rubby appearance, not much biota; 6 starfish, spaced couple of meters apart; sparkling reflections from sulfide.
18:05	3255	173*	P	Double spire [vent orifice], highly reflective [on SIT camera monitor] now in view on monitor (not visible out port side). Pilot thinks something coming out of spirevent visible on video. Tall mound, about 5-10 m high.
			P	Fired VC; several INT shots. Moving higher to check out vent. Light greenish-gray coating on blocks as top of mound is approached [probably anemone-like organism seen later, each has short tentacles and are circular in cross section]. Lots of white colored organisms (sponges?) attached to upper surfaces of blocks. Lots of anemones on surface of blocks near top of mound, just below spire. VC fired as we traverse up side of mound. Changing film (roll 1 out; roll 2 in) in INT camera.
			P	Passed over spire, looking into mud-filled bowl below. Sulfide mound sloping up away from port in distance. Pilot spots another [dead] vent straight ahead. [Will bypass to starboard]. Big, blocky, stubby-topped vent on this mound. Abrupt side on one side of mound. Pilot spots yet another mound ahead. We have sulfide mounds all around us, working our way through them.

## Appendix 1

Dive 2037

Time	Depth	Hdg°	Obs	Comments
18:21	3256	195	P	Spire spotted ahead by pilot, tube worms on lower shoulder. White, reflective coating on spire shows well on SIT camera (monitor). VC fired.
18:23	3248	162	P	Surface-navigated position requested to locate our position. Water is exiting one of the vents. Tube worms visible on video monitor, plus highly reflective material [caution over interpretation of "white" material that is very reflective since using very sensitive, SIT camera]. Water can be seen coming up (or perhaps behind) tube worms. Attempting to go around to right to see if vent is just beyond. INT shots of tube worms as we maneuver around mound.
18:28	3250	48	P	Circling large spire; it has a layered look to it, short fins protruding around spire; pagoda-style; below on shoulder of mound are several large colonies of white tube worms with red heads [tips]. Another spire now in view, but not one referred to first; it's another vent (spire; can't tell from here if active or not). Still circling vent. VC fired as we circle mound. Not much in the way of shimmering water; will take temperature. Observing long white tube worms with red "heads" on them. Appear to be larger worms than collected on dive 2036. Orange-tipped probe will be used.
			P	Temperature 15.0°C; VC fired. T=15° is max. temp. from water issuing through colony of tube worms. **Temp. = 18.0°C; see below**
			P	Tube worms sampled with port arm, as seen on video. Sample put in "critter box", door closed.
18:47	3250	221	P	Oxidation around edges of grayish blocks of massive sulfide. Water sample bottle set #1 taken from position 6 in basket [sam[le 2037-W1]. Video recorder tape changed. Both bottles fired. Good shot on video of bottles and sampling position; data frame recorded on second video tape. This location has been checked with surface ( <i>Atlantis II</i> ). VC fired.
			P	Bottles returned to basket position 6.
	3250	221	P	Noise on video; put on data frame, not sure if taken or not. Altitude on data display not working. Located halfway up the mound.
			P	Not a good place to anchor for a solid sample. VC fired. Noticing difficulty in steering (pilots have switched). VC fired. Water coming up through tube worms seen through port side.
			P	Moving on, passed over vent. Mud stirred up. Large pillar seen in video on left, not much life associated with it; will pass that one up. Cruising with southward bearing. Temperature probe, 18.0°C.
18:50				
18:54	3248	208	P	Maneuvering to maintain a southward bearing to stay along side sulfide. Murkiness created again as we move off station. Rotating about. Difficulty steering causes stirring up of bottom mud.
18:57	3245	176	P	Starfish, seapen visible from port side; INT shots taken. Shot of dormant mound out port side. Find another small mound,

## Appendix 1

Dive 2037

Time	Depth	Hdg°	Obs	Comments
19:02	3250	187	P	<p>circling to right side in order to view from port side. Sea pens. Much back reflection from suspended mud.</p> <p>Circling small mound; lot of mud stirred up; blocks visibility out port side. Lot of interference on SIT camera. See sulfide below. Heading straight for pinnacle; not as large a mound as the one just sampled with tube worms. Starfish and multi-tentacle, salmon-colored organisms in view [these were sampled on earlier dive, this cruise]. Steep sided, 5 m high, oxidized.</p>
19:06	3250	145	P	Moving south from small mound [noted previously]. Looking for mounds with tube worms. Surface drops off sharply to port side. Lot of mud cover over slop. INT shots of sea pens and sea fans.
19:07	3249	184	P	Sonar on, looking for reflectors. Mud-covered, hummocky surface with occasional holothurian and starfish, nothing exciting, bland.
19:10	3256	184	P	No outcrops of sulfide in sight.
19:13	3253	102*	P	Mud-covered surface and ridge ahead. Traverse as we cruise to find sulfide. I think we're covering unexplored territory as I remember from map. INT shots of starfish. Data frame entered on video. Ridge drops off abruptly to left side of video (dark area). Not much visible on video except for mud-covered ridges. Want to go back to active area, and search for more vents.
19:25	3261	352	P	INT shot of sea fan. White colored area on mud-covered surface. Coming over ridge with some sulfides (can see sparkling), mud covered in many places. Large mound of sulfide visible in front; fairly good size as estimated from port window. No tube worms, no hot water. Can see in video; dead vent. Sulfide visible out port side.
19:34	3258	54	P	Data frame turned on for video. Pilot is talking to surface <i>Atlantis II</i> . Bit of mud-covered sulfide straight ahead. Attempt to operate Osprey; problem thought to be with power supply.
19:35+			P	Slabby outcropping of sulfide (I believe it's sulfide). Lot of mud cover. Starfish every 2-3 m. on top ridge. Undulating surface, white fish below. Pilot checks to see that critter box is still closed. O.K.
19:40	3261	79	P	Cruising to last sample point [forgot to get hand-held video coverage of sample location as substitute for Osprey footage]. Will then move northward to find other vents. Mud-covered ridge with subcrop exposed. Large blocks of sulfide ahead (in view of video). Larger boulders have small, white reflective organisms (sponges?). VC fired. Intricate appearing pinnacle directly ahead.
19:44	3259	86	P	Still cruising to previously sampled location with tube worms (this dive) to get hand-held video to complete the record since Osprey (color video) is not working.

Time	Depth	Hdg°	Obs	Comments
			P	Pilot has just spotted tube worms, back at sample location. Pilot takes hand-held video through pilot's window. Lights on. View out port side is oxidized sulfide.
19:48	3250	180	P	Shooting hand-held video of sample location sampled earlier this dive for water and tube worms. Oxidized sulfide with small white animals on upper surfaces of blocks (sponges?). Note here that sulfide blocks do not have much sediment on them, perhaps indicative of somewhat older age of other mounds observed this dive [note that this one was weakly active]. Film change on INT (roll 2 out, roll 3 in).
19:54	3253	354	P	Film change on INT complete. Passing over sulfide mound, large crab on top. Water murky out port side, view impaired.
19:55	3252	350	P	VC fired; first attempt was a fish [we passed over]. Moving north of sulfide mound with marker 6-dot .
			P	Mud-covered ridge drops off sharply to port side. Looking at sonar for any reflectors ahead to explore. Forgot to turn on external camera as we passed over previous sulfide mound (I was busy changing film in INT). As we head north, rolling topography ahead, in video. Large fish out port, INT shots of it.
19:58	3258	003	P	Surface a bit more uneven. Pilot spots mound, now heading for it. Sulfide mound off to left side. Muddy-looking exposures [mud-covered]. Exposed rock looks bedded. I think we are looking at sediment here; not massive sulfide. Several INT shots taken [of "bedded" rock].
			P	Something sticking up through surface off to left. Looks like skid tracks. Skid tracks seen out port side.
			P	Cruising up hill. Sediment-covered bottom, very similar to that seen throughout the dive. Data frame entered on video.
20:02	3259	038	P	Using sonar, reflector ahead. Turning left 10°. Heading due north. Dark-colored fish photographed with INT, has large fins, 1 to 1.5 m long. Sonar switched into video [reflector ahead]. View out port window is sediment-covered surface. We're on edge of ridge, drops off to north. Attempt to get Osprey working again [no success].
20:06	3258	003	P	Blocky outcrop visible through port side. Some sediment on top of blocks. Several starfish (one every meter or so). This is not massive sulfide. Looks as though it may be basalt, or some sediment. At the moment I see some sort of layered look to it. Some fracture. [This was passed quickly. Gave the impression of fractured, or fissured sheet flow basalt]
			P	Sulfide-looking mound dead ahead, but right below me [exposure] doesn't look like that; looks more "slabby". Thought I saw something that looked like a sheet flow; passed too quickly for me to tell. Pilot sees sulfide mound towards starboard.
			P	On top of prominent mound. Looking down from port side. On video see constructional vent -- can't tell if active or not. INT shots of mound. Drops off sharply [on north side]. On top

## Appendix 1

Dive 2037

Time	Depth	Hdg°	Obs	Comments
20:11	3253	194	P	of mound, doesn't look like sulfide, there isn't any sparkle to it. Could have been basalt; didn't have texture of sulfide. Leaving this mound heading due east. In front see even, sediment-covered mound.
20:14	3251	93	P	Viewing massive sulfide. Heading due east.
			P	Over a sulfide mound. 183 frames shot on port EXT.
			P	Starfish-like creature below us. U-turn and exploring mound. Between two mounds. From what seen before, biota key [to hot vents]. I can't see much because of mud stirred up.
20:18	3241	202	P	Sulfide mound visible out port side. Traversing around base of large sulfide mound.
			P	See lots of sediment between and covering blocks of sulfide. So, it has been sitting here for awhile. VC fired by pilot.
20:26	3243	157	P	Just left sulfide mound. INT shots taken from port side. All noted that outcrop looks a little different than sulfide. Perhaps it's sediment, with layered appearance in places to outcrop pattern (may be basalt, although it doesn't strike me that way). Dark in color. Not regular fracture. No obviously magmatic features (to my eyes).
			P	Another large outcrop right in front of us, just can see from port side.
20:28	3239	208	P	INT shots taken. Switching pilots.
20:29	3234	212	P	See dead, constructional feature in front of us. An older vent, with fair covering of mud on top. Not much in the way of biota on this mound. Occasional starfish. A few crabs. Pilot has direct view of mound. No hot water sighted. Considerable oxidation visible through port window. Several tube-like things [projections from surface]. INT shots taken of these [appeared antler-like, with orange-brown coating].
			P	Mound in view of SIT camera; can't tell much about it from my [port side] perspective. Looks fairly dead. Don't see a lot of life on it. Swinging around for better view out port side. A few crabs and starfish now visible. Lot of sediment draping over sulfide [blocks]. INT shots taken.
20:33	3234	157	P	INT shots and VC shots as we passed over top of small pinnacle. Mat of biota growing on sulfide blocks; gray-green color [organisms seen earlier; anemone-like -- circular cross-section, attached at base, low profile with short tentacles around outer circumference].
			P	More sulfide to port side. Occasional starfish, sea fan below. A few pinnacles sticking up, otherwise sediment-covered [drowned appearance]. INT shot of white-headed fish.
20:37	3235	0	P	Changing tapes in VCR. Coming about and going back to previously-visited tube worm sight (where we filled one set of hot water bottles) in order to collect sediment core.
20:41	3232	222	P	Heading 221°, heading back to tube worm site. INT film changed (roll 3 out, roll 4 in). Ridge of sediment in front, trying to climb up over it. VC fired, also on ridge. Occasional blocky subcrop on sediment-covered ridge. Moving uphill.

## Appendix 1

Dive 2037

Time	Depth	Hdg°	Obs	Comments
20:48	3258	223	P	VC shot of fish.
			P	Data frame entered on video. Undulating topography. Surface still mud-covered. 292 frames on port EXT.
20:51	3263	223	P	Closer look at bottom, see "pock-marked" surface, with some boring apparent. VC fired. (pilots talking: heading 150°). Fairly mundane surface.
20:53	3261	155	P	VC fired. Mud-covered ridge ahead. Can't see bottom from port side.
			P	Passing over holothurian, VC fired.
20:56	3254	54	P	Mound up to left, tall, can't see top from port window.
20:58	3252	181	P	Mud-covered mound with whitish precipitate. EXT on as we pass over top of ridge.
20:59	3246	54	P	Approaching another ridge with some sulfide showing. Heading 063°. VC fired. Fish ahead, attempted VC photo (strobe not recharged). Sulfide outcrop, slopes up to right as we head north. Sponges(?) visible on sulfide blocks, quite a few more crabs and starfish visible.
21:01	3248	61	P	VC shot. Steep slope [of sulfide]. Large mound, good 20 m high, but difficult to judge from inside sub.
21:07	3230	249	P	Found active vent, area populated by clustered tube worm colonies and by long (>1 m) tube worms individuals laying parallel to sulfide surface (looks like a mat on the sulfide.). First sign of tube worms since this morning. Crabs visible. Off to right on video, another constructional vent visible. Do not see evidence for large flow of water, but we're stirring up quite a bit of sediment, etc.
			P	Positioning sub to better view and sample this site. Tube worms directly in view on video. Can't shoot VC because we've stirred up quite a bit of mud. EXT off.
21:09	3234	213	P	Data frame entered on video since view impaired by stirred-up sediment. Preparing to take temperature measurement. Some difficulty maneuvering port arm.
21:12	3235	222	P	Surface has our location fixed. Taking temperature measurement. See arm and probe on left side of video. [metal probe tip bent during pickup] Pilot trying to straighten probe tip. Depth 3235 m.
21:14	3235	222	P	Holding steady for temperature measurement. Attempt to bring up Osprey worked. Osprey now on video. Co-pilot focuses Osprey, picture sharpens. Colony of large tube worms in view.
21:15	3235	222	P	Osprey working. Temperature probe returned to basket. Pilot attempts to pickup second probe. Lot of wire in his way. VC fired (should be right over some tube worms). Out port side see lots of little "spongy things" clinging to rocks [blocks of sulfide]. INT shots taken, with variation of f-stop (shutter at 1/60; will push process this ASA200 film as if it were ASA400; ASA on camera body set to 400).
21:21				Temperature (probe 1) = 13.5° C.

Time	Depth	Hdg°	Obs	Comments
			P	Still having trouble maneuvering port arm. Sulfide out port side has some oxidation, but only a very little bit of brownish mud on upper surfaces [indicates younger vent]. Small white organisms attached to rock (anemone-like?), tubular "stock" attached to rock, with tentacles around upper portion. These cover rock surfaces about one to every 4-6 cm apart. Now have color video on the monitor.
21:22	3235	222	P	Water [plume] samplers on vane fired [sample 2037-W3]. Getting ready to sample water with hot-water samplers. Red end on white tube worms, elongate down-slope on sulfide mound. INT shots.
			P	Switched to SIT to get better shot of water bottles and sampling location on site. Using starboard arm. Check, both have fired.
21:30	3235	222	P	Pilots changed. Second pilot (Steve) will attempt to sample with water bottle pairs. SIT camera on video to locate bottles. Mud stirred up. A little shimmer in water seen issuing from tube worm mounds. Peek out pilot's portal, shimmer on water easily seen, not large flow rate, however.
21:33	3235	222	P	Collecting water sample, both have fired. Depth 3235 m.
21:37	3235	222	P	Water samplers returned to basket. Temperature probe tangled around box cores [sample 2037-W2].
21:39	3235	222	P	Pilot will take hand-held video through pilots view-port. Switched back to Osprey -- it comes on.
21:40	3235	222	P	Hand-held video footage of tube worm colony sampled for hot water (two pairs of water samplers); adjacent to this colony water samplers on sail were triggered [with no problems encountered; sample 2037-W4]. Maneuvering to pick up rock (sulfide) samples. VC fired.
21:43	3235	222	P	Positioning port arm to sample sulfide. Mud stirred up. Attempting to pick up sulfide with biota attached.
			P	[no recording on audio cassette of actual sampling, but two samples were taken, each recorded with video before being placed in the basket [sample 2037-B1]. Voice recording on video].
21:53	3248	210	P	On side of sulfide mound [note 120v low battery alarm can be heard in background]. Maneuvering to take box core. One of the core samplers is tangled in wire from temperature probe. Viewed with SIT camera.
			P	[Video records sampling attempt; note that sample was lost from core sampler; I later learned that this sampler must be closed by several revolutions of T-handle, but pilot was unaware of this. This explains lack of recovery of box core. Sediment was probably thick enough at this point to sample]
			P	Pilot loses core. I ask if sediment not deep enough. Pilot sees that bottom did not close on box core device.
			P	Pilot says we must surface. Sediment coring attempt halted. Attempted to take more Osprey footage, could not bring up

**Appendix 1****Dive 2037**

<u>Time</u>	<u>Depth</u>	<u>Hdg°</u>	<u>Obs</u>	<u>Comments</u>
				Osprey camera again. Data frame added to video as this marks end of dive.
			P	Weights dropped. Port arm has fallen forward, pilot repositions arm (secured) for ascent.
21:58	3230	244	P	Dive ended. Ascent begins.

## DIVE TRANSCRIPT

Location: NESCA  
 Port observer: Edmond-no transcript prepared  
 Starboard observer: German

Julian day: 160  
 Date: June 8, 1988  
 Pilot: Foster

Transcript of divers' voice recorders; Hdg = gyrocompass heading, Obs = observer (S; starboard, P; port, E; external photo description), comments in ( )'s are diver's comments, comments in [ ]'s are editors clarification.

Note: No external photos were described because the data frame was not working, so no times were recorded on the frames.

Time (GMT)	Depth (m)	Hdg°	Obs	Comments
16:44			S	Arrive on bottom. Rippled sediment cover. Abundant fauna and flora, worm casts.
16:45		025	S	Set off across sediments.
16:50		355	S	Holothurians seen. Gentle slope. Sea pens in abundance also. Now over flat sediments, ripples with ~1 m wavelength. Large fish seen.
16:52		360	S	Slope steepening sharply, travel up hill.
16:53:30	3280		S	Heading due north. Fish.
16:54			S	Crossed broad-channel running downhill from NE to SW ~ 1 m deep, 10 m across.
16:56			S	Disrupted sediments, swells and depressions of ~ 50 cm order of magnitude. Sea stars, crinoids, holothurians.
16:57		360	S	Hill steepening.
16:57:30			S	Worm casts.
16:58			S	Blocks rising out of sediments, sulfides. Heavily populated, crinoids, fly-catcher anemones, sponges.
16:59			S	Sulfide outcrop, linear and seen continuing along strike ahead of <i>Alvin</i> which was headed along 031° at the time. Sediment cover seen beyond outcrop.
17:00		073	S	Passing over blocks of sulfide which rise ~ 20 cm above the seabed (sediments) contouring round the hill, port side uphill.
17:02	3260	050	S	Flat sediments.
17:03	3260		S	Still contouring round hill, sediments and holothurians
17:05		023	S	Ridge of sulfides seen contouring hillside ~30 m away from ALVIN downhill and to starboard side. ALVIN swung to head 113°. Topography here very steep downhill. Sub passes over outcrop and out into water column.
17:06			S	Overshot sulfides, sub swung around to head 280°. Only sediments seen. Hit ALVIN wake. Turned to North waiting for wake to clear. Outcrop not found.
17:07			S	Ridge of sulfides seen running downhill ahead of ALVIN from port to stbd side. ALVIN at base of slope, swung East of North for port observer to observe.

## Appendix 1

Dive 2038

Time	Depth	Hdg°	Obs	Comments
17:08		078	S	Back contouring round steep-sloped hill. Sediment cover, seastars. Individual blocks of sulfide ~10 cm square and protruding 1-2 cm from sediments, which are somewhat disrupted.
17:10			S	Still photo 1: venus fly-trap anemone.
17:11		344	S	Moving gently uphill. Sediments much more regular/conventional.
17:13		348	S	Slope steepens uphill; sediments flatten out, ripple structures break down. Large block outcrop of sulfide passed by on starboard side ( ~ 2 m by 2 m by 2 m).
17:14	3250	360		
17:15			S	More sediments. Now contouring hill at 093°. Still photo 2: holothurian (sea-slug).
17:17	3246	358	S	Changed course to head up-hill. Saddle between two hills seen ahead and to right (starboard side) estimated to be to NNE. Sediments and seapens seen.
17:19		002	S	Flown over steep hill into mid-water.
17:20			S	Descended to sea-bed. Outcrop on port side. Large scours and thrown up chunks of white-grey sediment which apparently used to underlie yellow surface sediments, e.g. scour channel cut into sediments, ~3 m x .5 m x .5 m excavated surfaces all white-grey color identical to adjacent "ripped-up" clasts.
17:22			S	Moved over disrupted sediments, onto flatter surfaces. Still photo 3: typical sediments.
17:25		002	S	Sediments. Sea urchin seen. Still traveling gently uphill. Hill dropping off to SE (i.e. behind and to right).
17:26		360	S	Hill steepening. Dandelion, sea pens, holothurians on sediment cover.
17:27			S	Still photo 4: fish?
17:28	3252		S	Heading north. Approaching hilltop. Switch to 030°. Plenty of sediment cover. No outcrop, same critters.
17:29			S	Turn to 040°.
17:31	3252	346	S	Photo 5: Fish. Passing over sediments. Approaching steep scarp dropping off in front to right (starboard). (North side of hill?) (Out into mid-water column off bottom).
17:32	3250	323	S	Continuous rippled sediments.
17:33		330		
17:34			S	Outcrop seen to port. <i>Alvin</i> turned towards sulfides, heavily colonized. Still photos 6, 7, 8 taken. Sulfides look old, rubbly surface and patchy (c.f., [sic] surface appearance of a conglomerate). Dark brown mostly, but some red weathering.
17:37		210	S	Parked over outcrop to port; mid-water to starboard with sediments down below.
17:39			S	Facing 111°. Sediments, holothurians, sea pens (dandelions).

## Appendix 1

Dive 2038

Time	Depth	Hdg <sup>o</sup>	Obs	Comments
17:40	3260		S	Driven into <i>Alvin</i> wake.
17:41	3264	063	S	Lots of sediments. Few blocks of sulfide.
17:42	3265	111	S	Left sulfides to cross more sediments. Back to more sulfides. Now contouring second hill, downhill to starboard side. Two ridges of sulfide striking approximately 030° to 210° ~1 m above sediments and 1 m across (wide).
			S	Next, pass over much sulfide, shaly outcrop continuous over hillside with <5 cm sediment cover and 5 cm of sulfide protruding through it.
17:45		090		
17:46	3264	077	S	To locate CTFM target. Passing uphill, gentle slope.
17:47			S	Passed over sulfides. Very old, much sediment on it. Outcrop no more than 50 cm above sediments.
17:48	3264	220	S	Sediments, holothurians. Change course to 140°, approaching steep scarp, continue to swing to 060° and then NE (047°). Slope on right, downhill to left.
17:50	3260		S	Holothurians.
17:52		047	S	Still to the SW of top of hill. Slope still downhill left to right.
17:54			S	Located at 400 m east of hill ('B'). Still lots of sediments. Venus fly catcher anemone on old sulfides. Continuous outcrop (wall) of sulfides seen with <i>Alvin</i> facing 320°. Outcrop is old and rubbly.
17:56			S	View down-hill to starboard. Heavily colonized outcrop (as 17:54).
17:59		099	S	To next reflector.
18:00		095	S	Passing over sediments. Gentle uphill slope.
18:01			S	Rubbly sulfide outcrop, very rounded. Fly-catchers, sponges. Outcrop ~3 m high. Outcrop shaped like curved walls in terraces downhill side.
			S	(A sketch and details about sketch, showing sulfide interbedded with sediment.) [not shown here.]
18:04	3260	260	S	Heading due west to target B. Passed over <i>Alvin</i> wake.
18:06:08		258	S	Sediments, holothurians, sea pens. Eight-pointed seastars in places.
18:10		267	S	Heading gently uphill diagonally to right.
18:13			S	More sediment, sea pens, holothurians. Occasional anemones and crabs.
18:14			S	Outcrop with critters on sulfides. Put in body box. (Sample 1 [sample 2038-R-1]). Filmed on Osprey.
18:21	3264	272	S	Sampling completed. 275 m from "B" which is about due west of us. Heading 244° continuing gently uphill.
18:25		263	S	Passed two more blocks of old sulfide. Sulfides overlapped.
18:26		294	S	Sulfides 1-2 m below <i>Alvin</i> .
18:27			S	Yet more blocks of old sulfides. Prove to be quite large outcrops, order of 1-2 m high and 10s of m long.

Time	Depth	Hdg°	Obs	Comments
				Preferential weathering in places, color alteration from brown-green to red-orange.
18:30	3265	303	S	Sediment-covered bottom. End of video tape 1.
18:33	3270	271	S	Sediments.
18:36	3272	170	S	Climbing gently uphill over sediments. Few critters.
18:39	3265	171	S	Sediments continuing uphill ahead and to port.
18:40			S	Channel cut through sediments into mudstones running off to starboard.
18:42		241	S	Pepsi can seen. Also holothurians and sea pens.
18:43			S	Next sulfide outcrop.
Turn Tape Over.				
18:44.	3265	283		
			S	Red colored weathering of sulfides. Crab.
18:47	3267	319	S	Passed over outcrop, 2 m off-bottom.
18:49	3273		S	At 'B'. Seemed to travel up channel to east of 'B' until north of target and then traveled back, south, towards hilltop. Top of hill; lots of rubbly, old sulfide outcrop with extensive sediment cover. No chimneys. Left 'B' along 130°.
18:51			S	Steep broken scarp of sulfide downhill in front of us, while heading ~130°
18:53	3264	132	S	Steep hillside of disrupted sediments (white-grey mudrock exposed). About 1 m across and ~5 cm tall.
18:55	3260	132	S	Contouring round hill, past saddle between two highs and then hillside dropping away again below <i>Alvin</i> on starboard side. Holothurians, dandelions, sea pens, etc.
19:00	3250	133	S	Sediments, planar topography, dipping away ahead and to starboard.
19:03		133	S	More sediment, steepening uphill. Osprey rammed into mud. Lots more sediment.
19:05	3245	133	S	Hollows ~1 m x 50 cm in sediment (fish-hollows).
19:08			S	Sulfides on a steep scarp. Poor exposure, never continuous outcrop. In situ? Becomes apparent that sulfide probably is continuous just subsurface and just breaks (protrudes) through sediments by a few cm all across hillside in layers (horizontal) to slaty appearance from submarine. Still photo?
19:10	3250	134	S	Back to 130°, out into midwater column.
			S	Contouring round hillside -- pervasive, well colonized sulfides.
19:11			S	Off sulfides, onto sediments. <i>NB.</i> : Hillsides very smooth, no angular geomorphology as with faulted blocks: sediment rate too fast and disguises this?
19:12	3253	130	S	More shallow sulfide outcrops. Approaching sulfide ridge (i.e. large outcrop with pinnacles). Passed out off hill into water column.

## Appendix 1

Dive 2038

Time	Depth	Hdg°	Obs	Comments
19:14			S	Mudstone, turned to 065°. Outcrops all way down-scarp: white upon yellow as in braided shear pattern. Photo 15.
19:16	3252	132	S	Left that outcrop and back over sediments. Typical biology, gentle slope. <i>NB</i> : All sediments have extensive bioturbation (worm-casts).
19:18	3260	080	S	In mid-water, off bottom.
19:20		040	S	Hill drops downhill to starboard. Slope steepens; starboard side out off-hill into deeper water.
19:22			S	Back in sight of sediments, hill now much shallower. Sub turned onto 128°. Still plenty of sediments, no sulfides.
19:23	3253	132	S	400 m from "C" along a bearing of 070°.
19:25			S	Slope steepened; no mudstones, just sediments.
19:27	3263	134	S	More sediment, sea pens, sea dandelion and sea star. Still contouring hill.
19:31	3267		S	South of "C" and headed downhill. 425 m along 030° from "C". Turned <i>Alvin</i> to 030°.
19:34	3262	033	S	Sediments as before. Sea urchins. Abundant tracks in sediments.
19:36	3256	033	S	Uphill, gentle slopes, sediments, and biology.
19:39	3254	033	S	Uphill, gentle slopes, sediments, and biology.
19:40	3255	034	S	Side of hill.
19:43	3260	033	S	Sediments. Still gently uphill to port and ahead.
19:48	3260	002	S	Sediments. Still gently uphill to port and ahead. Turn to 353°.
19:53		033	S	Sediments.
19:55			S	Top of "C". Sediments, anemones. Mudstone hollows and domes again ~10 cm high, 30 cm long.
19:58		030	S	Across "C"; topographic high?
20:01	3260	078	S	Toward bright reflector on CTFM. Sediment; mounds in sediments, circular with <1 m diameter.
20:06			S	Reached CTFM target; sulfide outcrops set in side of sediment-covered hill (few cm out of sediments.). Old, not very highly colonized
20:08	3265	293	S	Next target.
20:09			S	Turn to 300°. Sediments sloping downhill to starboard.
20:10	3266			
20:14	3265	337	S	Still crossing sediments to CTFM target. Spotted sulfide outcrop on starboard side. Line of blocks each 1-2 m cubic. Following a ridge curling around and running down hillside. Extinct, but highly colonized. Sponges.
20:16			S	Wall of sulfides, highly colonized. Seen with <i>Alvin</i> facing 048°.
20:18			S	<i>Alvin</i> at base of scarp, facing 250°. Wall of sulfides towers above <i>Alvin</i> for a few meters. Wait for sediment in wake to settle and clear.

## Appendix 1

Dive 2038

Time	Depth	Hdg <sup>p</sup>	Obs	Comments
20:29			S	Sampling at above location.
20:30			S	Change from video tape 2 to video tape 3.
20:43			S	Sampling completed (sulfides sample 2, sample 3). Move off along 354° passing over more sulfides with pretty pink/orange coloration/weathering and then passing onto sediment-covered slope once more.
20:46	3265		S	Still on sulfide outcrop on hillside; contact between sulfide and mudstone? (John [Edmond] on port side). Starboard side; appeared horizon of white material (assumed mudstone) interlayered with thicker sulfide units. Section only seen in 2-D but appeared subhorizontal. Sediment stirred up, lost visibility.
20:48			S	Further continuous outcrops of sulfide now visible, no sign of [shimmering] water. Outcrops again forming promontories rising 1-2 m above sediments being eroded off hillside. Pinnacles seen on ridges.
20:53	3263		S	Back over sediments.
20:55	3264	217	S	Passed back over same (?) sulfides and back onto sediments.
20:57			S	Steeply up slope, banged into sediments, continue more gently up slope.
20:58	3268		S	200°, turning to 160°, 3268 m but rising up slope still. Turned through to 130°.
21:00			S	Running out of power. Time to fill baskets and leave bottom.
21:17			S	2 box cores taken [samples 2038-BC-A, 2038-BC-B], push cores next.
21:37			S	2 push cores also taken [samples 2038-PC-1, 2038-PC-2] and 1 sea urchin placed in critter box [sample 2038-B1]. Left bottom.

## DIVE TRANSCRIPT

Location: NESCA  
 Port observer: Slack  
 Starboard observer: Palmer

Julian day: 161  
 Date: June 9, 1988  
 Pilot: Foster

Transcript of divers' voice recorders; Hdg = gyrocompass heading, Obs = observer (S; starboard, P; port, E; external photo description), comments in ( )'s are diver's comments, comments in [ ]'s are editors clarification.

General Comment: Dive in northeast quadrant of "Fresca"[far north Escanaba Trough] area [~4 km North of NESCA]. Dive target [start] at: X=62,300, Y=64,500. Design of dive was to investigate scarp or slope to immediate east of initial target, head north for approximately 0.7 km, then head west to small hill about 1.3 km away [this hill just ~1.2 km northeast of slightly larger hill visited by Edmond & German on previous dive [2038].

Time (GMT)	Depth (m)	Hdg°	Obs	Comments
16:46	3303	000	S	Sediment-covered bottom in base of north-south trending valley. Well bioturbated. No biota in sight.
16:48:15	3303		P	Just rising above bottom [after initial touchdown]; stirring up sediment; minor amount of red hydraulic fluid streaming by window.
16:48	3304	018	S	As above, plus a few sea cucumbers.
16:49	3304	026	S	Valley wall sloping up steeply to right. Bottom as above.
16:49:40	3303	027	E	Sediment-covered bottom
16:50	3303	031	S	Bottom as above.
16:50:00	3302		P	Sediment-covered bottom; small amount of bioturbation; no sign of rock outcrops of any type on port side.
16:51:00	3302		P	[still sediment-covered bottom].
16:55	3298	270	S	Bottom as above.
17:00	3311	278	S	Bottom as above but becoming flatter.
17:00:00	3312	279	E	Rattail fish over sediment-covered bottom.
17:00:00	3312		P	Still in sediment. Quite a lot of bioturbation. A few anemones; [bottom] looks very flat; a sediment-covered holothurian; a small sea fan. Quite a flat-looking topography on port side.
17:02	3311	280	S	Bottom as above.
17:02:30	3311		P	Still very flat bottom; minor bioturbation; not much fauna, a large starfish, sea anemones.
17:04	3309	279	S	Bottom as above.
17:04:00	3310		P	Took first two pictures [hand-held 35-mm still camera] of bottom. A large holothurian, sea anemones here and there; small sea fans.
17:04:40	3307		P	On the port side some small mounds; difficult to say whether they are isolated, several meters apart; large blocks could be sulfide, however, there is white material on [and near base of them] that is probably sediment [looks like white fresh sediment seen on

Time	Depth	Hdg°	Obs	Comments
				sediment [looks like white fresh sediment seen on videos of previous dives]. Ralph [pilot] says there is nothing on sonar showing as [sulfide] mounds.
17:04:55	3306	294	E	Small sulfide? outcrop on sediment-covered bottom.
17:05	3306	270	S	Sediment blocks up to 10 cm across forming mound 2 m across. Otherwise bottom as above.
17:07	3307	266	S	Sediment covered bottom dropping off to right.
17:07:45	3309		P	Still in heavy sediment. Martin [Palmer] reports a drop-off to his right [starboard]; we're swinging around in that direction, going down that slope slightly; very thick sediment cover, not much bioturbation.
17:08	3310	010	S	Bottom as above except flattening to right.
17:09	3314	000	S	In base of sediment-filled valley with bottom sloping up steeply to right.
17:10:10	3315		P	Heading north, still thick sediment cover. Some anemones and small sea fans. No sign of rock outcrops.
17:11	3315	000	S	Bottom as above.
17:11:20	3314		P	A small rattail fish.
17:12	3314	000	S	Bottom as above.
17:13	3314	346	S	Sediment blocks forming mound similar to that described above.
17:13:00			P	Ralph reports mounds. Slight rise on the port side with some big blocks sitting on top of sediment.
17:13:30	3314	325	E	Isolated 5-40 cm talus of blocky basalt sitting on sediment. The blocks are only lightly dusted with sediment, but are heavily colonized by anemones and other biota.
17:13:51	3314	333	E	"Fairy ring" bioturbation mound and [with]3-4 cm amplitude, isolated sediment ripple marks?
17:14	3314	014	S	Sediment covered bottom.
17:14:15	3314		P	Still mostly 99% sediment covered. Ralph reports a tall mound in front of him.
17:15	3314	058	S	Bottom as above.
17:15:06	3315	014	E	Isolated talus of blocky basalt sitting on sediment. The blocks are only lightly dusted with sediment, but are heavily colonized by anemones and other biota.
17:15:45	3315		P	Ralph putting the mound[s] around on the port side; he says it looks like basalt. Three pictures of very angular blocks completely surrounded by sediment, with sea fans and anemones on the top.
17:16:50	3313		P	Came back down on bottom [after rising up]; some rattail fish, brittle stars; a lot of sediment cover; no mounds visible here. Appears to be a small ridge 1/2 meter high [sediment covered] trending sub-parallel to our heading.
17:17	3310	129	S	Bottom as above but now several meters below.
17:18:00	3311		P	Small ridge now normal to our heading [on port side].

Time	Depth	Hdg°	Obs	Comments
17:18	3311	120	S	Sediment-covered bottom with small mound of what appeared to be basalt, but turned out to be siltstone with a thin black veneer. Heavily colonized with anemones and sea cucumbers. Siltstone too friable to sample.
			P	Ralph is approaching angular basalt blocks surrounded by sediment; attempting to sample. This is more of a hummocky topography. Appears to be a small, orange-red shrimp about 8-10 cm long, with a bright eye [still taking photos].
17:19:30	3313	134	E	Isolated talus of blocky basalt sitting on sediment. The blocks are only lightly dusted with sediment, but are heavily colonized by anemones and other biota.
17:23:30	3313		P	Two photos taken of rattail fish. Ralph just took a [rock] sample, grapefruit-sized, flat piece; has some fauna on it; approximately 6 in x 8 in according to Ralph; sample put in basket [bin] no. 8 [sample 2039-R-1]. [Note: After recovery, this sample is seen to be a greenish-gray mudstone coated by a thin film of black Mn-oxides[?]; views from Osprey video indicate that this sample was taken from thin, flaggy outcrops just at the base of the large [1-2 m] dark blocks mentioned above, which sit isolated above the sediment and mudstone; these large angular blocks are almost certainly basalt.]
17:26	3313	000	S	Leaving siltstone mound and heading over sediment-covered bottom scattered with mounds similar to that described above and randomly spaced about every 10 m.
17:27:30	3312		P	Still in heavy sediment cover; a small amount of bioturbation; a holothurian; a sponge or two; nothing much else.
17:28	3312	000	S	Sediment-covered bottom.
17:29:00	3314	002	E	Abundant feeding traces and signs of bioturbation.
17:29:40	3314		P	Still heading north in small valley; thick sediment cover, moderate amount of bioturbation; holothurians here and there, anemones, sea fans; some white, subrounded, hemispherical shells of some type, very sparse and small [< 5 cm].
17:30	3314	350	S	Following sediment-filled valley trending slightly west of north.
17:31	3313	350	S	Bottom as above.
17:32:45	3313		P	Still in thick sediment cover.
17:35:00	3312		P	Ralph reports a sonar target a little west of north and 170 meters away; we're going to check this out.
			P	Ralph reports a possible basalt outcrop ahead. Some large starfish, anemones, rattail fish; a moderate amount of bioturbation. Looks like a gentle slope ahead of us here. Two holothurians.
17:36	3312	348	S	As above.

Time	Depth	Hdg°	Obs	Comments
17:36:45	3312		P	Coming up still on this slight rise; a gentle slope.
17:38:30	3312		P	Thick sediment cover [still], and moderate bioturbation; very sparse fauna.
17:39	3309	000	S	As above.
17:40:00	3309		P	A few meters off the bottom. Still thick sediment cover. Nothing much visible.
			P	Ralph reports a mound up ahead; he says there is rubble on the mound now visible, but only to the pilot.
17:41:00	3305		P	A few meters off the bottom. Small blocks [rock]; a fair amount of fauna here. The blocks are fairly angular, and look like sheet flow, consisting of thin slabs in part. Turning around and attempting to sample this material [failed because of stirred-up sediment].
17:41	3306	028	S	Approaching mound 2 m across, 20 cm high, gravel-like texture. A few blocks several meters across. Dark colored, angular.
17:41:30	3306	066	E	Small area of sediment-buried sulfide colonized by crinoids.
17:45	3309	058	S	Approaching similar mound to above.
17:45:20	3308		P	Moving slowly; thick sediment cover.
17:48	3305	155	S	Bottom as above.
17:48:30	3305		P	On a topographic high, covered by sediment.
17:49:30	3304		P	We're off the bottom by a fair amount.
17:51	3305	024	S	1 x 2 m block covered with anemones, sea cucumbers, tunicates. Dark grey. Very angular. No glittering crystal faces. Basalt?
17:52:15	3307		P	Back on the bottom now. Still lots of sediment cover. A tiny rattail fish; small amount of bioturbation. No rocks visible at all [from port window]. However, out the front [window], there are some blocks that might be basalt [according to Ralph].
17:53:30	3307	072	E	Worm in sediment tube with three lobes of white filter feeding plume exposed.
17:55	3307	054	S	Leaving outcrop and heading over sediment-covered bottom.
17:55:30	3307		P	We're continuing to head north.
			P	Still heading north, going up a slight rise. Thick sediment cover; bioturbation.
17:58:00	3308		P	Ralph reports a wall to the east as a sonar reflector. We're turning to head east towards this strong reflector.
17:59	3308	032	S	Sediment-covered bottom.
17:59:30	3308		P	A quick picture of a part of a block [shot #11] in the middle of a sediment-covered gentle slope with a lot of fauna on it; hard to tell what it was.
			P	Ralph reports a round hole with a white deposit in it. We're going to go down and investigate this. Apparently it was a gentle gully only a couple of meters deep with nothing in it in the bottom.

Time	Depth	Hdg°	Obs	Comments
18:00	3307	072	S	Hole in sediment, 3 m across, 1 m deep with large white anemone at bottom.
18:02	3308	056	S	Steep sediment-covered slope ahead and to right.
18:02:30	3307		P	Still in thick sediment cover. Heading over towards this reflector to the east.
18:03	3307	057	S	Moving up sediment-covered slope.
18:03:30	3306	057	E	Two generations of venus fly-trap anemones colonizing stalked animal.
18:06	3303	057	S	As above.
18:07:00	3305		P	Large starfish on the bottom; sea fans; brittle stars. We're fairly close to that sonar reflector to the east, which is probably just north of 65,000 on the X coordinate [map scale].
18:08:00	3311	056	E	Mudstone? talus blocks.
18:08:45			P	Some fairly large blocks on this sediment-covered slope. They're still isolated blocks, with white material on them. Could be sediment, but this is unclear. [Also here] one venus fly-trap [trying to photograph]. Ralph reports that these blocks are very friable and loose; the material is probably mudstone sediment. Couldn't get a sample here.
			P	More blocks of rock coming up [ahead]; we might try to get a push core here, if this is indeed sediment.
18:09	3312	062	S	As above.
18:09:30	3311	073	E	Basalt talus on sediment, colonized by venus fly-trap and other anemones. White neogastropod shell? 5 cm long at bottom right of photo.
18:10:15	3308		P	A couple of meters off the bottom. [I see] one of these other [types of] fish with the white head - - not the rattails. Trying to get pictures of this fish.
18:11	3308	094	S	Taking push core of sediment breccia [sample 2039-PC-1]. Breccia up to 5 cm angular fragments.
18:12:00	3308	099	E	Subcropping sulfide?
18:14	3308	085	S	On steep sediment slope with mounds of sediment breccia with gravel-like consistency. Leaving station.
18:16:00	3308		P	Ralph reports that picking up the sediment with the arm, it just crumbles, so we're going to try a push core [attempt fails]; it all falls out [of push core].
			P	Ralph reports the slope is quite steep, all sediment covered; very small clumps of mudstone ahead, however.
18:18	3302	043	S	Moving up steep sedimented slope.
18:19:30	3301	324	E	Folded sheet flow?, sulfide crust?, log?
18:20	3302	231	S	Outcrop of sediment breccia on flat sedimented bottom.
18:21:00	3308		P	More of these apparently mudstone mounds, on both the port and starboard sides.

## Appendix 1

Dive 2039

Time	Depth	Hdg°	Obs	Comments
18:22:00	3306		P	Large blocks, several meters across, of basalt, very blocky; possibly glassy in places [probably not glass after looking at Osprey video and recovered samples].
18:22:00	3305	046	E	Sediment covered, highly fractured basalt flow surface. Sediment appears semi-lithified.
18:23	3303	285	S	Sediment slump several meters across. Sediment breccia of gravel like consistency. On edge of basalt sheet flow 1-2 m high. Dipping 30° from west. Outcrop trending roughly north-south for 25-50 m. Very heavily colonized with what looks like green lichen. Lots of anemones, tunicates, starfish, crabs and tunicates. Biota cover up to 40% of outcrop. Thick sediment layer [10 cm] covering top of outcrop. Took basalt sample here.
18:24:00	3306		P	Ralph is sampling basalt [in same area]. Lots of fauna on this basalt. Collecting a large block [of basalt] with quite a bit of biology on it [sample 2039-R-2]. White "sea squirts" all over this outcrop. Two pictures [hand-held stills camera] taken here. [Completed sampling of basalt outcrop, which forms apparently continuous ledge about 2 m high on top of sediment, with only a thin veneer (20-30 cm) of sediment above; appears to be a sheet flow.]
18:24:00	3306	081	E	Basalt talus on sediment slope.
18:25:00	3306	084	E	Basalt sample in arm.
18:28:30	3306	004	E	Basalt outcrop on slope.
18:28:50	3307		P	[Still at same basalt outcrop.] Swinging around to get video views of this basalt. [Video Osprey suggests this outcrop is about 2 meters thick, both underlain and overlain by sediment; flaggy slabs of locally white mudstone sediment <1/2 meter thick on top of sheet flow (?).]
18:30:08	3306	358	E	Crinoid on basalt talus block.
18:31:16	3305	004	E	Basalt talus on sediment.
18:32:00	3306		P	Heading 250° west-southwest towards the target [hill] area of sulfides [approximately 1 km away]. Moving away from the basalt blocks, thick sediment cover on this [port] side.
18:32	3305	252	S	Leaving basalt outcrop.
18:34:00	3306	251	E	Crinoid on folded sheet flow?
18:36:00			P	Moving 250° [heading] on thick sediment cover.
18:37	3312	252	S	Heading over sediment-covered bottom. Heavily bioturbated. Few anemones, sea pens, sea cucumbers visible. Bottom generally flat apart from a few gentle rises 1-2 m high and 20-30 m apart.
18:41:00	3309		P	Still heading west-southwest towards the massive sulfide target. Passing over a small depression; thick sediment cover, very sparse amount of fauna.

Time	Depth	Hdg°	Obs	Comments
18:46:30	3309		P	Martin is changing the Osprey video tape. Still heading west-southwest 250° bearing towards the sulfide hill; still in thick sediment-covered area, sparse fauna; no rock outcrops at all since we left the basalt sampled at the last locality.
18:48	3303	252	S	As above.
18:51:00	3301		P	Still in thick sediment cover; sparse fauna; very minor bioturbation; no outcrops. We're retaining our west-southwesterly heading towards the postulated sulfide hills. [Terrain in this area consists of alternating shallow ridges and valleys with topographic relief typically of several meters, up to perhaps 5-7 m possibly in one case; these features oriented approximately. NS or NE-SW, perpendicular to heading; all sediment covered.]
18:59	3280	252	S	As above.
19:12:30	3278		P	Approaching the ridge top to get a fix [from ship]; probably 5 or 10 meters off the bottom at this point.
19:14	3278	266	S	As above.
19:14:15	3277		P	Now back on bottom at base of the [sulfide] target area. Thick sediment cover; holothurians; a small mound of bioturbation. No rock outcrops visible.
19:16	3267	251	S	Heading up steep slope consisting of more indurated sediment. Steps of sediment up to 5 cm high poke through sediment.
19:19:00	3257		P	We're near the top of the [sulfide] target hill. Thick sediment cover; nothing of interest so far. Ralph sees one sonar target and we're heading for that.
			P	Picture taken of probable sediment clumps. [These] small lumpy blocks appear to be mudstone, thickly sediment covered. [They may actually be sulfide.]
19:20	3252	272	S	On top of sediment-covered ridge trending north-south. No outcrops in sight.
19:22:30	3253	272	E	Isolated dark talus block on sediment.
19:23:00	3254		P	[Still in same spot looking at small, lumpy mudstone [?] outcrops. Again, they could be sulfide.]
19:26	3253	226	S	As above.
19:29:00	3253	216	E	Small sulfide (?) outcrop in sediment.
19:30:00	3254		P	Starting to take a sample of probable mudstone [?] with a lot of fauna on it. Some larger blocks [here also] with a lot of biology on them. In one case a large block sitting on a thin sheet [outcrop] of mudstone; a perched block, essentially, a couple of meters in diameter; difficult to determine how that [block] could have gotten there. [These blocks may also be sulfide.]
19:30	3253	206	S	Small blocky outcrop 1-2 m across, 10 cm high. Appears to be siltstone. Sampled small piece [10 cm square; sample 2039-R-3].

## Appendix 1

Dive 2039

Time	Depth	Hdg°	Obs	Comments
19:37:00	3254		P	Still sitting among these sediment-covered areas, apparently on or near the top of the small target hill. We're going to move off of the hill because there doesn't appear to be any significant outcrop here worth sampling.
19:39	3253	146	S	Leaving outcrop. Moving over sediment-covered bottom. A few small mounds a couple of meters across and 2-3 cm high. Look like brown crust. Heavily colonized with anemones, starfish, etc.
19:41:30	3254		P	Some small blocks of mudstone [or sulfide] among older thick sediment. We have some really bright sonar targets off to our right that we're going to try and get, if we get the mudstone [sulfide?].
19:42	3252	129	S	Heading over sediment-covered bottom with no outcrops in sight.
19:44:00	3255		P	Still coming upon these sonar targets, but out the port [window] is thick sediment cover with nothing of interest. Ralph reports things [rock] coming up on either side ahead.
19:44	3254	150	S	As above.
19:45	3254	139	S	Large brown block 1 m x 1 m x 0.5 m. Subangular. Heavily colonized by biota. Block sitting on brown crust. When crust broken during sampling, glittering sulfide crystals exposed.
19:45:30	3254	117	E	Isolated sulfide block.
20:05:00			P	Ralph just finished taking both a push core [sample 2039-PC] and a massive sulfide sample, [the latter] with a lot of biology on it. Anemones, some small crabs, a galatheid, and a large pink starfish. The sulfide where it was broken off appears to be massive pyrrhotite [actually mostly chalcopyrite], very old, partly sediment-covered, sitting perhaps 1/2 meter above a sediment-covered bottom, with no other sulfide in sight. [This block of massive sulfide is approximately 1/2 m high, isolated and perched on sediment.]
20:07:00	3254		P	Just starting to move now from that previous sampling locality.
20:07	3254	148	S	Leaving station and heading over sediment-covered bottom.
20:10:00	3254		P	Still in sediment cover, going up a slight rise; [now] apparently a little dip or depression, but nothing visible.
20:11	3254	164	S	Depression in sediment 2-3 m wide, 30 cm deep. Few brown subangular blocks sticking out a few cm above sediment surface. Again, when surface crust broken, glittering sulfide crystals exposed. Sulfide coated with 2-3 mm of brown oxide. [Most of the oxide appeared to have washed off when the samples were examined on the surface].

## Appendix 1

Dive 2039

Time	Depth	Hdg°	Obs	Comments
20:11:00	3254	165	E	Sediment-buried sulfide ridge.
20:18:00	3254		P	Photos 27-29 taken of a baby octopus and sea fans [still sitting in same spot as above].
20:27:30	3254		P	Same spot. Attempting with the starboard arm to sample some possible massive sulfide that is exposed in ledges about 1/2 meter high; several photos taken of that [outcrop] with fairly abundant [fauna].
20:31:00	3254		P	Samples being put in bin 6 with the arm. That sample might have gone in the critter box; Ralph's going to try for another sample.
20:31:15	3254	041	E	Rattail, and two types of sea pen on sediment near sulfide.
20:33:35	3254		P	[Same spot]. Continuing to sample friable ledges, thin crusts of apparently oxidized massive sulfide in a very sedimented area. A fair amount of fauna attached to these outcrops as [favorable] substrate.
20:35:00	3254		P	[Same spot]. This sample is going in the critter box. [Sample 2039-R-4B]. There are therefore two samples in the critter box from two different areas, the first one that had a critter on it, and this one -- the latter one -- that did not.
20:38:00	3254		P	Moving now, searching for additional mounds to sample. Still heavily sediment-covered area. There appear to be thin massive sulfide crusts and ledges intermittently dispersed in this very sediment-covered area. In fact, it's possible that this whole [hill] region is massive sulfide draped by sediment.
20:38	3254	114	S	Leaving station. Generally sediment covered, but sulfide mounds break surface every few meters.
20:39:00	3254	061	E	Sediment-buried sulfide.
20:40:30	3254	046	E	Sampling attempt?
20:41	3254	046	S	Stopping at another sulfide outcrop similar to previously described features. Heavily colonized with biota. Protrudes up to 10 cm above sediment surface. Total exposure of sulfide is only a few square meters, but situated on mound of sediment 0.5 m high and 5-10 m across. Sulfides covered with 2-3 mm of brown iron oxide. Took sulfide samples, push core [sample 2039-PC-2] and box cores [sample 2039-BC-A].
20:44:00	3254		P	The right-hand push core taken in this thin sulfide and sulfidic sediment. Martin is also changing the third video roll for the Osprey.
20:50:30	3254		P	The aft box core -- box core B -- taken at this site [sample 2039-BC-B]. Box core taken in the vicinity of massive sulfide, hopefully with critters on top.
20:53:00	3254		P	Trying to collect a rock from this same area.
20:56:30	3254		P	Two photos taken of small, probable sulfide fragment with a small crab [same spot].

**Appendix 1****Dive 2039**

Time	Depth	Hdg°	Obs	Comments
21:00:00	3254		P	[Same area] Another rock sample taken here [sample 2039-R-5]. This grapefruit-sized rock is put in bin no. 3.
21:08:00	3254		P	[Same area] An unusual creature put in the critter box [sample 2039-B1]. [This is a milky-white, multi-arm type of anemone nearly 1/2 meter in diameter.]
21:09:30			P	All weights away, heading for the surface. [End of dive observations.]
21:10	3254		S	Dropped weights and left bottom.

## DIVE TRANSCRIPT

Location: NESCA  
 Port observer: Campbell  
 Starboard observer: Gamo

Julian day: 162  
 Date: June 10, 1988  
 Pilot: Etchemendy

Transcript of divers' voice recorders; Hdg = gyrocompass heading, Obs = observer (S; starboard, P; port, E; external photo description), comments in ( )'s are diver's comments, comments in [ ]'s are editors clarification.

Time (GMT)	Depth (m)	Hdg°	Obs	Comments
14:45	~80		P	Tape counter: 550. Begin descent. Goal: sample hot springs near sites of dives 2036 and 2037.
14:45			S	Dive started.
14:50	150		P	Port external camera (?)
15:00	425		S	
15:10	713		S	
15:20	1000		S	
15:30	1268		S	
15:40	1491		S	
16:00	1948		S	
16:30	2678		S	
16:40	2861	225	S	
16:43	2900	138	P	Tape counter: 550-900. Approaching bottom.
16:43	2923	138	S	Video tape started.
16:47	3000	137	S	
16:52	3120	138	P	Tape counter: 1240. Assume initial heading was incorrect and that we were sent to wrong spot.
			P	As approaching bottom sonar shows targets oblique to sub heading.
17:00	3267	138	P	Bottom in sight. Sedimented bottom. No sign of hydrothermal [activity]. Target ~800 m away according to surface. Not many critters. Quite a few "chicken" tracks in sediment. Sediment ridge to left under sub. Target 150°, 900 m, a tad off in navigation. Surface: Changed target. Us: What is target then? Surface: Looking for hot water vents, going up large ridge.
		150	P	Ski mark, old <i>Alvin</i> dive weight buried in sediment. Sulfide ridge is old mound, older chimneys buried in sediment.
17:03			S	Bottom in sight. Bottom covered with sediment.
17:05	3267	100	S	Almost [all] sediment.
17:08			S	Sediment easy to resuspend.
17:09			S	Hill in front of <i>Alvin</i> . Climbing sulfide mound (?) covered with sediment.
17:11		150	P	Coming up on another ridge. Worms in sediment, anemone, mud balls, <i>Alvin</i> skid mark (bottom pictures). Ugly fish lying in sediment. Steep ridge to port side (can't see top), all sediment covered, steep sides. Top

Time	Depth	Hdg°	Obs	Comments
				of hill. Shots of hilltop, several settings tried on hand-held [still camera].
17:12			S	Still climbing hill covered with sediment.
17:14			S	Small basin in side of the hill
17:15			S	Almost top of the hill
17:17	3255	149	P	Coming up on another ridge. Lots of mud balls, typical flora and fauna for sediment areas. Rattail on port side, lots of holothurians on sediment coming to top of ridge. Big fish and holothurians in gully to port.
17:17			S	Flat bottom covered with sediment.
17:17:00	3257	149	E	Sediment-covered bottom.
17:18			S	Trouble in benthic camera flash.
17:20			S	Down 2-3 m from sediment-covered hill to flat bottom covered with sediment.
17:22		150	P	Trouble with benthic camera. No strobe. Heading up sedimented hill. White clam shells on port side. Large number of them.
17:23			P	600 m at 140° to target.
17:23			S	Climbing small hill covered with sediment.
17:24			P	Coming up on sulfide mound, covered with sediment. Hand-held pictures and external camera, clam shells, galatheids, 2 or 3. Top of mound, sediment-covered starfish with fingers protruding from sediment. Holothurians, various types, pink holothurian.
17:24			S	Small outcrops of sulfides along the slope.
17:24:00	3241	145	E	Sediment-covered sulfide exposed on steep slope.
17:24:48	3234	144	E	Top of sediment-covered scarp, no sulfide.
17:25			S	Many outcrops of sulfide or basalt (?). All outcrops covered with sediment.
17:25:15	3232	145	E	Minor amounts of sulfide crust on sediment slope.
17:27			S	Small step upward, covered with sediment.
17:27:30	3230	144	E	Top of sediment scarp or channel.
17:28		140	P	Ridge dropping away at a step Starting up another ridge.
17:28	3230	145	P	Data display, back to SIT camera, small ridge to port. Step down to starboard, large hill ahead. Eel-like fish and rattail together, large fish in distance (hand-held picture), large holothurians, shrimp, starfish, anemones. No signs of hydrothermal activity. (120°, 350 m to target). Small pink holothurians, quite a few. Going over small gully.
17:29		144	S	Small step downward, covered with sediment.
17:29:00	3230	144	E	Meander bend in top of channel.
17:30			S	Flat bottom covered with sediment.
17:30:00	3230	144	E	Possible clam shell.
17:32			S	Small step downward to flat bottom covered with sediment.
17:32:30	3233	130	E	Sediment channel.

## Appendix 1

Dive 2040

Time	Depth	Hdg°	Obs	Comments
17:34	3236	120	P	Ridge coming up ahead of sub. Come up off bottom to get a fix (~100 m)
17:34	3236	120	S	All sediment.
17:38	3165	121	S	Going upward.
17:40	3136	120	S	Down again.
17:45	3199	120	S	Reset for video timer (to 50 minutes)
17:48	3237	121	P	Back near bottom. Targets on ridge ~100 m away. "Big ugly" rattails (2) ahead (hand-held pictures, bottom all muddy. Coming up on another ridge (fairly steep-covered in mud).
17:48			S	Bottom in sight.
17:48	3238	121	S	Flat bottom covered with sediment.
17:51			P	Top of ridge. Step ridges increase steeply then fall off slightly.
17:51			S	Step downward. All sediment.
17:51:00	3238	121	E	Clam shells and galatheid crab.
17:52			P	Area of many clam shells. Pods of clams, off to port. Many clams, all appear to be open, no obvious chimneys (speculate that clams brought to area by predator). (Later informed that they live in sediment).
17:52			S	White fragments of dead clam shells within an area with a few meters radius.
17:54	3242		S	Downward at the edge of a hill. Outcrops of sulfides covered with sediment.
17:55			P	(100°, 65 m to target). Large sulfide mound on starboard side. Clam shells on bottom. About 2 dozen strewn along bottom, various sizes, galatheids, some buried partially in sediment, ~6 galatheids to port.
17:58	3258	120	P	"Right on target ~1 minute ago" from surface. Turn around to head north (sonar caught plume sampler), water murky, lots of clamshells below. (Murkiness may be our own cloud.) Pat reports sulfide mound ahead.
17:58			S	Downward at the edge of a hill covered with sediment.
18:01			S	White crabs on a top of a hill covered with sediment.
18:02:15	3255	252	E	Large sulfide slab on sediment-covered slope.
18:02:30	3255	248	E	Broken pavement of sulfide slabs 1 m across.
18:02:45	3254	252	E	Massive sulfide with slabs of sulfide and chimney base.
18:03			P	Easing up hydrothermal mound. Sediment at base, sulfide outcrop, Osprey on ~4600 on counter, large sulfide, massive edifice coated with sediment. Galatheids around, but no tube worms or signs of activity.
18:03			S	Slightly climbing up sulfide outcrops (maybe mound) slope.
18:05			S	Big benthic fish (armatus?) on a sulfide mound.
18:03:45	3250	239	E	Massive sulfide with slabs of sulfide.
18:04:15	3250	237	E	Top of sulfide mound.
18:05:20	3250	256	E	Fissures in massive sulfide.

## Appendix 1

Dive 2040

Time	Depth	Hdg°	Obs	Comments
18:06:45	3251	323	E	Steep sediment-covered slope.
18:07	3249	324	P	Ridge ahead, nothing on it (Trip plume samplers to try to free up sonar.) Pat: "Stuff up higher". Base of another mound. Clam shells out window.
18:09			S	Climbing a slope of a mound covered with sediment.
18:10	3241	327	S	
18:11	3241	327	P	Slowly climbing mound, see only sediment. Surface: "Pat: Standby: Target was incorrect: ~1000 m from proper target". Before we start driving 1 K let's check out some targets in this area (to the north). Galatheid inside clamshell (eating it?) Took hand-held [camera] picture of it.
18:14	3242		S	Community of 10-15 living (?) clams standing on a slope of a hill.
18:15	3248	~036	P	Pat spots sulfides, hunt around. Top of mound is dead, but to left is large chimney structure (has sediment on it). White specks all over rocks, no tubeworms. Large massive sulfide blocks, hand-held [picture] of galatheids, blocks of sulfides covered with what looks like slime, white slime.
18:15:51	3241	053	E	Fissured sulfide with some sediment cover.
18:16			S	Big sulfide.
18:17			S	Several massive sulfides. Moving slowly downward.
18:17:00	3241	349	E	Massive sulfide mound covered with white biota including bacterial mat.
18:19	3240		P	Big hole below us full of "white stuff", X-Y coordinates given from surface. Attempt to sample first sulfide collected on [dive] 2040 ("don't want this to be a complete loss"). Plot out position on map. Near asterisk on navigation plot. Osprey on ~5290 on counter).
18:19	3240		S	In a small basin surrounded by sulfide outcrops, some sulfides look like dead chimney.
18:23			S	Sampling started.
18:23:59	3243	278	E	Brecciated massive sulfide mound covered with bacterial mat. One small cluster of tube worms near center of photo.
18:24			P	Dead tube worms. Sampling of sulfide with anhydrite mound covered with goo; white specks [sample 2040-R-1], Osprey shot of sulfide samples; S1, counter at 5425, middle front basket #2, Osprey footage of area, apparent fractures in mound [which] died in recent past and is starting to fall apart.
18:26:40	3243	291	E	Sulfide sample in arm.
18:28			S	Sulfide samples taken (Basket 5?) [sample 2040-R-1]
18:29:15	3241	265	E	Brecciated massive sulfide.
18:30			P	Attempt to sample starfish; no good. Begin trip north to correct quite a few other targets in area, look at another one before we go, mound is apparently dead,

Time	Depth	Hdg°	Obs	Comments
				have visited ~6 mounds in area, no obvious signs of activity so decide to head back to "correct target". Navigation originally was correct. Sent us to wrong target here. Now sending us back to original target, decide to travel mid water back north since we already covered that area.
18:36	3240	North	P	End of video tape 1.
18:45	3210	2	S	Northward to the target.
18:54			S	Bottom in sight.
18:54	3246	327	S	
18:55			S	Flat bottom covered with sediment.
18:56			S	Small up and down [bathymetry?].
18:57:54	3244	302	E	Sediment covered slope.
19:00			S	Coming up a hill covered with sediment.
19:01	3235	336	S	Reached a sulfide field, several dead chimneys standing. [ <i>Alvin</i> ] slowly [going] down.
19:02:00	3236	354	E	Massive sulfide.
19:05:04	3238	127	E	Small sulfide chimneys protruding above sediment-covered sulfide.
19:06			S	2 white crabs on a top of a 2-3 m dead chimney.
19:06:40	3239	118	E	Barite chimneys and barite crust in sediment, local areas of bacterial mat, at the base of a massive sulfide mound.
19:07			S	Sediment easy to resuspend.
19:13	3240	256	S	Going toward the target.
19:14:15	3255	254	E	Sediment-covered bottom.
19:16	3261	242	S	Down a hill slope.
19:18			S	Slope down the starboard side. All covered with sediment.
	3262		S	Up a slope.
19:21			S	Steeply downward, crossing a mound covered with sediment. No flat bottom due to sulfide outcrops.
19:23	3265		S	Almost reached the target.
19:23:00	3264	172	E	Massive sulfide.
19:24			S	Starfishes and anemones occasionally.
19:26			S	Big dead sulfide chimney (5-10 m high?)
19:26:45	3261	118	E	Fissured sulfide crust at the top of 5 m high massive sulfide mound.
19:28:30	3261	096	E	Sediment-covered bottom.
19:32			S	In a sulfide field, rather small fragment of sulfide.
19:32:30	3257	071	E	Massive sulfide.
19:33:30	3255	100	E	Coalesced chimneys at near the top of massive sulfide mound.
19:37	3256		S	
19:38			S	Starfish in a grey box sampled.
19:40		242	S	Sediment.
19:42			S	Small fragments of sulfide covered with sediment.
19:43:15	3261	309	E	Sediment-covered bottom.
19:53	3263	183	S	Big sulfide mound before <i>Alvin</i> .

## Appendix 1

Dive 2040

Time	Depth	Hdg°	Obs	Comments
19:53:00	3274	184	E	Massive sulfide.
20:01:00	3275	153	E	Barite chimney on sediment-covered sulfide.
20:02	3270		S	Two dead chimneys.
20:03	3271		S	Found warm water shimmering.
20:03:00	3210	336	E	Massive sulfide mound covered with bacterial mat and tube worms.
20:08			S	Water temperature measurement started: 108, 109, 109, 110, 109, 110, 108, 109, 109, 109, 109, . . . , 107, 109, 110, 108, 107, 108, . . . 2(°C).
20:11:00	3271	311	E	Temperature probe and tube worm covered mound.
20:12			S	Water sampling started.
20:25			S	Pair #4 water sampling [samples 2040].
20:35			S	Pair #3 water sampling.
20:37	3271		S	Sulfide sampling started (basket 2?) [samples 2040-R-2, 2040-R-4].
20:42			S	Marker 3 on the bottom (in front of the vent).
20:44:00	3270	305	E	Marker 3 on tube worm-covered mound.
20:46:00	3274	213	E	Sediment-covered bottom.
20:49	3274		S	Box core sampling port side.
20:50			S	Box core #1.[sample 2040-BC-A]
20:52			S	Sample corer (2 Corers).[samples 2040-PC-1, 2040-PC-2].
20:52:00	3274	218	E	Push core in arm.
20:58			S	Box core #2. [sample 2040-BC-B]
21:09	3270	121	S	Several dead sulfide chimneys covered with sediment. No creatures.
21:11			S	Many chimneys surround <i>Alvin</i> . No creatures around.
21:13			S	Began to coming up [end of observation].
21:40	2307			
22:56			S	On surface.

## DIVE TRANSCRIPT

Location: NESCA

Julian day: 163

Port observer: Grassle-no transcript prepared

Date: June 11, 1988

Starboard observer: Foster-no transcript prepared

Pilot: Etchemendy

Transcript of divers' voice recorders; Hdg = gyrocompass heading, Obs = observer (S; starboard, P; port, E; external photo description)

Time (GMT)	Depth (m)	Hdg°	Obs	Comments
18:23:30	3242	254	E	Temperature probe in vent.
18:30:30	3242	254	E	Sulfide rubble at the base of the mound.
18:44:30	3243	219	E	Scoop net on bottom slope of mound.
18:45:30	3243	245	E	Lithified plates of barite? on side of mound near marker 6X, some tube worms on surface.
18:47:00	3241	231	E	Shimmering water from ridge below 6X.
19:45:00	3240	287	E	Marker 6X.
19:57:30	3241	183	E	Marker 0.
19:58:30	3239	143	E	Active vent near 0.
20:19:00	3245	143	E	Sediment-covered bottom between sulfide mounds.
20:25:30	3244	290	E	Sulfide talus at base of active mound.
21:36:25	3242	195	E	Brecciated massive sulfide on second mound, some vent fauna.
21:41:24	3234	177	E	Tube worms on massive sulfide.
21:13:48	3225	123	E	Top? of sulfide mound 20 m high.
21:45:16	3223	096	E	Sediment-covered bottom.
21:54:30	3235	122	E	Sediment-covered slope.

## DIVE 2042

Location: NESCA

Julian day: 164

Port observer: Edmond-no transcript prepared

Date: June 12, 1988

Starboard observer: Campbell-no transcript prepared

Pilot: Hollis

Transcript of divers voice recorders; Hdg = gyrocompass heading, Obs = observer (S; starboard, P; port, E; external photo description).

Time (GMT)	Depth (m)	Hdg°	Obs	Comments
16:53:37			E	Marker 6X.
16:54:45	3241	163	E	Sediment onlapping base of 220° C mound.
16:55:47	3239	196	E	Tube worms near marker 0.
16:57:34	3234	166	E	Tube worms on adjacent tall mound.
17:00:16	3224	136	E	Sediment-covered slope SE of tall mound.
17:00:40	3223	157	E	<i>Alvin</i> weights in mud.
17:05:52	3229	140	E	Sediment channel.
17:37:41	3262	183	E	Clams in sediment.
17:38:30	3263	214	E	Slabs of hydrothermal crust on sediment slope with vent fauna.
17:42:00	3260	180	E	Massive sulfide blocks in sediment with abundant bacterial mat and vent fauna including barnacles? at middle right edge of photo.
17:51:30	3254	211	E	Massive sulfide and sulfide talus.
18:02:15	3253	196	E	Top of 7 m high sulfide scarp on graben wall, sediment buried at top.
18:16:30	3250	201	E	Fractured sulfide crusts in sediment.
18:18:30	3249	194	E	Massive sulfide edifice built above crust.
18:19:30	3249	168	E	Clams in sediment.
18:20:45	3249	227	E	Sediment-covered sulfide.
18:24:00	3248	181	E	Tube worms on massive sulfide.
18:36:30	3249	150	E	Sediment-covered sulfide at base of mound.
18:40:00	3251	180	E	Abundant clams in sediment with hydrothermal crusts.
18:44:30	3251	104	E	Large fish over sediment-covered bottom with clams.
18:45:00	3251	080	E	Octopus dining on clams.
18:50:30	3254	231	E	Abundant clams in sediment with sulfide crusts. Some clams are colonized by anemones.
19:27:28	3261	039	E	Live clams in sediment including some colonized by anemones.
19:30:15	3266	204	E	Large mudstone talus block, clams less abundant.

<b>Dive 2033</b>					
<u>Sample #</u>	<u>Time</u>	<u>X</u>	<u>Y</u>	<u>Depth</u>	<u>Comments</u>
2033-R-1	19:13	58916	55785	3248	Large sulfide fragment collected from low sulfide mound.
2033-R-2	19:20	58886	55716	3236	Two brisingid stars and a small sulfide fragment, tip of spire.
2033-R-3A&B	19:57	58858	55848	3271	Two sulfide chimneys.
2033-R-4	20:23	58880	55707	3249	Bivalve shell, deployed marker 9V.
2033-R-5	21:40	58760	55460	3257	Two large fragments of massive sulfide from talus, deployed marker 6-dot.
<b>Dive 2034</b>					
<u>Sample #</u>	<u>Time</u>	<u>X</u>	<u>Y</u>	<u>Depth</u>	<u>Comments</u>
2034-R-1	19:03	60230	57595	3354	Three pieces of sediment covered basalt.
2034	20:07	59810	56905	3366	Sunken log and associated biology.
2034-BC-A	20:07	59810	56905	3366	Collected about 10 cm away from a sunken log colonized by small galatheid crabs and other fauna. The log was collected between taking box core A and B. There were abundant worms in the sediment near the log and several holothurians in the area. Hand-held camera, external camera, and video camera pictures exist for this site.
2034-BC-B	20:29	59810	56905	3366	Core B was taken about 3 m away from and slightly uphill from core A in an area with normal sediment cover.
<b>Dive 2035</b>					
<u>Sample #</u>	<u>Time</u>	<u>X</u>	<u>Y</u>	<u>Depth</u>	<u>Comments</u>
2035-1	18:54	58140	53100	3298	Massive sulfide.
2035-3	19:15	58114	53223	3298	Sulfide block and holothurian.
2035-3	19:27	58114	53223	3298	Tunicate and small sulfide.
2035-2	20:28	57395	54050	3303	Massive sulfide.
2035-PC-1	21:36	57260	53040	3180	Push core 24 cm long. Light grey mud to 9 cm, black layer present below 18 cm. 16 samples for pore fluid chemistry.
2035-PC-2	21:36	57260	53040	3180	Cores taken at end of dive on the top of the uplifted Southwest (sediment) Hill. The top of this hill appeared to an area with very low sedimentation, possibly eroded, which is swept by strong bottom

currents. Isolated bioturbation mounds are common.

2035-BC-AB 21:36 57260 53040 3180

## Dive 2036

Sample #	Time	X	Y	Depth	Comments
2036-R-1A	18:06	58835	55405	3239	Piece from 220°C vent near marker 0.
2036-1A	18:15	58835	55405	3239	Five to eight small pieces from 220°C vent near marker 0.
2036-1A	18:24	58835	55405	3239	Triangular piece from 220°C vent near marker 0.
2036-1A	18:26	58835	55405	3239	Small piece from 220°C vent near marker 0.
2036-1A	18:42	58835	55405	3239	Basketball size sample from area of 220°C vent near marker 0.
2036-B1	19:10				Tube worms from vent near marker 0 and sulfide-sulfate substrate.
2036-R-2	19:52	58832	55410	3240	Seven pieces from vent near marker 6X.
2036-W1	18:45	58835	55405	3239	Vent fluid from 220°C vent near marker 0.
2036-W2	18:52	58835	55405	3239	Vent fluid from 220°C vent near marker 0.
2036-W3	20:24	58832	55410	3240	Vent fluid from vent near 6X.
2036-W4	20:34	58832	55410	3240	Vent fluid from vent near 6X.

## Dive 2037

Sample #	Time	X	Y	Depth	Comments
2037-R-1	21:43	58836	55376	3235	Two sulfide samples with biology attached from mound with tube worms where fluid samples 2&3 were taken.
2037-W1	18:44	58767	55407	3250	Fluid sample from worm tube colony at 18°C vent.
2037-W2	21:25	58836	55376	3235	Fluid sample from worm tube colony at 13.5°C vent.
2037-W3	21:20	58836	55376	3235	Jugs tripped above worm tube colony at 13.5°C vent.
2037-W4	21:34	58836	55376	3235	Fluid sample from worm tube colony at 13.5°C vent.
2037-B1	21:25	58836	55376	3235	Worm tube colony at 13.5°C vent.

## Dive 2038

Sample #	Time	X	Y	Depth	Comments
2038-R-1	18:19	58758	65250	3264	Sulfide colonized by biota.
2038-R-2	20:39	59020	65280	3265	Sulfide.
2038-R-3	20:39	59020	65280	3265	Sulfide.
2038-B1	21:27	59072	65290	3267	Anemone.

**Appendix 2****Sample Descriptions**

2038-PC-1	21:24	59072	65290	3267	12 cm-long push core, 11 samples for pore fluid chemistry.
2038-PC-2	21:24	59072	65290	3267	12 cm-long push core, 11 samples for pore fluid chemistry.
2038-BC-AB	21:01	59072	65290	3267	Box cores taken side by side in area of normal sediment-covered bottom. Some video of the site.

**Dive 2039**

<u>Sample #</u>	<u>Time</u>	<u>X</u>	<u>Y</u>	<u>Depth</u>	<u>Comments</u>
2039-R-1	17:23	61340	65295	3313	Flat olive-grey siltstone.
2039-R-2	18:24	61415	65920	3305	Large block of basalt colonized by biota.
2039-R-3	19:30	60100	65600	3254	Massive sulfide.
2039-PC	20:05	60128	65582	3254	Chalcopyrite-rich massive sulfide.
2039-R-4B	20:35	60100	65600	3254	Oxidized massive sulfide with biota.
2039-R-5	21:00	60120	65540	3254	Massive sulfide.
2039-B1	21:08	60120	65540	3254	Strange 8-armed anemone.
2039-PC-1	18:11	61390	65830	3308	Push core through siltstone breccia.
2039-PC-2	20:44	60120	65540	3254	13.5 cm core collected near sulfide breccia. 12 samples for pore fluid chemistry.
2039-BC-AB	20:50	60120	65540	3254	Box cores taken at end of dive near sulfide sampling site. This area had numerous small outcrops of old, inactive sulfide that were heavily colonized by biota. The area is predominantly sediment-covered at the surface, but may be underlain by sulfide. Some video footage of the site.

**Dive 2040**

<u>Sample #</u>	<u>Time</u>	<u>X</u>	<u>Y</u>	<u>Depth</u>	<u>Comments</u>
2040-R-1	18:30	59179	54879	3243	Pyrrhotite-rich sulfide sample.
2040	~20:30	58525	55420	3271	Three water samples taken from 108°C vent.
2040-R-2	20:37	58525	55420	3271	Sulfate sample.
2040-R-4	20:37	58525	55420	3271	Sulfate sample.
2040-PC-1	21:00	58500	55410	3274	8 cm push core taken a few meters from 108°C vent. Some sediment lost in quiver; black tar recovered from quiver.
2040-PC-2	21:00	58500	55410	3274	14 cm push core taken a few meters from 108°C vent. Crystalline layer at 6-8 cm. 12 samples taken for pore fluid chemistry.
2040-BC-AB	20:50	58500	55410	3274	Box cores taken in sediment-covered area a few meters away

from active vent with 108°C water and vent fauna. Video coverage of sampling site.

Dive 2041					Comments
Sample #	Time	X	Y	Depth	
2041-R-1		58834	55402	3240	Video shows two water samples, one anemone, and one rock sample collected near 6X.
2041-BC	21:10	58824	55396	3244	Box core taken at base of sulfide mound with 220°C vent. Top flaps on core pre-tripped. The sampling site is covered by video.

Dive 2042					Comments
Sample #	Time	X	Y	Depth	
2042-PC	~17:45	59270	54953	3260	Push core site on video.
2042-R-1	~18:00	59249	54937	3253	Rock sample in bin 8.
2042-B1	19:00	59270	54585	3254	Clams collected from sediment-covered area with extensive clam field. Hydrothermal deposit occurs a few meters away, the thin surface sediment is underlain by hydrothermal crusts and black, presumably sulfidic, sediment. Good video coverage of the site.
2042-BC-AB	20:04	59135	54435	3260	Cores taken in a sediment-covered area with hummocky topography. The core site is probably in the bottom of a small (erosional?) channel. There is some layered siltstone exposed on the slope in the background and some mudstone talus in the area where the cores were taken. Core B is reported to have a "fluff ball", presumably a xenophyophorian, on top. Video coverage of sampling site.