DEPARTMENT OF THE INTERIOR

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DIVE REPORT: ALVIN DIVE #1461

September 28, 1984 (JD 272)

Plume Site, Southern Juan de Fuca Rift

by

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Abstract

Dive 1461 was the seventh of nine dives during a sea-going field program to investigate hydrothermal activity along the crest of the southern Juan de Fuca Ridge. During this dive on the Plume site, ALVIN crossed the western floor of the axial valley and traversed about 300 m of the rim and floor of the narrow inner cleft. Hydrothermal vents were observed only along the east wall of the inner cleft, and venting was concentrated in a single area less than 50 m long near the base of that wall. The principal vents extended up the wall from the floor of the cleft to a height of about 10 m. Deposits of hydrothermal minerals occur as incrustations and chimneys on the floor and wall of the cleft. Associated with the hydrothermal vents is a community of vent organisms dominated by vestimentiferan worms and fluffy materials of uncertain nature.

The inner cleft at the Plume Site is about 60 m wide and 15-30 m deep. It has a simple U-shaped profile north of the active vent area, but to the south it contains at least one high, narrow ridge which converges with the east wall of the cleft at the site of hydrothermal venting. This area was also the site of a volcanic eruption, which occurred sometime earlier. Like many similar but subaerial examples, this eruption was episodic, but the cause of its interruptions is not yet known. The present hydrothermal activity appears to be a residual effect of that last eruption, and the rate of hydrothermal deposition will probably decline in this area until another eruption occurs.

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INTRODUCTION

Dive 1461 was the seventh of nine made along the southern Juan de Fuca Rift in September 1984 (Normark and others, 1986). Its purpose was to examine by submersible the Plume site that had been photographed previously using deep-towed camera systems (Fig. 1; Normark and others, 1984). Dive #1461 was preceded by one other (Dive #1457 by K. von Damm and R. Koski) in the same area and followed by a third (Dive #1462 by K. von Damm and R. Zierenberg). Each dive traversed a part of the axial valley floor and collected samples from the main hydrothermal vent area. Dive #1461 was focused especially on the structure, lava-flow morphology, and volcanic history of the Plume site.

The dive traverse is summarized in Table 1; it is shown in map view on Figure 2 and in profile on Figure 3. We first made visual contact with the valley floor about 300 m west of the inner cleft. We traversed eastward into the cleft and then south about 100 m to the main vent area near the base of the east wall of the cleft. After collecting a suite of samples (Tables 2, 3), we ascended to the east rim of the cleft, traversed southward along the rim for about 300 m, descended again into the cleft, and returned along the base of its east wall to the main vent area, where we attempted further sampling until making our final ascent to the surface.

NAVIGATION

Transponder triangulation was used to locate ALVIN frequently during the dive, and weighted floats were deployed in order to mark places that could be relocated during later investigations. During this dive we reoccupied the site of marker [0V], which had been deployed during dive #1457, and we deployed 8 new markers at sites of sampling or of other special interest. Floats [0-] and [1X] mark the western and southern extremeties, respectively, of the dive traverse; [3X] and [0X] mark morphologic boundaries on the floor of the axial valley west of the inner cleft; [4/] and [4V] mark the northern and southern ends, respectively, of the main vent area on the floor of the inner cleft. Float [5V] was placed on the east rim of the inner cleft above the main area. Float [2-] was dropped accidentally and fell by chance onto a sloping part of the cleft wall a few meters below [5V].

The confidence in navigation is shown by symbols on Figure 2. Navigation was excellent during much of the dive, especially when high precision was obtained in three-range transponder fixes. The best-navigated parts of the dive are the initial west-to-east traverse from marker float [0-] past float [0X], and on the east rim of the cleft in the vicinities of [5V] and [1X]. Navigation is less certain in areas where there were long time gaps between transponder fixes. Most of these gaps were filled using progressive vector plots (PVPs), especially during our traverse across the axial cleft (18:06 to 18:25), part of the traverse south along the east rim (21:22 to 21:33), and the traverse north along the base of the east wall (22:03 to 22:21). In a few places our tape-recorded verbal notes were used to approximate the dive track. Except for the gap in navigation along the east rim, most long gaps between fixes occurred where we were shadowed from the tethered transponders by the high, steep east wall of the cleft. A few apparently reliable fixes were obtained within the cleft at places where we were not especially close to that wall; the west wall is apparently less steep and more step-like than the east wall and did not seem to interfere as much with our transponder navigation.

The most important consequence of navigational uncertainty is a lack of precision in locating the main hydrothermal vent area near the base of the east wall. We have no fixes within the cleft anywhere near this vent area, though marker float [5V] is well-located on the cleft rim above it. In the absence of navigated fixes, the locations of marker floats [4/], [0V], and [4V] are inferred approximately; the accuracy of these positions is believed to be about 5-10 m. Fixes obtained during the other dives to this area may help to locate these floats better.

STRUCTURE OF THE INNER CLEFT

The cleft seems to be a simple graben about 80 m wide in the area where we crossed it 50 m north of the main hydrothermal vents (Figs. 5A, 6). Though its base is hidden by talus, the visible part of the west wall rises steeply as a single vertical step more than 10 m high. Its face has a massive appearance from plastering by multiple layers of younger lava. The east wall too seems to be high and steep in this area, but we did not ascend to its rim. The east wall also is plastered, and in addition it is draped discontinuously by even younger lava that has flowed down from above and built low lava cones in front of its base. Neither wall shows any sign of major displacement since being veneered by the lava. (A few cm of displacement may be recorded by the 18:09:15 photograph of a possible fault near the base of the west wall.) The floor of the cleft appears unbroken; we saw no fissures, and the floor is nearly flat except for a possible trough 1-2 m deep near the base of the west wall. This trough is not sharply defined, and short pillars along it suggest that it is a lava channel or some other product of lava-flow subsidence. It could be a small interior graben or fault sag, however, that was veneered by younger lava.

Farther south, the cleft is deeper and has a more complicated structure, but there we examined only its eastern part. Near the hydrothermal vents, the east wall appears to be bordered by a narrow terrace or horst about 10 m high (Figs. 5B, 6), and south of these vents a narrow horst-like ridge seems to diverge from the wall to enclose an interior graben more than 20 m deep (Figs. 5C, 6). These features were not recognized during the dive and have been identified later only through detailed analysis of the dive data. Their nature is still not certain because of inconsistencies in the depth recordings and uncertainties in thenavigation. The evidence for their interpretation will now be described in more detail.

East wall at main hydrothermal vents. The east wall between [4V] and [5V] is more than 30 m high and is not a simple massive cliff. During the dive we recognized a narrow ledge on its face, but we did not realize then that this ledge supported a cluster of hydrothermal vents 10 m above those we sampled at [4V]. We began to suspect this from conversations with R. Zierenberg, who (in Dive #1462) observed chimneys in this area at two distinctly different depths. Such vents at two depths could explain our observation of apparently enormous chimneys still rising high above us after we had climbed some distance up the east wall. This possibility provoked a detailed re-analysis of our climb up the wall.

Our observations in the interval 20:24-20:37 are summarized on Figure 4. When we rose from [4V] at 20:24, our view was obscured by a thick cloud of sediment that we had stirred up during sampling. At first our heading was SSW, nearly parallel to the trend of the cleft, but as we rose we rotated counterclockwise in order to face the east wall. At about 20:27, when our depth was 2228 m and the floor was 12 m beneath us, we stopped climbing in order to examine the east wall above the cloud of suspended debris. At about 20:29 we began to rotate slowly clockwise so that the port observer could see the wall, and at about 20:30, when we were once again headed SSW, two large chimneys could be seen to port, rising out of the sediment cloud to a height several meters above the viewport. According to our altimeter at that time, the seafloor was still 8 m beneath us (at a depth of 2036 m), and we inferred that the chimneys must be more than 10 m tall, implicitly assuming that they rose from the floor of the cleft. Shortly after this, however, as we began to rotate counterclockwise again to approach the chimneys, the seafloor rose sharply so that we were only 2 m above it when we bumped against one of the chimneys. After an interruption caused by the bumping, we continued to rotate counterclockwise, and at 20:32 we began to rise again. As we did so, we could see beneath us a horizontal surface thickly coated with yellow organic mats and many tube worms. Then at 20:33, as we continued to rotate slowly, the altimeter showed the seafloor falling away again steeply. By 20:34:07, when the forward-looking external camera recorded the top of a chimney ahead of us, seafloor depth had again reached 2238 m. As we then rose faster and moved forward, the altimeter recorded another sharp rise in the seafloor, which peaked at 2224 m at about 20:35:30. The seafloor then dropped again sharply to 2230 m at about 20:36:20 before beginning its final rise to the east-rim depth of 2212 m.

These observations are best interpreted if we consider the location of the downward-looking sonar altimeter on ALVIN's hull, which at the time of this dive (according to Arnold Sharp, head engineer of the ALVIN group) was mounted 8 inches forward and 24 inches below ALVIN's port viewport. The two large chimneys must have been standing on a platform that rose sharply about 10 m above [4V] such that the altimeter still recorded the cleft floor when they were first seen to port at about 20:30 but recorded the platform as it rotated past them at 20:31-20:34. The altimeter later recorded the top of one chimney as it passed directly above it at about 20:35:30. The shape of the platform is not resolved clearly by the sonar record; it could have been a narrow ledge protruding from the wall, or it could have been a detached ridge as shown in Figure 5B.

<u>Eastern cleft at south end of traverse</u>. During the dive we also misunderstood the east wall at the south end of our traverse. We had intended to drive out over the cleft and descend to its floor while turning around to face the east wall, then make a photographic traverse up that wall; during the dive we thought we had done this. Some of our visual observations were puzzling, however, and our navigation fixes and azimuth records show that we examined instead the east-facing wall of an apparently narrow ridge within the cleft.

Our observations during 21:44-22:06 are summarized on Figure 4. After leaving [1X] heading north, we passed over the east rim of the cleft at 21:45 and then began turning counterclockwise toward the west. At about 21:47:45 we unexpectedly crossed over the flat crest (photographs STBD 3-18, STBD 3-20) of a rocky wall at a depth of 2223 m, about 10 m below the rim of the cleft. At that time we assumed that we were still heading west and thought that this crest must represent a ledge or alcove on the east wall. But the data logger shows instead that we had continued in a tight turn as we descended and were heading ESE when we crossed the wall. We then maintained that heading through 21:54, and the lava-draped wall recorded at 21:52-21:54 must have been the true east wall of the cleft. After 21:54 we began to rotate clockwise and were again heading southwest when we neared the seafloor at 21:56. We then began a photographic traverse up the wall in front of us under the illusion that it was the east wall of the cleft, facing west. This wall proved featureless, however; so we broke off the traverse and by 22:00 lost contact with the wall at a depth of 2224 m before seeing its top. We then returned to the floor. Though at that time we thought we had examined the west-facing east wall of the cleft, our true position farther west is indicated by two good fixes at 22:02:22 and 22:02:52 as we re-descended.

In our present interpretation, shown on Figures 5C and 6, a narrow ridge crests at a depth of 2224 m about 30 m west of the east wall of the cleft. Between this ridge and the east wall is a lava lake whose floor has sagged to a depth of 2246 m. The depth and character of the floor is inferred largely from visual observations and depth records between 21:50 and 22:10. This interpretation is not consistent with the depth records between 21:46 and 21:49; according to those records, the floor of the inferred depression descends only to a depth of about 2230 m instead of 2246 m. Greater depths were found only after 21:49. The depth data are noisy, however, and we believe that systematic errors have produced the apparent differences in seafloor depth before and after 21:49:30. We prefer to accept the data after 21:50 and ignore the shallower depths recorded between 21:46 and 21:49. The dotted profile on Figure 5C shows an alternative interpretation in which the eastern depression has a shallower depth. Additional analysis of depth data from Dive #1457 may lead to further reinterpretation of this area.

Structural synthesis for the southern area. Our zigzag northward traverse after 22:05 showed that the ridge within the cleft converges with the east wall northward, so that by about 22:15 we could see at the same time the east wall to starboard and the ridge to port; the inner depression here must have been only 10-15 m wide. At about 22:17 the ridge had neared the wall so closely (probably about 5 m) that we had to cross over its crest at a depth of about 2228 m. We then went along its west side above talus to the vicinity of [0V]. In Figure 6, a ledge above [0V] is shown to grade into a narrow ridge diverging from the east wall southward. The northward extent of the ledge is not known; it may merge into the wall only a few dekameters north of [4V]. A fracture between the ledge and the main wall may extend northward in the wall as a source vent for lava drapery observed on the lower part of the wall north of [4/].

The nature of the west wall and floor west of the interior ridge is not known from this dive. Information from Dive #1457 suggests that the west wall in this area south of the hydrothermal vents is vaguely defined and descends in a series of steps. (This is uncertain, however; post-cruise analysis suggests that the apparent steps may be artifacts of errors in ALVIN depth/altitude data.) There may be a step also in the floor of the cleft, such that it deepens rapidly about 10-20 m near the northern part of the main vent area. Certainly the eastern margin of the cleft deepens in this area around marker float [4/] (Fig. 3), but it is not clear if this deepening represents a step extending across the floor or a more restricted depression along the east wall. Whatever its nature, stepping in the west wall or floor of the cleft probably arises from the en echelon or splaying faults that are evident in the SeaMARC II image of this area. The main vent area of the Plume site may be localized at an intersection of these structures. Further detailed analysis of data from Dives #1457 and #1462 should define better these complications in the structure of the cleft.

LAVA ON THE MAIN VALLEY FLOOR

We found evidence that several separate lava flows--at least three, and perhaps six or more--occur on this segment of the valley floor. These flows are distinguished from each other by morphologic criteria and form three groups: an outer fringe of older uncollapsed flows, a broadly subsided flow, and younger flows on the collapsed floor of the subsided flow. All of these flows seem to have spilled from the axial cleft onto the main valley floor. Though they seem to represent separate overflows, their similar sediment cover suggests that they are not greatly different in age.

Peripheral uncollapsed flows. An outer zone of lava beyond 150 m from the west rim of the cleft still retains its primary lobate surface morphology and displays no sign of widespread subsidence or crustal foundering. This lava was observed in the initial western part of our traverse near [0-] from 17:08 to 17:30. It is typical of the lobate sheetflows seen elsewhere, being a billowy or hummocky tangle of overlapping flow lobes ranging in width from several cm to a few dekameters. Its surface relief commonly ranges from several cm to a few decimeters over areas several m wide, and up to a meter or more over distances of a few dekameters (Table 4: photograph PORT 1-20).

Minor morphologic features on the lobes include striations, wrinkles, and various small fractures. Many such features are ascribed no special significance, but some are; among the latter are features diagnostic of local deflation (collapse pits in shelly lobes, as observed at 17:11:04) and others that indicate various degrees of inflation (residual pits also seen at 17:11:04, shallow surficial cracks and faults such as those noted at 17:09:16 and 17:19:28, and tilted crusts such as those noted at 17:22:30).

Features diagnostic of deflation and inflation are closely juxtaposed in some places (as at 17:11:04 and 17:22:30), and because they do not normally occur together in a single flow they suggest that separate flows overlap each other here, some of them being inflated and others being deflated. In some places, contacts are visible between successive flow lobes (17:26:13), and a few of these contacts seem to coincide with slight changes in sediment cover (17:20:09 and 17:22:30).

If real differences in sediment cover do occur across contacts, they suggest that the separate flows are products of different eruptions separated by significant lengths of time. The sediment differences are not precisely defined, however, and if age differences do exist their effects are probably blurred by a gradual decrease in sedimentation rate from the edges of the valley to its center. Age differences cannot be determined until the rate of sedimentation and its variability across the valley floor are better known.

It should also be borne in mind that it is difficult to distinguish morphologically between separate lava flows of the same age and separate lobes in a single flow; if the differences in sediment cover do not reflect differences in age, some inferences of separate flows may be incorrect.

The billowy/hummocky surfaces of all these lobate flows seem to slope gently (about 0.5 m/km, from bathymetric data) away from the axial cleft; this suggests that they overflowed from the cleft. A local lava source within the cleft is suggested also by a lack of morphologic features diagnostic of sustained, long-distance flow. We saw none of the lava channels or master lava tubes that characterize the mid-sections of long flows, nor the rough and broken or highly inflated surfaces that characterize their distal parts. We saw no sign in this area that any of the lava flowed along the valley floor parallel to the cleft.

Collapsed lava flows. A zone of lava-flow subsidence separates the unsubsided lava of the outer valley floor from the axial cleft (photographs STBD 1-17, PORT 3-19). Earlier camera lowerings had suggested that this subsided area broadens around the main hydrothermal vents, and one purpose of our diving program was to evaluate its possible genetic relationship to the vents. On this dive between 17:30 and 18:12 we traversed the western part of the subsided area. We found its outer edge where expected, about 150 m west of the rim of the cleft, where we deployed marker float [3X]. Though some interpretive uncertainty remains, our observations are consistent with the occurrence of a subsided area totaling about 400 m wide, centered on the hydrothermal vents, and partly flooded by two or more younger flows that subsided also.

A transitional zone of pitted sheetflows about 50 m wide, observed in our traverse at 17:28 to 17:30, occurs between the unsubsided lobate sheetflows and the area of broad subsidence. The pits are typically a few to several m wide and up to one m deep. They have overhanging roofs, steeply outward-sloping walls that are ridged in some places with lava-subsidence selvages, and flat floors that are commonly littered by thin plates of roof rubble. Sediment cover is more extensive and thicker on their floors than on the lobate surfaces of their rims. They are wider, deeper, and more numerous near the subsided area. Though they seem to be isolated from each other, these peripheral pits probably were connected to the broader subsided area when the lava drained from them. Even though they lack pits, many lobes in the transition zone have gently sagged tops indicative of partial drainage.

Also common along the margin of the large subsided area are shelly remnants of more thoroughly drained lobes. In some places the lava seems to have drained away entirely from behind steep, billowy fronts of lobes to leave only residual upturned plates (17:30:16). Small lava toes have subsequently flowed around these tilted plates and have then had their own proximal ends truncated by subsidence. Evidently there was a complex repetition of surges or overflows interspersed with subsidence here, like that which forms the lava levees of subaerial perched lava ponds.

The broadly subsided area differs morphologically from the smaller pits. Whereas the small pits are isolated from each other and are restricted within large lava lobes several meters wide, the broader subsided area cuts across such lobes and embays them to form a subdued amoeboid shape. This broader collapse has a rim that generally does not overhang, a wall that slopes gently inward and lacks subsidence selvages, and a floor that is not littered by roof debris. In some places it appears that the smooth surface of the subsided floor can be traced unbroken up through a series of tilted, draped folds into the shelly lobes of the rim (17:30:54 to 17:31:50 and 17:35:13 to 17:35:40), as if the flat subsided crust and lobate unsubsided crust were coeval. In other places, low swells along the edge of the subsided floor resemble successive fronts of lava that oozed out over successive crusts that foundered as the lava subsided and receded (17:34:46).

The subsided surface of the broad collapsed area is mostly flat, with a low relief of a few cm over distances of several m and no more than a few decimeters over larger areas. Most of this surface is featureless or scored by only shallow lineations, though higher-amplitude wrinkles and folds are common near its margin. It seems to slope very gently toward the axial cleft. Sediment cover is much greater here, perhaps as much as 95% (17:31:00), than on adjacent coeval lobate surfaces, probably because the featureless flat surface has no small depressions or smaller-scale roughness where sediment can be concentrated in sediment ponds or cavities.

The flat floor of the broadly subsided area is narrower than expected, at least along the line of our traverse. Earlier camera surveys had suggested that pillars and other remnants of a primary flow surface projected above a subsided flat floor extending 150 m from the rim of the inner cleft. Along our traverse (17:31 to 17:36), however, we found the flat surface to be only about 20 m wide; after crossing onto it where expected about 150 m west of the cleft, we unexpectedly left it again 130 m west of the cleft, where tilted plates of lobate lava seemed to cap a mound. We initially interpreted the mound as an island of unsubsided flow surface rising above the subsided surface. But instead of finding more of the flat surface further east, we again encountered small pits in lobate lava (17:37 to 17:46, with lava-subsidence selvages appearing on pit walls after about 17:41). The interpretation of these observations is not certain; three alternatives seem most likely: First, the subsided area could be much smaller than inferred from the camera surveys, with only isolated pits occurring rather than a single broad collapse. Second, we could have crossed merely an embayment of the large subsided area, so that we were back outside it at 17:36 and then skirted its northern margin until we reached the cleft. Third, a younger flow could have spread across most of the flat surface here, so that only its western edge was still exposed. We prefer the third alternative, which is consistent with everything seen during the dive as well as the earlier camera surveys indicating an extensive subsided area. A corollary of this interpretation is that at least two different lava flows subsided here.

At least one other subsided flow is also present; this became clear as we neared the west rim of the cleft. At 17:41:31 we found the margin of another broadly subsided area about 50 m from the rim of the cleft. Here again, along its margin we saw lava toes that had oozed around the shelly remnants of earlier collapsed lobes, suggesting that multiple surges had occurred. By 17:43:46 we had observed still another lobate sheetflow that had flooded this subsided area, ponded within it, and then drained away to produce pillars and pits about 2 m deep. Pit walls in both of the inner subsided flows were corrugated by many lava-subsidence selvages (well-documented from 17:50:00 to 17:55:55; photograph PORT 3-24).

Interpretation of the cleft overflows. In summary, we saw lobate sheetflows of at least three generations on the valley floor west of the cleft, with the younger flows flooding subsided parts of the previous flow (Figs. 6 and 7). In addition, we saw evidence for multiple surges in two of these lobate surfaces: These include two or three different flows on the outer valley floor near [0-], surging beyond the first margin of subsidence at [3X], and surging beyond the second margin of subsidence near [0X]. As many as seven separate lava flows could be inferred from our observations, each having subsided and collapsed before the next was extruded across it. This sequence of lava flooding and subsidence is more complex than we anticipated; it appears that lava repeatedly overflowed the cleft to produce a stack of thin, discontinuous flows on the outer valley floor.

The source of these overflows was not definitely established during this dive. Earlier camera lowerings indicated that the width of the subsided area swelled from less than 50 m along most of the cleft to more than 100 m here and around a few other principal hydrothermal vent areas. If these widths are correct, they suggest that the eruption of lava was concentrated along the cleft at sites coincident with the present main hydrothermal vents. Because this dive was restricted to the vicinity of a vent area, however, we could not confirm the narrower width of subsidence inferred from camera lowerings elsewhere along the cleft.

One feature on Figure 7 that remains to be explained is the earlier, larger subsidence depression (shown by chains of large dots on the maps) inferred to be buried by the younger overflows. This feature is conjectural; it is inferred from the apparent overlap of pitted lava by the oldest presently exposed subsided flow (17:22:30). Subsequent observations (17:28 to 17:30) showed that small pits in the upper flow occur near the margin of its broader subsided area. We suspect that this is a common occurrence, and that small pits in unchannelized flows usually occur near larger areas of subsidence. We therefore infer that a broadly subsided area probably formed near the pits in the older flow, but that it was buried by the younger flow. This inference is not yet well founded, however, and deserves further testing.

All of these overflows from the axial cleft seem to be of similar age. Differences in their very light sediment cover are not large and seem to be explainable mainly by differences in surface roughness and distance from a sediment source along the edge of the valley floor. If the separate overflows are products of different eruptions, those eruptions must have been recent and closely spaced unless the rate of sedimentation here is very slow. More likely, the overflows represent surges during a single sustained eruption. This inference, however, must remain uncertain until the sedimentation rate is better known.

LAVA WITHIN THE CLEFT

The morphology of lava within the cleft is generally quite different from that outside. Although lobate flows and associated draperies do occur in some places on the floor and east wall of the cleft, most of the lava consists of thin veneers on the walls and rough, fragmental surfaces on the floor. The draperies and lobes are confined to the eastern cleft near the hydrothermal vents; they probably represent final small surges of lava in a waning eruption.

Veneers plastered on walls of the cleft. The walls of the cleft and the crest and walls of the interior ridge are coated in some places by thin veneers of lava that are plaster-like and almost featureless. These veneers were seen best (18:09 to 18:11) on the west wall below [OX]. Though the wall was examined going from bottom to top, it is more easily described in the opposite direction because the veneers seem stratigraphically simpler at the top and more complex at the bottom.

Near its rim, the west wall displays in cross-section the rough, pitted topography that fringes the cleft, with thin shelly septa separating the cavities of adjacent drained lobes (Fig. 5A). Below the septa is a rubble composed of shelly plates from the collapsed crust. This rubble may be as thick as a meter or more and could represent multiple overflows, but we did not see any contacts between such flows. Beneath the rubble is a steep cliff about 10 m high; it has an irregularly massive appearance arising from its nearly continuous coating of lava veneer. Its upper part has a hackly texture (18:10:31) that could reflect older rubble, pillows, or lobes behind the veneer. In places where the veneer has partially broken away, multiple thin layers can be seen in it, their truncated edges hanging like flat tapestries (18:10:08). The lower part of the wall has many lava-subsidence selvages and small vertical ridges that look like driblets of lava which flowed short distances down the face (18:09:56). Below the abrupt base of the cliff a gentler ramp slopes (about 40° near its top and 30° near its bottom) another 5-10 m to the floor of the cleft. When viewed from a distance, much of the steeper upper slope has a lumpy but nonfragmental appearance resembling that of lobate sheetflows. When viewed close-up, however, it is clearly a fragmental deposit. But although its slope is near the angle of repose, the fragmental deposit does not seem to represent a simple talus; it appears to be a mixture of talus and lava, with an earlier generation of fragments coated by a thin pimply-textured veneer of younger lava (18:09:09) and then littered by a later generation of uncoated rubble (18:09:07). The small blocks and plates of the younger rubble were probably derived from the partial collapse of presently surficial wall veneer seen above, and the earlier talus was probably derived similarly from earlier veneers. Farther down the slope the talus veneer too seems to consist of multiple layers: Pillars rising from the slope have a layered structure like onion skin (18:09:21), and cracks that penetrate the coated rubble reveal beneath it a massive surface that probably represents an earlier veneer (18:09:15).

The crest of the southern ridge within the cleft is plastered by sheetlike lava that is broken into a mosaic of thin (1-3 cm) but wide (1-2 m) polygonal plates (21:47:40 to 21:48:44; photographs STBD 3-18, STBD 3-20). The plates at first appeared to have been dropped helter-skelter onto the ridge, resting precariously on its convex upper slope. Closer inspection, however, showed that the plates broke apart in situ and slid a few cm before freezing to the slope; their broken edges fit together like pieces of a jigsaw puzzle, and the flat floors of wide cracks between them have striations, formed while the lava was still tacky, indicating slip direction. The plates probably represent an ephemeral crusty skin on a lava stream, draped onto the ridgecrest as the stream subsided rapidly past it. The lower east wall of the ridge too appears to be plastered with a massive-looking veneer of lava. In one place this veneer too appeared to be separated into polygonal plates by cracks a few cm deep and wide (21:58:57), but the organic drapery was so thick on the wall there that we could not be certain of this, and in most places the lava veneer appeared nearly featureless.

Though similar veneers of lava are assumed to occur everywhere else along the cleft near the Plume Site, they were not observed as well at other places and are presumed to be hidden by draperies of younger lava and organic material. We did see possible lava veneers at a few other places. Near the northern extremity of our dive we may have seen an onion-skin layering near the base of the east wall (18:21:02 to 18:21:56), but this probably resulted from surging of a shallow lava stream within the cleft instead of successive overflows. Crude horizontal ribs were observed on a possible wall veneer in the vent area (20:25:34), but similar ribs nearby were oblique (20:26:20). If these rounded ribs are lava-subsidence features, some must have been tilted subsequent to formation; more likely they had some other origin. Farther south on the east wall we also saw a similarly crude vertical ribbing (21:51:26 to 21:53:23). This ribbing too could be a feature of a thin veneer, but it is more likely a younger drapery that flowed down the wall, or possibly a drapery of organic material.

The lava veneers on the wall probably represent successive floods that drained away quickly after leaving thin coatings of quenched lava. The different layers presumably correspond to the different overflows seen on the valley floor outside the cleft.

One place where a thin, sheetlike veneer may be absent is the east wall of the eastern interior depression, south of the main hydrothermal vents. It appears that much of this wall is thickly draped by younger lava streams that flowed or dripped down the wall. This drapery is not continuous, however, and in a few places it appeared that a thin lava veneer did not occur behind it. Instead, horizontal steps on the wall resemble truncated layers of older lava exposed in cross-section (eg, 22:10:58). If a thin veneer really is absent here, this eastern compartment of the cleft may have opened after the last flood filled the cleft. (Floods that overflowed the cleft must have filled the eastern compartment because the interior ridge is lower than the rim of the cleft.) Alternatively, the steps on the wall could be younger lava-subsidence terraces frozen against the wall.

<u>Rough lava on floor of main cleft</u>. Dive 1461 only crossed the main floor of the cleft once in an area partly covered by younger lobate flows. Therefore we did not observe the rough lava as well during this dive as in some others (such as dive #1456, described by Holcomb and Morton, 1986). Our best views of rough lava during this dive were near the west wall (18:04-18:09 and 18:14-18:22) and in small kipukas near the east wall (18:37-18:38).

The rough, rubbly floor, where we observed it, is mostly a semi-chaotic expanse of broken folds with an admixture of broken, shelly lobe fragments. The pieces of folds commonly are several cm wide, a few decimeters long, and appear to be derived from folds having amplitudes of about 10 cm to 1 m (photograph PORT 1-29). Though now broken apart, their long axes are commonly alined in parallel chains to form swirly patterns several meters to a few dekameters wide. This rough surface appears generally similar to that seen more extensively on the floor of the cleft near Vent 3 (Holcomb and Morton, 1986), and this too probably represents a lag deposit skimmed off the top of an ephemeral lava flood that filled the cleft. The rubble probably formed as a very fluid, still-molten fraction of the lava flood flowed away from beneath a skin quenched on its surface. As the lava flood drained away, the skin subsided onto the floor, piled up against obstructions, and was skimmed off the lava stream. The initially thin and pliable skin at first piled up to form draped folds, but as it thickened and became a tacky, brittle crust, it was broken and jostled before coming to rest on the floor of the cleft.

The rough lava on the floor of the cleft at the Plume Site does differ in a few ways from that seen at Vent 3. The rough lava here seemed to form a continuous expanse, while in the Vent 3 area the rough lava occurred in patches that were interspersed with patches of smoother, pimply veneer to form a mosaic. Little of the pimply veneer was seen at the Plume Site, except higher up on the talus above the floor of the cleft. One photograph by the external camera (18:16:59), however, appears to show a mound of veneered rubble projecting as a kipuka through elongate lobes. This mound could represent a place where crust-rubble of the last flood failed to accumulate, the pimply veneer being the only remnant there of that flood. If so, the rubble beneath it could represent a rough crust deposited by another flood which preceded it.

Another difference between the Vent 3 site and the Plume site is the presence at the Plume Site of squat pillar-like masses that give a more rugged relief to the surface (2-3 m over a distance of 10 m, at 18:13:58). We did not record these in the Vent 3 area. These masses superficially resemble accretionary lava balls and may be sitting atop the flow, but more likely they are short pillars projecting through the flow. In size and structure, with onion-skin layering and lava-subsidence selvages, they resemble the pillars rising from the lower stretch of the adjacent talus slope. They may be island-like remnants of a late lava stream only a few meters deep that flowed along the base of the west wall.

Drapery on the east wall. On the east wall of the cleft we observed a lava drapery that is distinguished from the veneer in having a robustly cylindrical structure produced by streams of lava that flowed down the wall. The drapery is distinctly younger than the last lava flood; it appears to cover much of the east wall, and lobate sheetflows that were fed by it cover much of the eastern floor (photograph PORT 1-42). In this respect the Plume Site differs strikingly from Vent 3, where only a few small pads of lobate lava and pillows were seen in the floor of the cleft and no drapes were seen on the walls.

The drapery was observed best in the area north of the hydrothermal vents (18:15 to 18:38), where it was not obscured by a thick mantle of organic material and hydrothermal mineral deposits. The younger lava has flowed down the lower part of the wall from an unknown source higher up on the wall or rim of the cleft to form column-like vertical ribs on the wall. The lava left broad, sheet-like stalactites where it flowed across overhanging ledges on the wall (18:19:44, 18:33:24, 18:35:53, 18:36:35). These stalactites have narrow longitudinal ribs and striations, which curve around wall projections in some places to give the columns a festooned appearance. Some are broken, their truncated ends hanging like icicles. Holes in some of the otherwise intact columns show that they are hollow, like downspouts (18:37:41). The columns divide at the base of the wall to form diverging chains of elongate lobes.

Overlapping chains have accumulated along the base of the wall to form lava cones. These cones become thin and discontinuous as they flare out on the eastern floor of the cleft, and patches of the rough underlying lava appear in small kipukas between them. As the chains diverge, their lobes become smaller and more cylindrical. One chain that was recorded especially well in the external photos (18:17:53 to 18:18:34) displays a transition from a broad, pitted lobe to more elongate, apparently solid (not hollow) links. The chains end in small mounds of toes and pillows (18:16:06).

The drapes and lobes occur also in the area of the main hydrothermal vents. The drapes appear to include truncated sheet-like (20:26:32, 20:31:41), tubular (20:25:39), and billowy drip-like (20:26:55) forms, but their identification is generally uncertain because they are obscured by thick organic drapes that resemble them closely, especially in photographs where the lacy texture and swaying movement of the organic drapes cannot be seen. Also obscured here, on the floor of the cleft, by organic and hydrothermal deposits are lobate sheetflows and pillow talus (19:47:50, 22:17:13) that presumably were fed by the drapes. Lava drapes seem to occur also on the east wall farther south, below [1X] (21:52:41, 22:07:10), though here too some of the drapes could consist of organic material.

The eruptive vent for the lava drapery has not been identified. It probably occurs in the upper part of the east wall, above the main hydrothermal vents. It could be a fissure that extends obliquely up the wall from the north end of the eastern interior depression shown in Figure 6. This is conjectural, however, and some evidence points to a different source. In one place on the east rim above the hydrothermal vents (21:08:54), elongate lava lobes appeared to plunge over the rim and down the cliff to form drapery and buttresses on the upper east wall. This observation is somewhat uncertain because breakage and a thick mantle of sediment have obscured the morphology of the lava. If the observation is correct, however, it suggests that the vent for these drapes is somewhere beyond the east rim.

Subsided lava pond. The southeastern compartment of the cleft is floored by a subsided lava pond (Figs. 6 and 7). This pond was observed briefly at 21:57-21:58 and examined more carefully during our zigzag northward traverse at 22:03-22:10. Because we saw only its northern part, the size and shape of the pond are not known; but its structural setting suggests that it is long and narrow. It consists of a subsided central crust and a less subsided marginal terrace. Variations in thickness of successive crusts suggest that the pond subsided rapidly at first and more slowly later. This pond may have been preceded by others in the same depression. Though its relationship to other nearby lava flows is not certain, the ponding here probably records the last effusion of lava from the Plume Site vent. Because it has several unusual features not described previously in a submarine environment, this pond will be discussed in some detail.

The subsided central part of the pond is surfaced by flat polygonal plates. The plates range in thickness from several cm near the margins of the subsided area to more than 15-20 cm in its central part (22:07:10). The surfaces of the plates are generally lineated, though the lineation may be weaker near the axis of the pond. Inter-plate fractures that are oblique to the lineation are less straight than those that parallel it (22:04:17). The lineations generally parallel the elongation of the pond, following an azimuth of about 025° (22:04-22:05). Misalinement of lineation between plates indicates that some plates were rotated. Some plates were shoved over the truncated ends of others (22:04:50), especially near the margin of the pond. Most of the thick plates in the central part of the pond are tilted. Though some small plates are tilted steeply in various directions, probably because of jostling, most of the larger ones are tilted gently toward the axis of the pond (22:04:40), forming a crease that appears almost channel-like in some places (22:09:45). The crease is not of uniform depth, however; strung out along it are small deeps shaped like inverted cones or pyramids (22:08:13). The crease and its deeps strongly resemble those between thick tilted plates on the 1959 lava lake in Kilauea Iki pit crater, Hawaii, in the constricted passages leading from the eruptive vent to the main lava lake. Isolated pillows occur along cracks between some adjacent plates (22:03:37), and near its margin the pond is littered by blocky rubble from the nearby wall (21:57-21:58).

At the margin of the pond is a shelly fringe consisting largely of chaotically tilted fragments (22:06:54). These fragments are only a few cm thick, and although some are scored by lineations (some curvilinear, like pahoehoe ropes, at 22:07:20), most are shelly fragments of a lobate crust. This surface appears surprisingly similar to the jumbled surfaces of subaerial lava-subsidence terraces; it even appears that lava toes have oozed from beneath the tilted remnants of earlier generations of subsiding crust. At the outer edge of this terrace, lineated plates of crust are tilted sharply away from the enclosing wall; angular rubble fills the crack between these plates and a rind still frozen to the wall (22:07:10). The wall appears in some places to be draped by lava that ran down it in rivulets (22:10:58); some of the drapery may also cover an earlier talus at the base of the wall (22:07:10).

The progressive thickening of plates toward the center of the pond suggests that subsidence of the pond slowed near the end. The less-subsided, thinner plates near the margins of the lake probably are fragments of early crusts that foundered as the lake subsided. The thicker axial plates probably cooled longer before they were broken apart and tilted. All of the subsidence in this pond must have been much slower than that in the main compartment of the cleft, where the flood of lava drained away quickly enough to leave only a veneer on the walls and thin shelly fragments on the floor. The reason for slower subsidence in the eastern compartment is unknown, but it may have been caused by a constricted exit.

This eastern compartment may have been partly filled by earlier lava ponds that also subsided. This is one possibility of several suggested by narrow ledges along the lower part of the east wall near the north end of the depression outside the lava pond (22:10:58-22:12:15). The ledges do not overhang but are steeply step-like, being generally about 0.3-1.0 m high but no more than a few decimeters wide, and they appear to be discontinuous along the wall. The risers of some are scored by fine vertical ridges that resemble drip-like rivulets or tacky striations (22:11:40). They could represent closely spaced step faults or older layers of lava exposed in the wall. Alternatively, they could be narrow lava-subsidence terraces around earlier subsided ponds. The earlier ponds of such a series could entirely enclose the later ones, or they could be successively upfaulted to leave their rinds still exposed only on the east wall.

The relative age of the pond in the eruptive sequence is not certain; two alternatives have been considered: 1, the pond is another residuum of the last high-volume eruptive episode, like the veneer and rough lava on walls and floor elsewhere in the inner cleft; 2, the pond developed during a later, smaller eruptive episode in which only the eastern compartment was completely flooded, the main compartment being only partially covered by lobate sheetflows and pillows. In the first alternative, ponding could have resulted from slowed drainage or cooling within an enclosed depression, in contrast to rapid lateral drainage from the main compartment of the cleft. In the second alternative, the pond would belong to the last dregs of an eruption series.

The second alternative is probably correct. The first should have produced, on the wall veneer above the terrace, small lava-subsidence selvages formed by slowed subsidence of the lava surface as it neared the level of an enclosing barrier. But the wall veneer is nearly featureless, with no sign of slowed subsidence; the wall veneer must belong to an earlier flood of lava that drained away rapidly. In addition, the first alternative would not have produced primary flow lobes on the terrace, because the primary crust would have developed at a higher level--above the rim of the cleft--and would have foundered as the lava subsided.

The cause of ponding is not determined with certainty because we did not circle the pond and do not know if it is fully enclosed. The pond could have been confined temporarily behind its flow front owing to a restricted exit or an effusion rate that exceeded the rate of spreading. If the barrier were ephemeral, subsidence could have arisen from drainage when the barrier was breached. If the barrier were permanent, subsidence would have to arise from loss of volatiles or backflow into the plumbing system. We favor the alternative of a permanent barrier because the lack of multiple thin lava-subsidence selvages and the thickness of tilted plates on the pond floor suggest that subsidence was slow; breaching of a temporary barrier should have produced rapid subsidence.

Another problem presented by the pond is the cause of its subsidence. If it was fully enclosed, its subsidence could not have arisen from surface drainage. The remaining alternatives are deflation from loss of volatiles, backflow into the eruptive vent, or drainage into a fissure that opened beneath the pond before it cooled. Volatile loss is unlikely because the lava appears to be non-vesicular and because volatiles probably would not be evolved after eruption under the high pressure (about 220 bars) existing at that depth. (The possibility of gas loss could be tested further by examining more closely the vesicularity of lava frozen in the terrace around the pond. If the lava was gas-rich and did deflate in this environment, evidence of it should be preserved as vesicles in the rind frozen to the wall of the enclosing depression.) Drainage into a fissure should have been much more rapid than is indicated by the pond morphology, and it should have left in the floor of the pond a gaping fissure which is not seen. The most likely alternative, therefore, is backflow into the eruptive vent.

The eruptive vent has not been identified, but in order to feed the pond it would have to be located on either the east rim or wall of the cleft. On the wall we did see features resembling a lava drapery, which suggests that a vent occurs somewhere higher on the wall or rim. But a rim vent would have to occur upslope farther north; we saw no sign of one during our traverse along the rim. Nor did we see younger lobate lava from the drapery superimposed on the terrace or floor of the pond, which suggests that the drapery dates from an earlier eruptive episode. Moreover, if the pond were fed by a higher vent via the drapery, the pond could not have drained back into that vent; backflow would require the vent to occur at a level lower than the subsided surface of the pond. We therefore favor the hypothesis that the pond was fed by a vent low in the east wall at the north end of the pond, where the enclosing depression probably narrows into a fissure in the wall. Such a vent would coincide closely with the present hydrothermal vents and eruptive vent inferred for the earlier cleft overflows.

If the pond subsided from backflow, however, there is a problem of what caused backflow. Backflow following subaerial eruptions commonly is thought to arise from loss of gases in the magma--but this raises an objection similar to that faced by high-pressure deflation of the lava pond. Another mechanism is lateral expansion of the shallow magma reservoir as fissures propagate along the rift zone, permitting the erupted lava to drain back into the vent and then along the fissures, where it may remain or be erupted again at a lower elevation. We believe that this hypothesis should be favored unless evidence is found of lateral surface drainage or loss of volatiles.

If it can be shown that the pond did deflate, or that the episodicity of eruption arose from effervescence processes, it could have a large impact on our understanding of submarine eruptive behavior.

INFERRED CHARACTER OF VOLCANIC ERUPTION

Now that we have interpreted the morphology of individual lava flows, we can synthesize a more general interpretation of the volcanic eruptions that produced the flows. Our interpretation is summarized pictorially in Figure 7.

Several eruptive pulses are recorded by the lava flows at this locality. The dive showed that at least five or six successive flows spread onto parts of the Plume Site, and four of these extended beyond the rim of the axial cleft. These successive lava flows evidently resulted from distinct eruptive pulses, each pulse being followed by waning effusion and drainage of lava along the inner cleft. The widening of the drained area around the Plume Site indicates that at least some of the overflows were erupted locally and did not flow into here from other parts of the cleft. Some of the lava, however, could have been erupted as far north as Vent 1, because the ground slope continues upward as far as that vent area. The lava erupted in these episodes drained away laterally along the cleft, apparently flowing southward down a gentle slope toward a catchment area that has not been identified.

Each overflow from the cleft was brief and represents an eruptive episode having a high rate of effusion. The lack of channels in the overflows--and lack of lava levees along the rim of the cleft--indicate that each episode lasted only a few hours or less. Sustained overflow would have produced channelization and levee development. The lava must have been extruded faster than it could spread away down the cleft, so that it filled the cleft to overflowing at the height of eruption and then drained away as the rate of effusion decreased.

The multiple overflows probably are products of a single pulsating eruption, with separate eruptive phases occurring in rapid succession. A short time between flows is indicated by the lack of a detectable difference in pelagic sediment on them. Even the obviously hydrothermal sediment thickens only gradually around the hydrothermal vents, with no detectable changes in thickness along contacts between lava flows. In addition, the different overflows probably do not represent discrete eruptions because all of them seem to have been erupted from the same vent. Discrete eruptions usually are erupted from different vents because a vent usually becomes cool and clogged shortly after eruption, and inflation of the deeper plumbing system produces new fissures for the next eruption.

The eruption probably lasted from a few days to a few weeks. It was at least long enough (several hours) to permit localization of effusion to discrete points along the fissure system, and probably long enough to include several eruptive phases (at least a few days). But the eruption was too short (probably less than a few weeks) for lava shields to grow around the localized vents and fill the inner cleft. Individual overflows were brief enough (less than several hours apiece) to preclude development of lava channels outside of the cleft. The intervals betweens successive flows are not known precisely, but by analogy with subaerial eruptions, the intervals could have ranged from less than an hour to several days.

The recorded overflows may represent a systematically waning sequence, but this is not certain. It is suggested by the apparent decrease in extent of successive overflows, which suggests a decline in eruptive volume or rate of effusion for successive episodes. Subaerial eruptions commonly wane in this way, and a similar pattern could have occurred here. The apparent decrease in extent of overflow, however, could be an illusion arising from obliterative overlap. The pattern could have arisen simply from obliteration of the smaller overflows in a series having random sizes, similar to the way in which the smaller moraines in a recessional series can be obliterated by the larger advances (Gibbons and others, 1984). If the overflows do represent a waning series, however, they pose an intriguing problem of mechanism; waning series in subaerial eruptions are commonly thought to arise from depletion of volatiles causing effervescence.

In summary, we suggest that the several overflows from the inner cleft are products of a single eruption which began as a long fissure eruption but became localized to a vent in the east wall of the cleft and continued for a few days or a few weeks. The eruption consisted of a series of eruptive phases, each of them lasting for less than several hours and separated from each other by hours or days. The overflows that are still visible may be members of a systematically waning series. This interpretation is uncertain in several respects, however, and several alternatives remain possible.

HYDROTHERMAL VENTS AND SAMPLES

The hydrothermal vents of the Plume Site appear to be generally similar to those examined at other places nearby along the southern Juan de Fuca Rift. The vents here are restricted to a smaller area than those of Vents 1 and 3. Most of the hydrothermal outflow of the Plume Site seems to be concentrated in a small area between marker floats [4/], [4V], and [5V]. Minor vents do occur along the east wall of the cleft over a distance of at least 200 m. Various vent animals are clustered around the principal vents, and carpets and drapes of organic material are extensive along much of the east wall. Most of the hydrothermal mineral deposits seem to occur around the main active vents, where they form extensive incrustations and chimneys. Thirteen samples of lava, sulfides, water, and organisms were collected near the vents (Table 2).

Extent of venting. Hydrothermal venting seems to be concentrated in an area less than 50 m in length along the lower east wall of the inner cleft (Fig. 6; examined during 18:41-20:24 and 22:20-22:30). The most active vents are marked by sulfide chimneys and many vent organisms, which occur in two main clusters, one along the base of the east wall of the inner cleft and another along the narrow ledge or ridge about 10 m above the base of the wall (Fig. 5B).

The lower cluster extends 30-50 m along the base of the wall and is less than 10 m wide (in a roughly east-west direction). The most active vents occur in a small area within 5 m of the wall between marker floats [0V] and [4V]. Small plumes of shimmering hydrothermal fluid issue extensively from the rubble around the bases of the chimneys but were not observed more than a few meters away from the chimneys on the slope in front of them.

The cluster of chimneys on the ledge above may be smaller than the cluster along the base of the cliff below; we could see only a few large chimneys in the upper group. (We did not traverse the length of the upper cluster, however.) We had no close-up views of hot water issuing from the upper chimneys, or around their bases, but the fresh appearance of these chimneys suggested that they were active. In addition, these chimneys appeared to rise from a base thickly mantled by organic material (20:26:20 and 20:28:22; though this material overlay many worm tubes, we saw no live worms here). We did see shimmering water streaming from sulfide-encrusted patches on the cliff face behind the chimneys (20:30:54, 20:32:39). The chimneys that we saw here (20:26 to 20:34) appeared to be larger than those of the lower cluster, suggesting that the upper cluster had more intense or more sustained hydrothermal flow. On the other hand, the upper chimneys seemed to be sparser and less numerous; the total outflow there could be less than in the lower cluster.

We found a much smaller vent area on the east rim of the cleft (20:38-21:00), which we marked with float [5V]. At this place we saw no chimneys (though some large pillars were initially mistaken for chimneys) or worm colonies, but shimmering water could be seen rising from a small mound that appeared to consist of hydrothermal deposits. Chimneys may have stood here formerly and collapsed with a waning of hydrothermal output.

We also saw many very small, isolated vents among bacterial mats elsewhere along the east wall. These vents were generally observed as plumelets of shimmering water rising from small holes in patches of bare sulfide a few cm wide and free of organic drapery (eg, 20:30:54, 20:31:19, 20:32:39, 22:10:58). More diffuse outflow may be widespread behind thick mats of organic material; the mats must be sustained by such outflows or by diluted water from the larger vents.

We also found evidence of former vent sites which are now extinct. Although we saw no large barren chimneys like those reported at some other dive sites, we did see some evidence of hydrothermal alteration of the basalt (18:19-18:33) and remains of dead tube worms (noted at 20:24:27 and 22:15:36, but also observed elsewhere) at places now lacking vents. This suggests that vents may have been more extensive formerly, and that the area of venting has contracted. Alternatively, as vents shut off in some places others could have sprung up elsewhere.

Mineral deposits. The observed mineral deposits coincide closely with the observed active vents. The deposits occur in various forms, including incrustations (eg, 18:42:38), spires (18:50), chimneys (19:48:51), blocks (18:50), and possibly fine sediment (18:54:3, 20:30:54). Incrustations on gentle slopes generally seem to be associated with diffuse outflow or dilution of hydrothermal fluid peripheral to larger vents. The larger sulfide structures occur at more vigorous or longer-lived vents. Only incrustations were observed on steep walls (eg, 19:25:55), however, presumably because larger structures cannot be be supported there.

The surfaces of incrustations, spires, and chimneys are of various colors that can be grouped as blue-to-black and red-to-yellow. The two kinds occur close together in most places (eg, 18:50, PORT 1-6), commonly with sharp boundaries between them. The blue-black surfaces appear to consist of fresh bare rock; they bear denser colonies of macroscopic organisms and are clearly associated with vents of shimmering water (eg, 19:51:13). The samples returned from these surfaces (5R) are grayish and consist of unaltered sulfides rich in sphalerite with less abundanat pyrite and marcasite. The red-orange surfaces appear less fresh and are coated thickly by fluffy organic material (eg, 18:50, 18:54:30, 19:51:13) thought to consist of bacterial colonies. The association with shimmering water is less conspicuous for these surfaces, and samples returned from them (4R) have a surface coating of iron oxides and bacterial mat. The red-orange surfaces probably represent sites where sulfide deposition had ceased and the iron-rich sulfides had been oxidized. The area of sulfide deposition might have contracted, or it might have simply shifted from place to place as old vents were clogged and new ones opened up.

Minor color variations are conspicuous among the blue-to-black deposits. The colors that were reported include white or very light blue (eg, 19:47:50), sky blue to baby blue (19:05:12), dark blue or blue-black (19:15:070), and turquoise (20:30:54). These colors perceived underwater seem to be inaccurate because the returned samples lack the bluish hues; however, small-scale color variations clearly do exist, and seem to correspond to mineral zoning in the samples. Therefore, although the various colors reported during the dive may have color casts caused by the water and illumination conditions, the reported differences in adjacent colors probably are significant.

The incrustations form apparently thin but extensive coatings on lava of the walls and floor of the cleft and blocks of rubble around the feet of chimneys. They may also form a cement between adjacent pieces of rubble, but we were not able to confirm this because we could not detach any of the coated blocks. In some places the incrustations are barren; in other places they are densely colonized by macroscopic organisms or covered thickly by fluffy organic material. The total extent of incrustations is unclear owing to this matted cover, especially on the walls of the cleft where scattered patches of blue-black incrustation may be surrounded by much more extensive older incrustation now hidden behind the ubiquitous drapery of fluffy organic material.

Rising from the incrustations in many places are small, needle-like spires. These spires commonly are several cm high and a few mm in diameter, narrowing upward, but they range in height up to perhaps a half meter. Some of them appear to be alined in rows, presumably along cracks in the substrate. They are variously colored red-orange or blue-black and appear to be brittle; they probably consist of sulfide minerals. Some of them have apical holes and appear to be hollow tubes, with shimmering water emitting from them. Others are capped by incongruously large puffballs of organic material, such that they resemble mushrooms or golf balls sitting on tees. The stalks of some mushrooms also are coated with pale yellow organic material.

Chimneys are larger and more complicated structures; commonly they are more than 1 dm in diameter and more than 1 m high (STBD 2-11, 2-17, 2-22). Some of them appear to be more than 5 m high and more than 1 m in diameter in some places (PORT 2-36). Many swell at the top to form pointed buds resembling asparagus. Some chimneys pinch and swell, so that other swellings occur at intervals beneath the apical bud (eg, 19:52:16), as if rapid upward growth alternated with intervals of apical swelling (or outer layers spalled off below the buds). Some chimneys branch, such that a single trunk splits Y-like into diverging branches. The surfaces of most chimneys are mottled, such that some parts are blue-black and other parts are red-orange or coated with yellowish organic material. Where a part of one chimney had spalled off to reveal its interior (19:47:50), we could see a porous, zoned internal structure, its reddish outer surface enclosing layers of black, white, and yellow. In another place where a chimney had completely broken off to leave a truncated stump (19:58:29, 20:02:21), we could see concentric bands of white and black around an axial hollow core (PORT 2-33).

The chimneys do not seem to be alined in rows like the smaller spines, but appear instead to be distributed irregularly, large and small together, along a narrow zone. The largest chimneys seem to occur in the southern part of the cluster near marker floats [OV] and [4V] (19:15 to 20:25).

An apron of rubble descends a few meters from the chimneys to the lava flooring the cleft; the rubble appears to form a mound-like substrate for the chimneys (Fig. 5B), but this is not certain owing to the obscuring carpet of organic material, which is at least several cm thick. The composition of the rubble is uncertain; its blocks appear to consist of sulfide, but they could be cored by basalt. (The blocks appear to be cemented together by sulfides, and we were not able to break off a sample.)

On the east rim of the cleft we found another possible sulfide mound (STBD 2-30, 3-6), which we marked by float [5V]. Though shimmering water seemed to eminate from the mound, large vent organisms were not present. The mound appeared to consist of thick yellow sediment mixed with blocky rubble that may have consisted of sulfide minerals. Here again, we were unable to collect a sample. Some pillar-like structures here were initially thought to be remnants of sulfide chimneys, but more likely they are basalt pillars.

The ubiquitous incrustations could represent slow accumulation from diffuse vents or diluted water peripheral to larger vents, or they could result from rapid deposition by ephemeral vents that shut off in one place and shifted elsewhere. Spires probably represent small but sustained outflows of hot water. Chimneys probably represent sustained sulfide deposition around the most vigorous vents. The rubble could have various origins; we prefer an interpretation of the rubble as mostly chimney fragments, with former chimneys in the same area having collapsed when they could no longer support their own weight. The largest chimneys now standing may be those that were straightest and thickest and therefore least likely to collapse.

The pinching, swelling, and branching of chimneys suggest that their growth patterns have varied through time, with upward growth of slender shafts alternating with widening or splitting of apical buds. These variations could have various causes; for example, the vents might have undergone changes in discharge, or communities of sulfide-precipitating organisms on the chimneys might have expanded or contracted for unknown reasons. The internal zoning of the chimneys too might have developed by means of growth changes through time; alternatively, the zoning might have resulted from other causes, such as temperature gradients or dilution of vent water, or alteration of minerals formerly present. Laboratory studies of the chimney samples should be useful in sorting out the various alternatives.

Organisms. Many sessile and vagile organisms occur in this vent area. They seem to be more numerous and diverse here than at Vent 3 and perhaps also at Vent 1, though the biogenic sediment here may be somewhat less abundant than at Vent 3. The various organisms occur in distinct ecological zones, but the species in the zones appear to differ from those in other vent areas, such as those along the Galapagos Rift.

The ambient bottom fauna on the valley floor outside the cleft includes many of the types found found elsewhere in areas of low sediment cover along the mid-ocean rift system. Small ophioroids are especially widespread and numerous wherever there is a little pelagic sediment, even where it forms only a thin, discontinuous scum. (We did not notice brittlestars, however, near the hydrothermal vents inside the cleft.) We saw several larger asteroids of various colors (eg, white at 17:21:31, red at 17:28:45, a pair at 17:26:10), and many fist-sized white honeycomb structures (eg, 17:27:10) which during the dive we thought were corals but which could be Xenophyophorians. We saw scattered fish less than 1 m long, most of which we thought were rattails (eg, 17:38:49). We also saw scattered glass sponges well outside the cleft (eg, 17:34:58), as well as anemones (eg, 17:38:49), sea pens (17:38:49), and other coelenterates (17:21:31). We noted a few crabs far from the hydrothermal vents (eg, 17:23:30), as well as one on the rim of the cleft in the vent area (21:00) and another on the crest of the narrow ridge within the cleft (21:48). We noted only one shrimp outside the cleft (17:34:58), though many others had been seen previously as small red blurs in deep-towed photographs. Early in our traverse near marker float [0-] (eg, 17:19:16, 17:22:30) we noted several small (a few cm long) soft-bodied swimming creatures that may have been ctenophores or worms. They commonly occurred in pairs a meter or so above the bottom, and skittered along apparently by means of fringing cilia or setae that moved in sequence to produce trains of wave-like undulations resembling the wave trains generated by strings of lights on theater marquees.

Glass sponges were abundant in some places along the rim of the cleft, especially in rugged collapsed areas near [1X] (17:45-17:55) and [0V] (21:13:30) above the hydrothermal vents. Many sponges are attached to the undersides of overhanging shelves and would escape detection by a deep-towed camera looking downward. They seemed to be less abundant as we moved southward along the east rim of the cleft, away from the vents. This suggests that they tend to cluster in a peripheral zone about 50 m from vents, which we had suspected also from their distribution inferred earlier using deep-towed photographs. Evidence for such clustering should be checked during other dives, however. Except for these glass sponges, yellow organically-bound near-vent sediment, and a few crabs and fish, the fauna is sparse near the rim of the cleft (eg, 21:22:04), perhaps because little pelagic sediment has accumulated there.

Inside the cleft, more than several m away from the hydrothermal vents (eg, 18:36:20), macroscopic organisms are sparse except for the near-vent yellow sediment of presumed organic origin. We noted no glass sponges anywhere inside the cleft. We did see a few fish, which may or may not be more abundant in the vent area. We saw none of the spaghetti and serpulid worms that were commonly peripheral to vent areas of the Galapagos Rift. We saw a few shrimp within the cleft (18:23-18:25, 21:48:44), but all of them were outside of the main vent area; we noted none near the vents. This too is quite different from vent areas along the Galapagos Rift, where red shrimp of similar appearance are common among the clumps of big vestimentiferan worms. It is possible that the shrimp here are concentrated slightly around the periphery of the vent area, but their occurrence also outside the cleft shows that they are not restricted to this zone.

The most striking creatures of the active vent areas are vestimentiferan worms, which commonly occur in clumps containing hundreds of individuals (photograph PORT 2-10). We sampled and photographed them extensively in the vicinity of [4/] and [0V] (18:40-19:50; port photographs 2-1, 2-10, 2-16, 2-25). Like the similar worms seen elsewhere, these have red gills protruding from flexible, tube-like sheaths. But the worms here are much smaller than those in the Galapagos Rift, having tubes commonly only 1-2 cm in diameter and less than 1 m long, and prominent growth rings at irregular intervals (PORT 2-25). In addition, their red gills are feathery (18:54:30; PORT 2-16). The Plume Site worms appeared to differ also from those at Vents 1 and 3; these seem smaller and more tightly clustered, and instead of rising up like bunch grass from horizontal surfaces (like, for example, those of Vent 1 shown in port photograph 2-19 of dive #1455), they hang down from the cleft wall (18:43:19), chimneys (19:14:27), and vertical surfaces of unknown nature just above active chimneys (19:48:51). Instead of representing different species, however, these differences may merely reflect differences in situation.

Pencil-like stalks are distributed widely in and around the hydrothermal vents. Their diameters are commonly 1-2 cm but as large as 2-4 cm (21:08:45). These stalks commonly occur in clumps (20:24:27), like the living tubeworms, and they are probably the tubes of dead worms. In the areas of active venting the stalks commonly are covered by fibrous organic-mat material (eg, 19:15:07, 19:51:13, 20:26:20, 21:08:45, 22:15:36, 22:19:30). Others are blackened and crinkled so that they have a charred or manganese-coated appearance (eg, 19:02:23, 19:15:11, STBD 2-5), possibly owing to thin veneers of sulfide minerals. These stalks, especially the blackened ones, are distributed much more widely than the living worms. They could simply represent earlier generations of worms in the same vent area, but because many occur in peripheral areas high on the walls of the cleft, where no worms are living now, they probably represent a formerly greater extent of hydrothermal venting. For this reason we infer that the area of venting, and probably the total discharge, has decreased. This inference is invalid, however, if the stalks are not the remains of dead tubeworms; some stalks should be collected so that their identity can be confirmed. (Fossil worm tubes were recovered in a dredge haul elsewhere during this cruise.)

In addition to the large tubeworms, a variety of smaller animals are numerous in the vicinity of vigorous vents, similar to the abundant microfauna observed at Vent 3. This fauna includes palm worms on chimneys and the wall of the cleft beneath tube worms (eg, 19:19:40, 19:52:16; PORT 1-6). At 19:21:26 (PORT 2-25) palm worms were noted below the dangling heads of a clump of tubeworms. The palm worms here occupied a horizontal band and were lined up along vertical, entrail-like bluish incrustations (STBD 2-11). The entrails could have been serpulid worms or stalks of dead tubeworms, encrusted by sulfides. Palm worms seemed to be absent higher up where live tubeworms were growing, as if the two animals occupied slightly different niches.

The microfauna observed here differed in a few respects from that seen at Vent 3. Here, as at Vent 3, we did see a few small but robust, knobby-surfaced spiders (19:12:40); but the spiders here were white or gray instead of reddish-brown (Holcomb and Morton, 1986). We did not see here any of the small creatures, common at Vent 3, which look like tiny tan-colored chitons but are probably scale worms. We did see (and obtained a blurry photograph at 19:05:12) one unidentified creature here that we saw nowhere else. It was a small dome-shaped object (possibly but not definitely soft-bodied) protruding from a yellow organic mat on the floor of the cleft near [4/]. It appeared to have a hole in its top, like a small echinoid without spines; but its surface was smooth and white. We noted no shrimp or limpets, and recorded only one crab (19:47:50) among the active vents.

Fish were common, including some that we identified as rattails (eg, 22:19:30). We did not pay close attention to these large fish, however, and they could be more diverse than our observations suggest. One small (6-8 cm long) creature that was never seen in its entirety looked like a finless fish with its nose poking into a thick organic mat, as if feeding (18:59:15). It was mostly white but marked in its forward ventral area by reddish-brown spots or patches having unsharp edges. We encountered no rays or skates, nor any large cephalopods, during this dive.

The most widespread organic (or otherwise apparently biogenic) material in the vicinity of the Plume Site is a very fluffy "sediment" that occurs as coatings, draperies, large puffy clumps like cotton candy, and smaller pebble-like clots resembling candy lemon drops. Much of it is attached to sulfide structures and the walls and floor of the cleft, but much is detached and very mobile. It occurs in several colors; though yellow and white predominate, we also noted peach (20:32:39), jade green (19:05:12), and black (20:30:01). Because of its wide distributiona, variety, and usefulness in finding hydrothermal vents, it will be described in some detail.

Many of the small sulfide spires are capped by ragged, pale-gold puffballs, as much as several cm in diameter and apparently consisting of loose aggregations of very fine, cottony fibers, which seem to grow around small hydrothermal vents at the ends of the spires. We speculated during the dive that these puffballs were bacterial colonies, but this is not certain. (R. Zierenberg notes that microscopic filamentous structures probably of bacterial origin are common on the exteriors of chimney samples and filters of slurp samples; he thinks it is fairly safe to infer that the puffballs are bacterial.) Material of similar appearance also forms extensive mats on the floor and wall, like sheets of golden cotton candy (19:58:09); shimmering water could be seen rising through these mats in many places (eg, 19:40:39).

Mixed with the ragged golden material in many places is brilliant white material that has a somewhat similar texture except that its surface appears smooth, not ragged. Larger clumps of this white "cotton candy" commonly have surfaces that billow into botryoidal clumps, like clusters of large grapes in bas relief (eg, 20:30:54). The relationship between the gold and white varieties is not clear; they could, for example, represent two species juxtaposed, growth stages in colonies of one species, or different admixtures of hydrtothermal minerals. In some places (eg, 19:12:40) it appeared to us that white cotton candy adhered preferentially to the bottoms of overhangs, while the yellow occured on the tops of shelves. (R. Zierenberg suggests that all of the colors may result from minor admixtures of inorganic pigments, especially iron oxide. The predominance of yellows on the tops of shelves may arise from sedimentation of flocculant particles of iron oxide. The botryoidal white material would represent fresh bacterial colonies still lacking an admixture of pigment.)

The east wall of the cleft behind the cluster of hydrothermal vents is almost completely covered by mats of similar fluffy material (eg, 20:24:27). Fluffy material forms extensive drapery hanging from the wall of the cleft as much as several m above the observed vents. Some of this material occurs in the form of mats, similar to those on the floor of the cleft, but it also includes drapes that hang down a meter or more and sway in slight disturbances of the water (18:40:23, 20:26:20). These drapes commonly have prominent vertical "folds" (20:26:32), like hanging window drapes. They also have a strong resemblance to lava drapes (eg, 20:25:39) and often can be told from the latter only by their slight swaying motion; in photographs alone we cannot always distinguish biogenic material from rock (eg, 21:52-21:53). The hanging ends of the drapes commonly are ragged, apparently because pieces have broken away, and as we rose up the wall above [4V] we saw clots of similar material--as long as 1 m, loose, and sinking slowly (20:25:34)--that probably were detached from the drapes when we disturbed them. We saw no sign (such as freshness of color or texture) that these ragged drapes grow at their truncated ends; perhaps they grow at their points of attachment to the wall, like hair, and shed older distal ends.

Another variety of white non-rock material, draped on the wall of the cleft and clumps of worms, consists of long fibers (18:40:23, PORT 2-1). Among the more beautiful sights observed at the Plume Site were wispy strands of this white material draped across colonies of tubeworms, providing exquisite contrast to the worms' vermillion gills. Because some of these fibers appeared yellowish to us during the dive, we considered them simply another form of the otherwise puffy yellow-and-white material; but perhaps they represent an entirely different kind of organism.

The density of the biogenic material is very low. It appears to have nearly neutral buoyancy, being stirred up easily and settling slowly. Much caution was needed while maneuvering the submersible near it, especially when the deposits were thick and abundant. Despite our precautions, we were sometimes forced to stop sampling because we stirred up thick clouds of sediment and could no longer see beyond the viewports. Twice upon returning after intervals of several minutes (18:07-18:14 and 21:57-22:06) to places where we had stirred up the sediment, we observed nearly motionless suspended clouds of it, which indicates that its settling velocity is quite low. (But a large cloud stirred up at [OV] seems to have cleared away during the 2 hours between our departure at 20:24 and return at 22:20.) We tried to collect samples of this material, but its collapsed volume after passing through the nozzle of the slurp gun was so small that it formed only an insubstantial scum in the sampler.

In some areas peripheral to the vents, thick deposits of bright yellow sediment (eg, 20:10:56) appeared to have higher density, and were not stirred up by the submersible. Pockets of sediment commonly appear to consist of similar material in sizes ranging from small cobbles to fine sand or silt. This sediment presumably is derived from breakdown and compaction of the fluffy material growing around the vents. The yellow mats on the floor of the cleft beneath the sulfide chimneys may be mixtures of such sediment and similar material growing in place.

Because of its mobility, the yellow sediment is distributed widely beyond the hydrothermal vents. Clumps of the fluffy material appear to break up into smaller clots as they move, so that pebble-sized pieces occur hundreds of meters from the main vents. These "lemon drops" were found to occur, at least sparsely, everywhere we went during this traverse, even on the main valley floor outside the cleft and well to the side of the hydrothermal vent area. They clearly are larger and more abundant, however, in collapse pits fringing the rim of the cleft. Their broad distribution but greater frequency near the hydrothermal vents make them very useful clues in the search for vents.

During the diving we generally regarded most of this fluffy material as bacterial growths. But this inference is not proved by our observations. Indeed, if the material really is bacterial, why is it so abundant? Why doesn't it appear to be consumed by other organisms?

<u>Samples</u>. Though the principal focus of this dive was the lava-flow morphology and volcanic history of the locality, we also tried to collect some samples and make other measurements, with mixed success. We did succeed in collecting some samples of hydrothermal deposits and organisms, and since those samples are subjects of detailed study, some additional explanation will be given.

The samples are listed on Table 2 in order of their time of collection. The sample identification codes begin with numbers; the numbering was intended to indicate chronological order of collection, but the order became confused when the codes were assigned after the dive. For each sample, the number prefix is followed by a letter indicating the kind of sample: R for coherent rock fragment (basalt or sulfide) picked up with the manipulator, S for rubble collected with the scoop, B for biological materials picked up with the manipulator, G for water collected in a Titanium water bottle, and P for water and particles collected with the Grassley slurp gun. For the slurp-gun samples, a number suffix indicates the valve for the compartment of the gun into which the sample was pumped.

Samples 3R and 2S were supposed to include the red particulate material that was prominent in cracks and cavities in a lava veneer near the base of the east wall of the cleft. When viewed through ALVIN's ports, this material had a vivid brick-red appearance reminiscent of cinnabar, and we thought it might be a product of hydrothermal alteration. But the particulate fraction seems have been lost from the sample before we reached the surface; the only non-lava material brought back consists of chunks of green clay (nontronite?) in the scoop sample.

The collection site of biological sample 1B is well-documented by photographs made by the external camera as the sample was collected. This sample was sent to the University of Victoria, where it was examined and found to contain a large number of organisms (Table 2), many of which were not recognized during the dive. In addition to the materials actually returned in this sample, more information about the behavior and distribution of some of organisms might still be extracted from hand-held photographs and verbal notes by the divers.

We tried, but failed, to collect samples of the pervasive bluish-black incrustations, which were too smooth and hard for the manipulator to grasp. Though this material probably is similar to the sulfides of the chimneys, we cannot confirm this.

We collected two large chimney fragments, 4R and 5R, which formed a "Y" as different limbs of a single chimney; both were actively venting "smoke" before collection, but whereas 4R appeared to be coated by 1-2 mm of orange-red iron oxide, 5R was merely dark gray. Water sample 6G was intended to come from the stump of 5R, but the Titanium bottles did not trigger and the temperature probe did not function. When 4R was sawed open aboard ship after the dive, it was found to be zoned. The outer wall was composed of sphalerite, while an intermediate zone was composed of anhydrite, sphalerite, and pyrite, and an inner zone composed of sphalerite and pyrite.

We had several problems in trying to use the slurp gun and other equipment. Our first slurp sample, 8P3, was supposed to consist of pure bottom water outside the inner cleft but was contaminated by particles stirred up by our activity. But when we tried to collect larger samples of hydrothermal sediment we obtained little, and the material seemed to clog the apparatus. When we tried to sample outflow from a hydrothermal vent near [4V], the nozzle fell out of the vent prematurely. We also tried to collect a push core of yellow sediment at [5V], but the coring tube broke (20:45:29) and problems with the mercury control system caused us to lose use of the port manipulator and nearly abort the dive (21:01:55).

The temperature probe malfunctioned during this dive. We did obtain some measurements early in the dive (19:15-19:25), from an active vent near [0V], but the maximum temperature measured was only 40^{o}.

INFERRED HISTORY OF HYDROTHERMAL ACTIVITY

The present hydrothermal venting appears to be a residual product of an earlier volcanic eruption; it probably is not precursory to a future eruption or unrelated to volcanic eruptions. The rate of hydrothermal venting appears to have declined, and the rate of sulfide deposition probably will not increase significantly until after the next volcanic eruption.

Relationship of hydrothermal activity to volcanism. As discussed above, several morphologic features indicate that the lava flows here were erupted from a volcanic vent localized among the present cluster of hydrothermal vents. This spatial coincidence suggests, by analogy with subaerial volcanoes, a causal relation between the volcanic eruption and hydrothermal outflow: The water probably is heated by the same magma body and transported along the same restricted conduit that fed the eruption. Study of subaerial rift zones has shown that new eruptive sequences usually involve the intrusion of new dikes and opening of new fractures at shallow depths, probably because the earlier dikes have solidified and newly risen magma must break its own way to the surface. New eruptions are spread out along fissures for distances ranging from hundreds of meters to tens of kilometers, but they soon become restricted to single vents, or strings of localized vents, along the fissures as channelways develop in the conduit system (Holcomb, 1981). The localized vents are ephemeral features of particular eruptions; later eruptions develop different channelways and localized vents determined by factors peculiar to their new situations. There is little chance that new localized vents will coincide with old ones, and water heated by new intrusions will rise through fracture systems produced by those intrusions. Hydrothermal water flowing from an eruptive vent probably was heated by residua of the eruption.

Because it is residual, the hydrothermal activity following a fissure eruption should be expected to wane as the dikes continue to cool; and in fact the hydrothermal activity appears to have declined at this locality. Some of our observations suggest a contraction of the area of hydrothermal deposition: The brick-red particulate material that we tried to sample north of the main vent area (3R, 2S) probably represents alteration around hydrothermal vents that are now extinct, and the hydrothermal mound on the east rim of the cleft at [5V] probably is rubble of sulfide chimneys that collapsed as hydrothermal venting declined at that place. The apparently much greater extent, formerly, of vestimentiferan worms also suggests that hydrothermal venting has declined.

We therefore suggest, because of evidence that hydrothermal venting has declined and coincides with a former eruptive vent, that the hydrothermal venting at this site is residual to eruption and will continue to decline. This conclusion is merely tentative, however, and should be tested further by means of detailed examination and monitoring of the hydrothermal outflow.

Rates of mineral deposition. We cannot yet estimate reliably the volume of sulfides in this locality. We can, however, estimate crudely some upper and lower limits for that volume. A minimum value of 4.2 m^3 is obtained if we assume that all sulfides are confined to 10 cylindrical chimneys having mean diameters of 0.5 m and heights of 2 m (volume 3.9 m^3) and patchy incrustations 3 mm thick over an area of 100 m^2 (volume 0.3 m^3). A maximum value of 650 m^3

is obtained by assuming 50 chimneys of the same dimensions (volume 20 m^3), incrustations 3 cm thick over an area of 1000 m^2 (volume 30 m^3), and a wedge of cemented sulfide rubble 50 m long and feathering out from a maximum thickness of 4 m over a distance of 6 m (volume 600 m^3). These estimates vary by more than two orders of magnitude. The larger estimate, however, still ignores the possibility of additional unobserved outcrops and other sulfides filling fissures and other cavities in the basaltic substrate. The maximum estimate is dominated by the assumed wedge of sulfide rubble. If we do assume that the rubble consists of sulfide and that interstitial sulfide is not significant, then a smaller, more realistic estimate of wedge volume yields an estimated total sulfide volume of perhaps 100 m^3. Because of their great uncertainties, these estimates may seem to have little value, but they should at least draw attention to the need for careful measurements of sulfide volume. Such measurements are needed especially in order to estimate the economic value of the mineral deposits.

We have little information to constrain the rate of sulfide deposition. The average long-term rate should be constrained by the age of the lava flows, since the visible sulfides postdate the youngest flows. Though the age of the flows is not known, they must be quite young because only the lava near the vents bears any appreciable sediment cover of hydrothermal origin. The very glassy, unhydrated appearance of the lava and almost non-existent cover of pelagic sediment also indicate that the lava is young. Some arbitrary assumptions may help illuminate the possibilities. If the mean sediment cover were 0.5 mm, and if the recent rate of sedimentation were 0.005 mm/yr, the age of the lava flows would be 100 yr. If the total sulfide volume were 200 m^3, the mean rate of sulfide deposition since the last eruption of lava would be 2 m^3/yr. If the lava were only 10 years old, however, the mean rate of sulfide deposition, corresponding to the same volume, would be 20 m^3/yr.

It would be useful to know if the rate of sulfide deposition has been constant or has changed since the lava was erupted. In this connection it would be helpful to know the current rate of deposition, but during the dive we saw little evidence to indicate this rate. We obtained no measurements of hydrothermal flow rate or sulfide accumulation rate, and no reliable measurements of vent temperature. One observation, however, did suggest that the current rate of sulfide deposition here is much lower than very high rates that have been reported elsewhere along the Juan de Fuca rift. The chimney stump described at 19:58:29 and 20:02:21 probably was broken 10 days earlier, on September 18, during sampling of dive #1457. Despite this and the fact that the axial pipe was still emitting a thin plume of dark smoke, the broken surface still appeared fresh on September 28, with no sign of a new sulfide incrustation on the zoning or other detectable sign of growth.

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TABLE 1: TIMED SUMMARY OF SEAFLOOR TRAVERSE

FROM	TO	ACTIVITY
15:52	17:05	Descending.
17:05	17:08	Slowing descent to touchdown site about 300 m west of cleft.
17:08	17:10	At touchdown site, getting trim and deploying [0-].
17:10	17:19	Drifting west while awaiting a fix from surface navigation.
17:19	17:30	Moving east over lobate sheetflows toward cleft.
17:30	17:34	Settling down on rim of subsided area and deploying [3X].
17:34	17:36	Moving northeast over subsided flat sheetflows.
17:36	17:38	Sitting on rim of subsided area, awaiting a fix.
17:38	17:46	Moving east at constant depth to measure seafloor gradient.
17:46	17:49	Turning around above the cleft to land on its west rim.
17:49	17:54	Deploying [0X] on west rim of cleft.
17:54	17:55	Moving north several meters to a better site for slurping.
17:55	18:00	Slurping 8P3 within pitted terrain on west rim of cleft.
18:00	18:02	Moving east toward west rim of cleft.
18:02	18:05	Descending along west wall of cleft.
18:05	18:07	Sitting on floor of cleft, near base of west wall.
18:07	18:11	Rising up and photographing west wall of cleft.
18:11	18:15	Descending again to floor of cleft.
18:15	18:19	Moving east across floor of cleft to its east wall.
18:19	18:33	Sampling brick-red material (3R, 2S) from lower east wall.
18:33	18:36	Turning clockwise & descending while backing away from wall.
18:36	18:41	Moving south along lower part of east wall.
18:41	19:11	Deploying [4/], sampling 9P4, 1B at north end of vent field.
19:11	19:14	Moving south along base of east wall.
19:14	19:47	Attempting to sample near base of east wall, north of [OV].
19:47	19:49	Moving south along base of east wall.
19:49	19:57	Attempting to sample from large chimneys.
19:57	20:01	Moving south along base of east wall.
20:01	20:24	Deploy [4V] & sample 10P5, 4R, 5R, 11P1, 6G, base east wall.
20:24	20:38	Ascending along east wall.
20:38	21:00	Deploying [5V] and sampling 7R on east rim of cleft.
21:00	21:10	Looping above cleft (hydraulic problem) near [2-] and [5V].
21:10	21:35	Moving south near east rim of cleft.
21:35	21:44	Deploying [1X] and sampling 7R near east rim of cleft.
21:44	21:46	Moving out over cleft, away from east rim.
21:46	21:57	Descending to floor of cleft on east side; sampling 12P6
21:57	21:58	Near floor of cleft, preparing to make traverse up east wall.
21:58	22:00	Rising partway up an east-facing wall within cleft.
22:00	22:04	Descending back to floor of cleft.
22:04	22:20	Moving north along cleft, near base of east wall.
22:20	22:30	Sampling near [OV] until final ascent.
23:12	23:24	Sampling 13P2 during ascent.

TABLE 2: SAMPLES COLLECTED DURING ALVIN DIVE 1461

SAMPLE	TIME	X	Y	MARKER	COMMENTS
8P3	17:49:23 to 17:59:13	11295	11445	[0X]	Water from west rim of cleft 75 m from main vent area. Includes biogenic particles stirred up on rim of cleft.
3R	18:23	11385	11455	None	2.3 kg fragment of glassy basalt from lava drapery near base of east wall.
2S	18:27	11385	11455	None	0.9 kg of glassy basalt fragments from same site as 3R.
9P4	18:47:38 to 18:54:30	11360	11405	[4/]	Fluffy yellow sediment slurped up from east wall of cleft, near shimmering water and worms.
1B	19:00	11360	11405	[4/]	Assorted vent animals and 140 g of sulfide near base of east wall.
10P5	20:00:00 to 20:10:00	11350	11385	[4V]	Filtered sample of water containing thick clouds of stirred-up sediment near stump of sulfide chimney.
4R	20:09	11350	11385	[4V]	16 kg sulfide sample 69 cm long; red-orange branch of Y-shaped chimney.
5R	20:09	11350	11385	[4V]	22.5 kg sulfide sample 64 cm long; black branch of same chimney as 4R.
11P1	20:14:20 to 20:19	11350	11385	[4V]	Diffuse outflow of shimmering water from hydrothermal vent; nozzle fell out of vent after 5 minutes.
6G	20:19	11350	11385	[4V]	Hydrothermal outflow from chimney stump left by removal of 5R.
7R	21:34	11290	11165	[1X]	Basalt, wall of collapse pit on east rim of cleft, south end of traverse.
12P6	21:55:37 to 22:01:34	11275	11165	Near [1X]	Water containing clouds of stirred-up organic particles near base of east wall of cleft.
13P2	23:12:00 to 23:24:00	11350 (approx.)	11400	Above [0V]	Ambient water from depth of about 1100 m as ALVIN rose toward the surface from the main vent area.

TABLE 3: COMPONENTS OF SAMPLE 1B, ALVIN DIVE 1461*

OBSERVATION	QUANTITY	IDENTIFICATION AND NOTES	REPOSITORY
4	250	Vestimentiferan worms	U.Vic.
10	35	Glob snails	U.Vic.
11	2	" "	U.Vic.
12	3	" "	U.Vic.
17	1	Vestimentiferan worm	U.Vic.
21	4	Palm worms: _Paralvinella palmiformis_	U.Vic.
22	-	" " " "	U.Vic.
23	-	" " " "	U.Vic.
38	-	Polychaete worm fragment?	U.Vic.
39	-	Worm tube fragment	U.Vic.
40	-	" " "	U.Vic.
58	50	Copepods	U.Vic.
62	-	Sediment	USGS
63	-	Sediment	USGS
67	-	Sediment	USGS
68	-	Sediment	USGS
69	-	Sediment	USGS
70	-	Sediment	USGS
71	-	Sediment	USGS
78	-	Rocks	USGS
81	-	Rocks	USGS
82	-	Rocks	USGS
94	10	Nematodes	U.Vic.
95	7	"	U.Vic.
110	10	Undetermined	U.Vic.
113	-	"	U.Vic.
130	4	Eggs	U.Vic.
133	-	Debris	USGS

*Observation numbers are those assigned during inspection of sample at the Un iversity of Victoria; a single species may be have multiple listings because of clumping or unusual characteristics of some specimens.

TABLE 4: SELECTED HAND-HELD PHOTOGRAPHS FROM DIVE 1461

(Listed here, in chronological order, are 24 frames of this dive that were included in a set selected from all 1984 dives for duplication and distribution to members of the research team and other scientists.)

TIME/LABEL	DESCRIPTION
17:16:17 PORT 1-20	Unpitted lobate sheetflow near [0-]; older lineated lobes slightly inflated; uninflated lobe left of center foreground. Small lemon drops, 10-15% sediment ponds, and 30-50% sediment veneer.
17:55:55 STBD 1-17	Pitted lobate sheetflow near [0X]; pillar and thin roof of primary flow surface near edge of inner cleft. Roof fragments on floor.
18:14 PORT 1-29	Shelly, broken, draped folds near base of west wall of axial cleft, opposite the hydrothermal vents. Many large lemon drops.
18:38 PORT 1-42	Shelly, elongate lobes and gutters on slope at base of lava drapes on east wall of cleft. Up is to the right.
18:41:21 PORT 1-1	Fluffy organic material on east wall of cleft above vents near [4/]; yellow and white mats have botryoidal structures and fibrous texture. Fingers may be dead worm tubes coated by this material.
18:50 PORT 1-6	Yellow organic mats, bluish-black sulfide incrustations, and red oxidized blocks at [4/]. Many reddish-violet palm worms on bluish incrustations.
18:59 PORT 2-10	Colony of vestimentiferan worms above hydrothermal vents at [4/], looking through pilot's front viewport (24-mm lens). Colony draped by cobweb-like network of white fibers and yellow mats.
18:59 PORT 2-1	Close-up view (105-mm lens) of colony shown in PORT 2-10, showing white fibers, and feathery red gills of vestimentiferan worms.
19:15:11 STBD 2-5	Dark, stick-like tubes near hydrothermal vents at [0V], believed to be tubes of dead vestimentiferan worms coated by sulfides.
19:20 PORT 2-16	Part of a vestimentiferan worm colony at [0V], viewed with 105-mm lens. Well shown is fringe-like structure of worms' red gills.
19:20 PORT 2-25	Vestimentiferan worms hanging from colony shown in PORT 2-16, on the side of a sulfide chimney, viewed with 105-mm lens. Palm worms are numerous below heads of tube worms but are absent above.
19:24:52 STBD 2-11	Temperature probe in black smoker at lower left, with tubeworms above it. Shaft of large sulfide chimney in center has many palm worms and short curved structures that may be roots of tube worms.

TABLE 4 (Continued)

TIME/LABEL	DESCRIPTION
19:51:13 STBD 2-17	Sulfide chimneys of various sizes rising in a field of numerous hydrothermal vents between [0V] and [4V].
19:51:13 STBD 2-22	Close view of shafts of clustered sulfide chimneys in same field of chimneys shown in STBD 2-17. Tube worms hanging from chimneys.
19:58:29 PORT 2-33	Gray smoke wafting from two axial tubes in stump of recently truncated large sulfide chimney, possibly one sampled earlier in Dive 1457. Stump is about 1 m wide and has concentric and radial structure around pipes. Tan chimney behind appears truncated too, and capped by stalks of dead tube worms coated by yellow material.
20:19:32 PORT 2-36	Apical part of asparagus-shaped bud on top of sulfide chimney, colonized by many palm worms. Side of another chimney to right.
20:38:12 STBD 2-30	Yellow sediment and shimmering water of hydrothermal vents at [5V] on east rim of cleft above main vent area.
20:50:37 STBD 3-6	Broken coring tube pushed into sulfide mound on east rim of cleft.
21:14 PORT 3-19	Cavernous pitted lobate lava on east rim of cleft. Horizontal lava-subsidence selvages on pit wall at lower right.
21:26:39 PORT 3-24	Two generations of lava flooding and collapse. Wall of earlier pit in left background; edge of younger inner pit extends from lower left corner across center to right-hand background.
21:39:20 PORT 3-30	Shelly, lobate rubble of collapsed flow at [1X] on east rim of central cleft.
21:47:50 STBD 3-18	Flat sheet flow broken into thick polygonal plates on crest of narrow ridge within cleft, west of [1X].
21:47:50 STBD 3-20	Tilted plates of flat sheet flow on edge of narrow ridge within cleft.
22:10:58 STBD 3-29	Sulfides, shimmering water, and yellow-and-white organic growths and sediment near base of east wall of cleft at south end of main hydrothermal vent field.

ILLUSTRATIONS

Figure 1. Map of the Plume Site area, showing traverse of Dive #1461 (heavy line) and tracks of towed-camera lowerings (fine lines). Numbers along margins indicate coordinates of survey net; distances (km) indicated north and east from an arbitrary origin. Relative locations along dive track are generally known to within a few meters, but these locations with respect to earlier camera tracks are known with less precision.

Figure 2. Detailed map showing traverse of Dive #1461 after final analysis of navigation data. Symbols indicate uncertainty in locations; pvp means progressive vector plot. Times along track noted in hours:minutes (GMT). Identities of marker floats indicated by symbols in boldface.

Figure 3. Explanation of symbols used on maps and profiles of Figs. 4, 5, 6.

Figure 4. Plot of seafloor depth vs time during dive #1461. Depths obtained by adding ALVIN depth (pressure) to ALVIN altitude (acoustic) recorded at intervals of several seconds during dive. The ALVIN depths are moving averages of 5 successive measurements: This averaging has smoothed out noise in the pressure dept but does not mask seafloor topography; abrupt changes are well indicated by the altimeter record, which has not been averaged. Intervals when ALVIN was stationary indicated by breaks in profile and time axis. Vertical scale 1:1000. Plot can be interpreted as a topographic profile of dive track with horizontal scale 1:5000 and vertical exaggeration 5 if constant speed of 25 cm/sec is assumed. However, it is not a faithful record of topographic details because of speed variations, lack of continuous data, and averaging of depth measurements. Locations of marker floats (and collected samples) indicated by codes in boldface; other symbols explained in Fig. 3. Direction of travel (north toward top) indicated by small arrows at 1-minute intervals beginning at 18:33; intervals of clockwise and counterclockwise rotation indicated by CW and CCW, respectively.

Figure 5. Transverse profiles across parts of axial cleft at three places, constructed by adding verbal and photographic records of scarps and other features (Appendix) to depth records of Fig. 4: A, northern profile of west wall and floor (traverse time 17:45-18:20; X=11400 approx.); B, central profile of east wall (20:25-21:00; X=11300); C, southern profile of east wall and part of floor (21:44-22:05; X=11150). Scale 1:400; vertical exaggeration 1. Symbols explained in Fig. 3.

Figure 6. Map of lava-flow morphology, structure, and hydrothermal features observed along dive track shown in Fig. 2. Locations of marker floats indicated by symbols in boldface; other symbols explained in Fig. 3.

Figure 7. Interpretive geologic sketch maps and cross-sections of the Plume Site, showing multiple lava flows that erupted in the vicinity of the main hydrothermal vents, overflowed the cleft, and then drained southward along the cleft. These sketches were based only on preliminary shipboard analysis of data from Dive #1461 and earlier camera lowerings; they do not incorporate data from other dives or postcruise analysis of this dive. The floor of the cleft is now known to have structures that are more complicated than shown here.

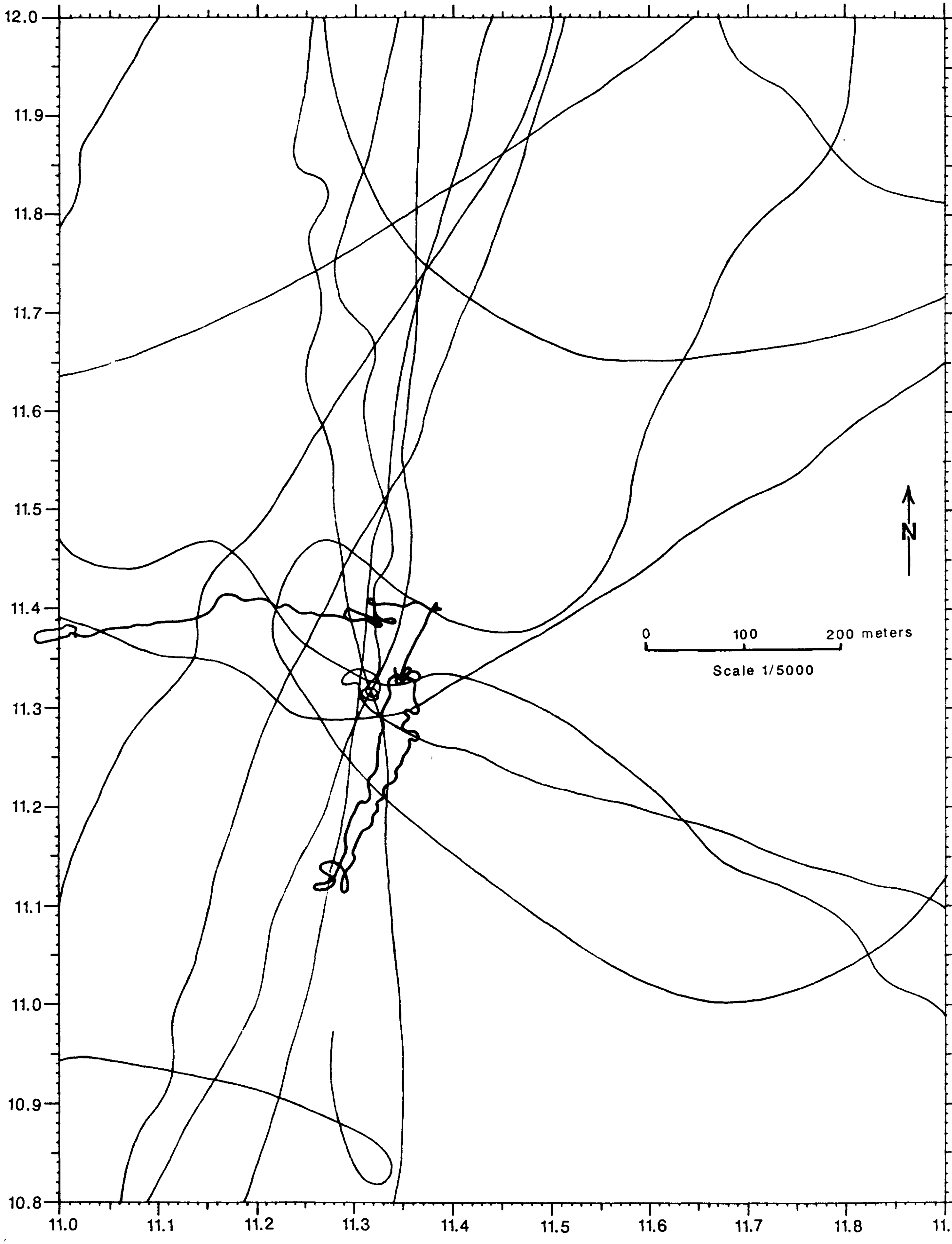
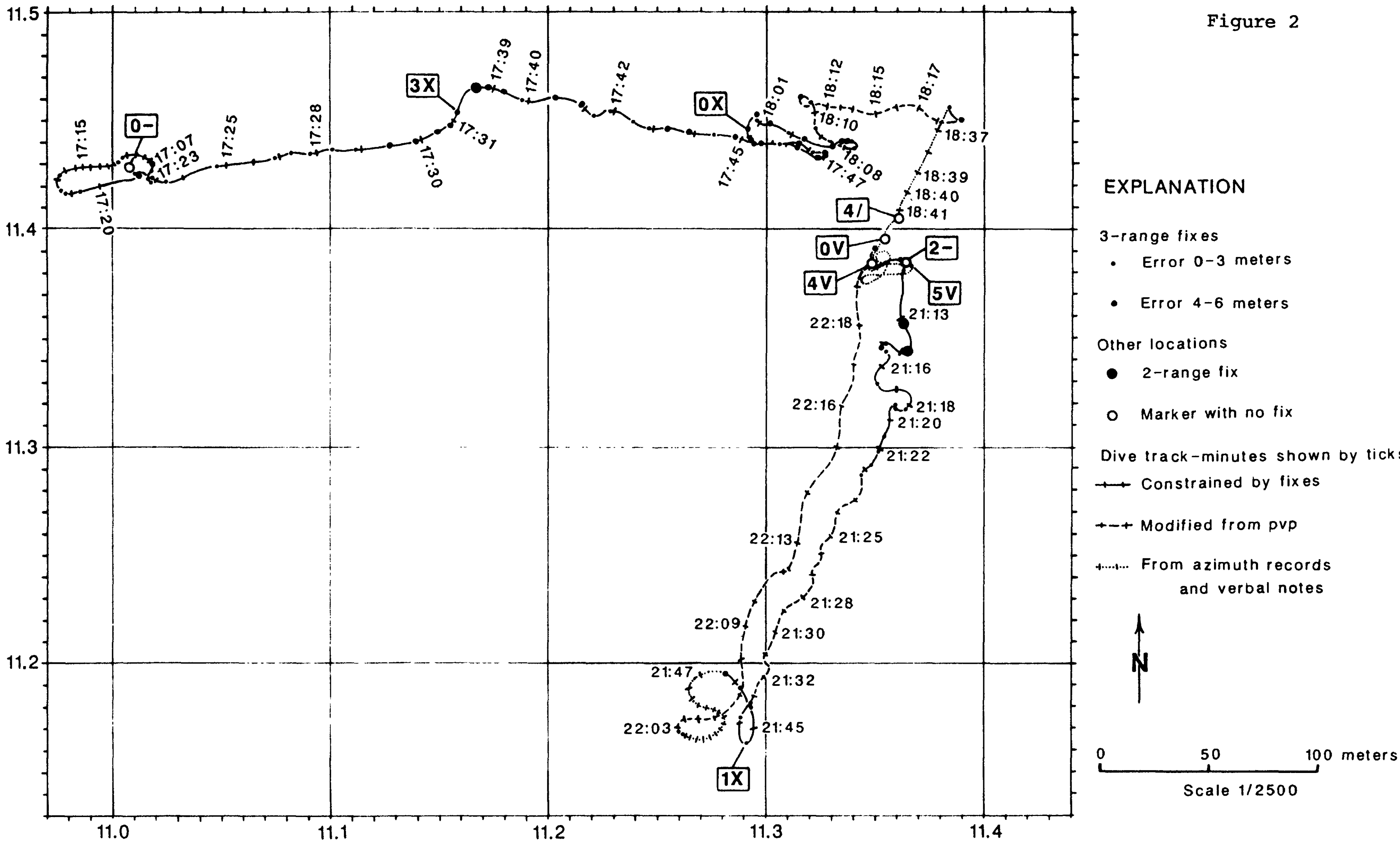

12.0
11.9
11.8
11.7
11.6
11.5
11.4
11.3
11.2
11.1
11.0
10.9
10.8
11.0
11.1
11.2
11.3
11.4
11.5
11.6
11.7
11.8
11.9
N
0
100
200 meters
Scale 1/5000

Figure 1

Figure 2


11.5
11.4
11.3
11.2
11.0
11.1
11.2
11.3
11.4
0-
17:07
17:23
17:15
17:20
17:25
17:28
17:30
17:31
3X
17:39
17:40
17:42
0X
17:45
17:47
18:01
18:08
18:10
18:12
18:15
18:17
18:37
18:39
18:40
18:41
4/
0V
4V
2-
5V
21:13
21:16
21:18
21:20
21:22
21:25
21:28
21:30
21:32
21:45
21:47
22:03
22:09
22:13
22:16
22:18
1X
EXPLANATION
3-range fixes
Error 0-3 meters
Error 4-6 meters
Other locations
2-range fix
Marker with no fix
Dive track-minutes shown by ticks
Constrained by fixes
Modified from pvp
From azimuth records and verbal notes
N
0
50
100 meters
Scale 1/2500

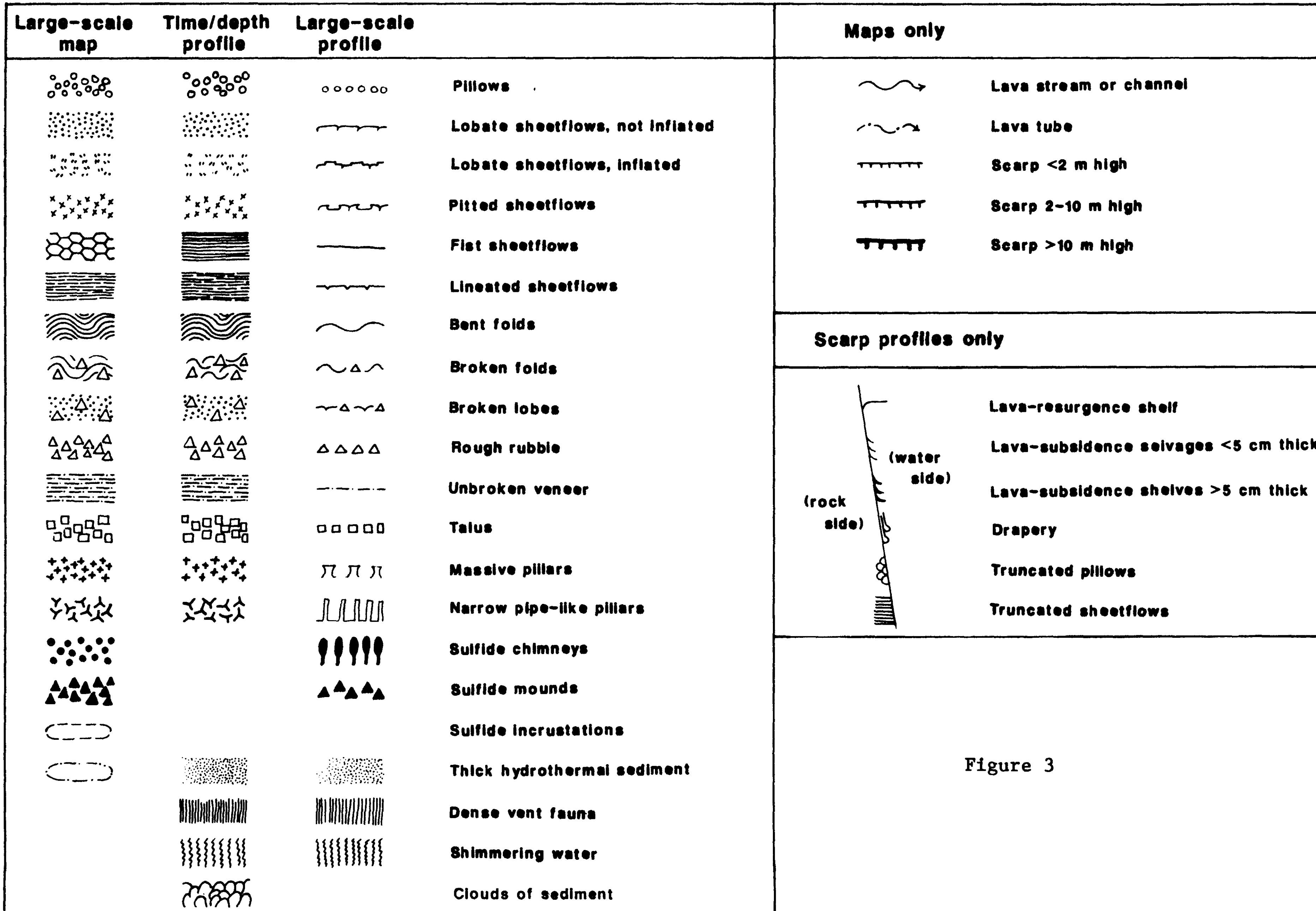

Large-scale map
Time/depth profile
Large-scale profile
Pillows
Lobate sheetflows, not inflated
Lobate sheetflows, inflated
Pitted sheetflows
Flat sheetflows
Lineated sheetflows
Bent folds
Broken folds
Broken lobes
Rough rubble
Unbroken veneer
Talus
Massive pillars
Narrow pipe-like pillars
Sulfide chimneys
Sulfide mounds
Sulfide incrustations
Thick hydrothermal sediment
Dense vent fauna
Shimmering water
Clouds of sediment
Maps only
Lava stream or channel
Lava tube
Scarp <2 m high
Scarp 2-10 m high
Scarp >10 m high
Scarp profiles only
(rock side)
(water side)
Lava-resurgence shelf
Lava-subsidence selvages <5 cm thick
Lava-subsidence shelves >5 cm thick
Drapery
Truncated pillows
Truncated sheetflows

Figure 3

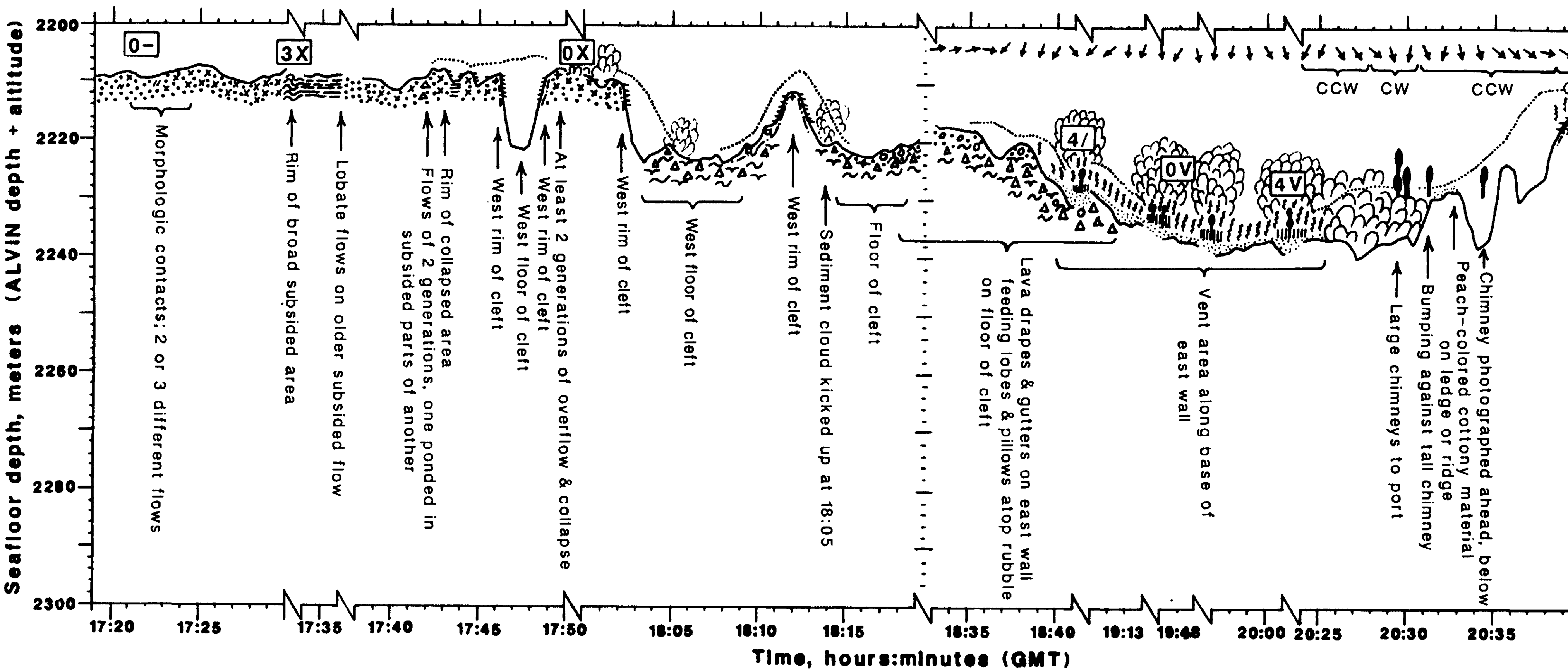


Figure 4, left-hand part

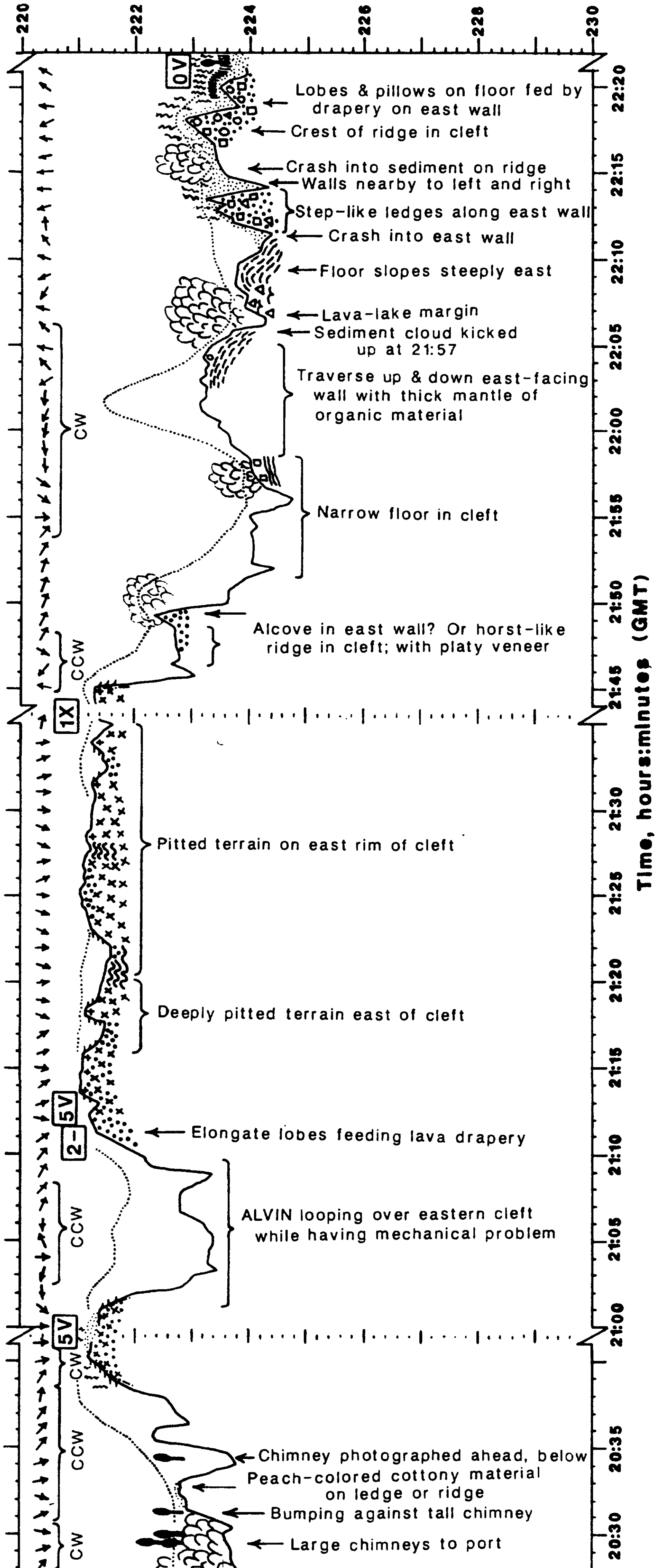
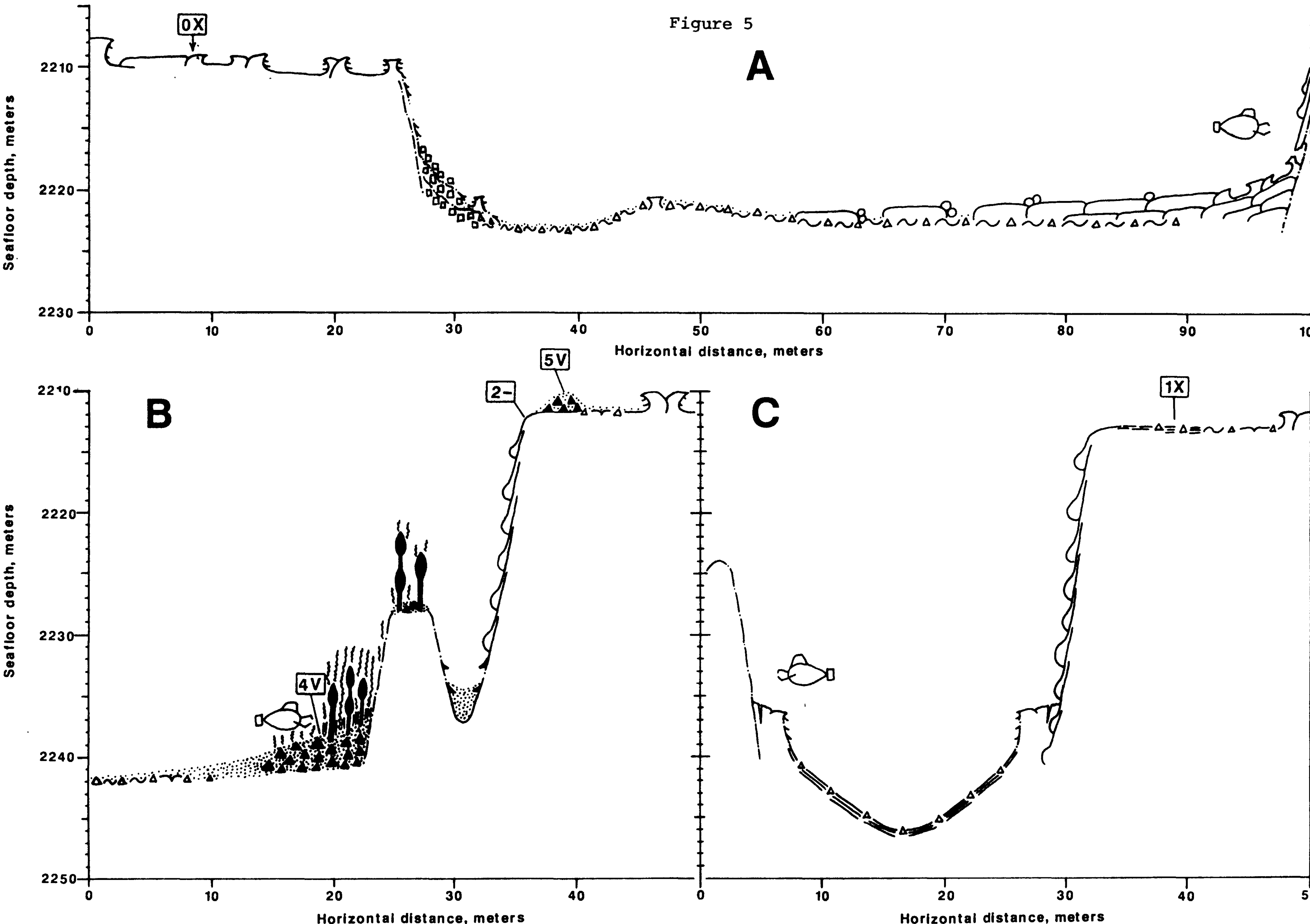


Figure 4, right-hand part

Figure 5


A
B
C
0X
2-
5V
4V
1X
Seafloor depth, meters
Horizontal distance, meters
2210
2220
2230
2240
2250
0
10
20
30
40
50
60
70
80
90
100

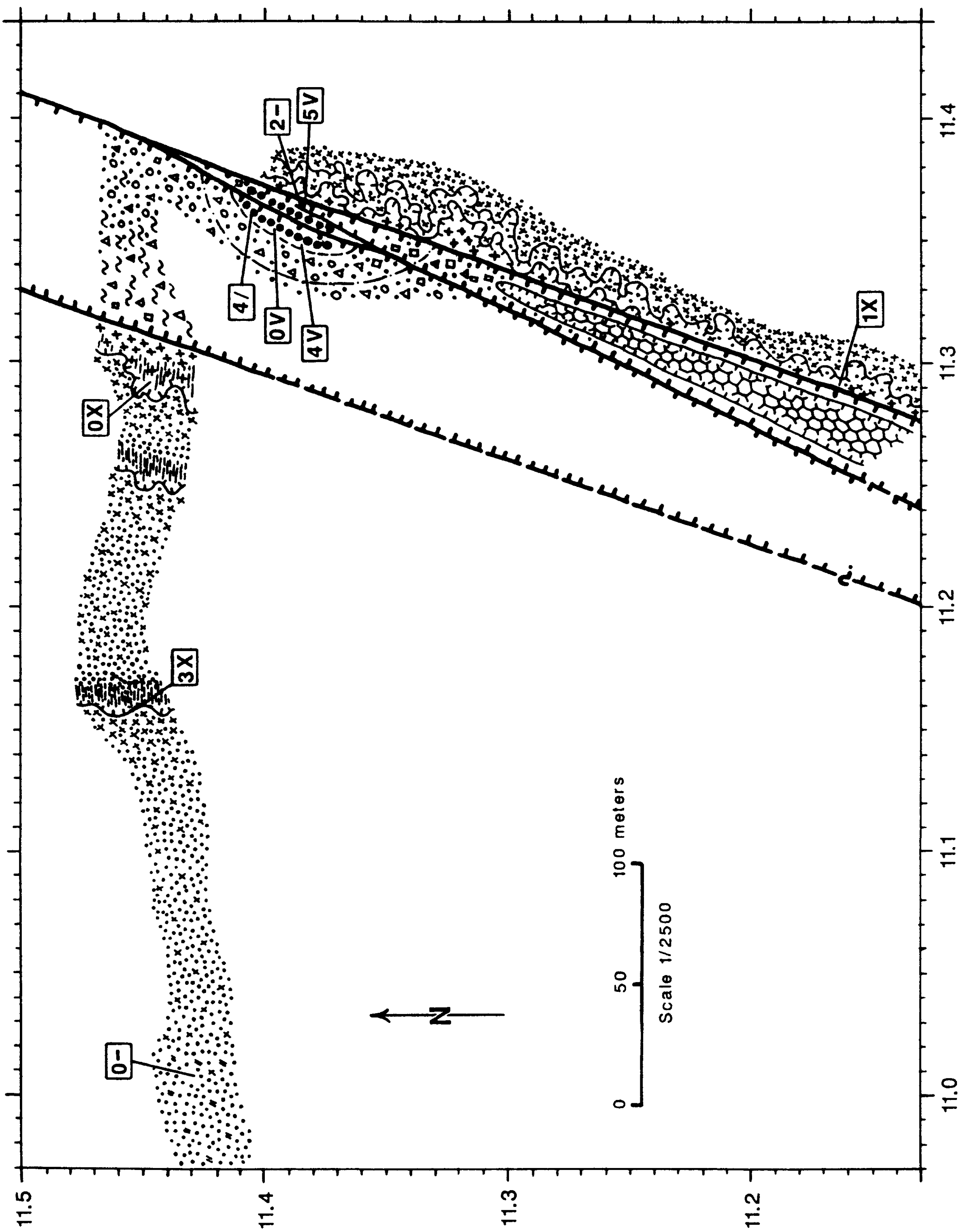

11.5
11.4
11.3
11.2
11.0
11.1
11.2
11.3
11.4
5V
2-
4/
0V
4V
1X
0X
3X
0-
N
0
50
100 meters
Scale 1/2500

Figure 6

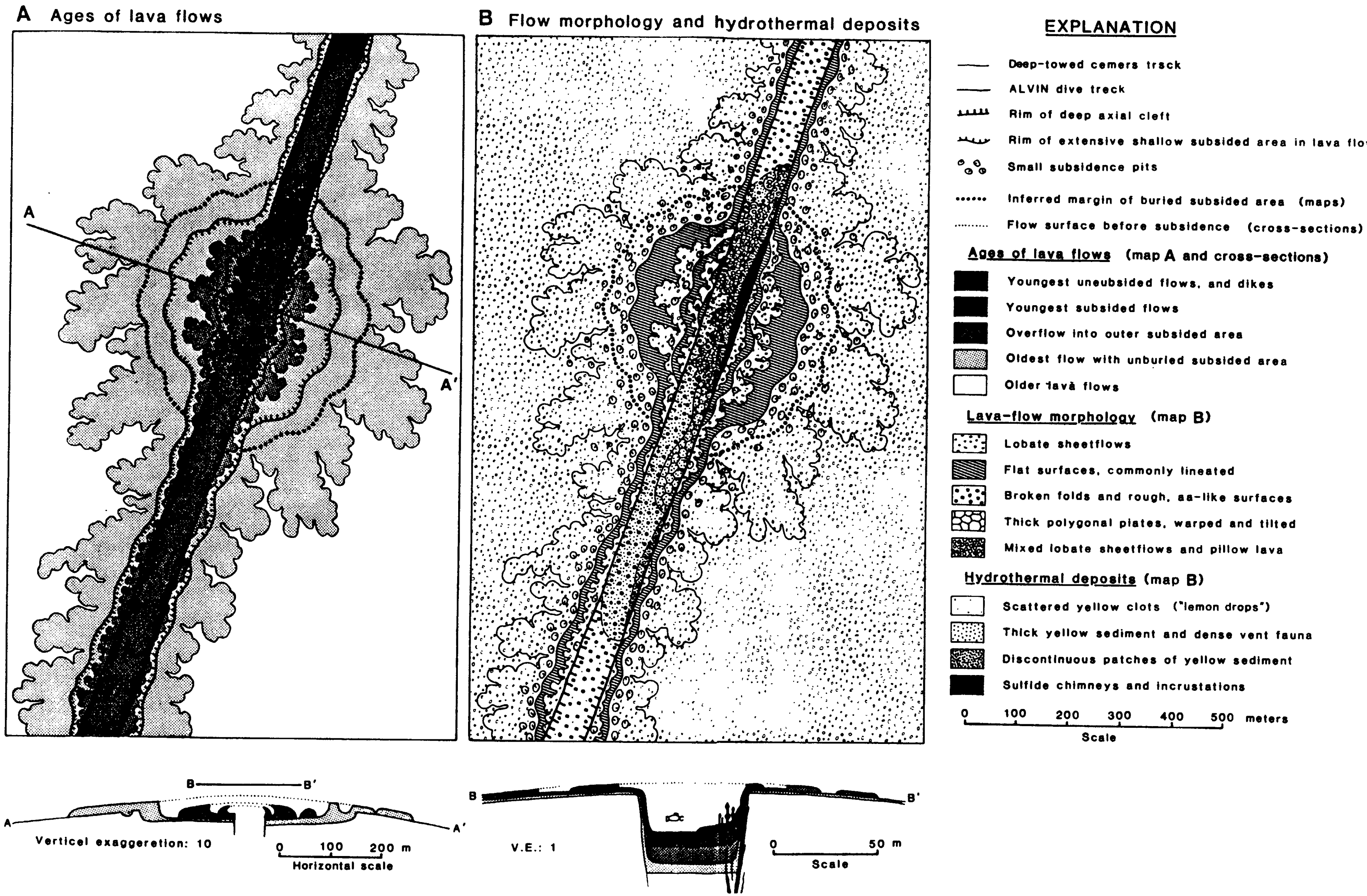

A Ages of lava flows
A
A'
B Flow morphology and hydrothermal deposits
EXPLANATION
Deep-towed cemera trsck
ALVIN dive treck
Rim of deep axial cleft
Rim of extensive shallow subsided area in lava flow
Small subsidence pits
Inferred margin of buried subsided area (maps)
Flow surface before subsidence (cross-sections)
Ages of lava flows (map A and cross-sections)
Youngest uneubsided flows, and dikes
Youngest subsided flows
Overflow into outer subsided area
Oldest flow with unburied subsided area
Older lava flows
Lava-flow morphology (map B)
Lobate sheetflows
Flat surfaces, commonly lineated
Broken folds and rough, aa-like surfaces
Thick polygonal plates, warped and tilted
Mixed lobate sheetflows and pillow lava
Hydrothermal deposits (map B)
Scattered yellow clots ("lemon drops")
Thick yellow sediment and dense vent fauna
Discontinuous patches of yellow sediment
Sulfide chimneys and incrustations
0 100 200 300 400 500 meters
Scale
B B'
A A'
Verticel exaggeretion: 10
0 100 200 m
Horizontal scale
B B'
V.E.: 1
0 50 m
Scale

Figure 7

APPENDIX A: MERGED LOGS OF VOICE AND EXTERNAL-CAMERA OBSERVATIONS

Notes
Edited transcripts of voice recordings are merged with photo logs, etc.; observations are commonly repeated in different ways by different observers.
Time is stated in hours:minutes:seconds GMT.
Column D is depth, in meters, from pressure measurement.
Column A is altitude, rounded to nearest meter, measured by sonar altimeter.
Column O indicates observer: P, port observer (Holcomb); S, starboard observer (Kappel); E, external camera.
Abbreviations: m, meters; km, kilometers; ft, feet; in, inches.

TIME	D	A	O	OBSERVATIONS
15:52			P	We're beginning to descend.
16:24	1037		P	The CTFM camera is set at f5.6 with film rated at ASA 200. Bill Normark's experiments suggested f4.5, but I will stop down for more color saturation and sharpness.
16:25	1074		P	A fix puts us 50 m west of our target (11050, 11450).
16:31	1272		S	We are still descending.
16:58	2135		P	CTFM photo: screen set on the 1500m scale.
16:59	2160		P	CTFM photo: heading 320°. A short time later our heading goes to 330°, and we begin to spin slowly.
17:03	2180		P	CTFM photo: heading 340° as we spin slowly.
17:05		17	P	The seafloor is coming slowly into view; it consists of unpitted lobate sheetflows.
17:05:19	2195	14	S	I don't see the seafloor yet.
17:06:25	2203	4	S	The seafloor consists of lobate sheetflows with a light dusting of sediment. The sediment looks fairly white. I see what looks like a very shallow collapse. There is a brittle star. The flows look broken-up, and some have possible drain-back features. There are some bathtub rings on the side of what looks like a shallow collapse.
17:07:10		1	P	Broad lava tongues of the gently hummocky lobate surface have substantially more sediment cover than I saw along the axial cleft near Vent 3. Sediment ponds here cover 10-15% of the surface, and veneer 40-50% between ponds. We kick up little clouds of sediment as we near the surface. Many brittle stars are living on the sediment.

TIME	D	A	O	OBSERVATIONS
17:07:54	2208	1	S	We've stirred up some sediment; the particles look white and quite fine-grained. I estimate sediment cover at 20-30% in some places and almost totally sediment dusted in most other places. I did see a collapse pit, but it was very small and shallow.
17:09:16		0	P	We're on the bottom, getting trim. Lobate sheetflows here have local relief of about 1/2 m. Small single lobes have gentle primary folds and wrinkles on their surfaces, but they are slightly inflated; they have surficial cracks (up to 6-8 cm wide and a few cm deep) arising from continued inflation as their skin became brittle. Sediment ponds in some areas cover up to 40% of the surface, but this occurs only where especially broad lobes have flat or gently sagged surfaces on which sediment can accumulate; most sediment ponds occur along interstices between the smaller lobes, and here the ponds comprise 15-20% of the surface.
17:09:20	2208		S	The sheets look fairly flat now and are almost totally (probably 80-90%) covered by sediment. Many particles are in the water column; they look black close-up, though many are white in the light. There are some striations on the sheets. There is a bit of sediment ponding.
17:10:20	2208		S	Benchmark [0-] has been released. It was set down in the middle of flat sheetflows. We are now going over a small depression, in which there are some collapse pits. I see lobate flows. There are many particles in the water, obscuring my view. I can no longer see the bottom.
17:11:04			P	We just came up over a small heaved-up mound with a pit in its surface; the pit seems to be residual, having originated by heaving instead of collapse. We see more heaving as we move along now, and also collapse pits in shelly lava.
17:11:22			S	The bottom has come back into view and is covered by lobate sheetflows. Some of these flows are broken, and there are many striations [wrinkles] on them. Sediment cover is about 70%. Locally there are small pits and depressions.
17:11:59	2207	2	S	The water column is very clear again. I see lobate flows, and the sediment cover is about 50% now. The sediments are generally white; some are a little brownish. I see a shallow pit, which I estimate to be about 1/2 m deep. Here all the lobes are unbroken. Beneath the rim of the collapse pit I see live fauna, possibly a worm and some smaller white things sticking out of the pit.
17:13:46			P	We've deployed marker float [0-], and will get a fix, etc.

TIME	D	A	O	OBSERVATIONS
17:14	2208	1	P	CTFM photo: sitting on the seafloor with heading 200°. [Later note: This frame shows no echoes except those from the east wall of the cleft nearly parallel to our heading about 400 m away. I asked Jim then about the image; he replied that we were sitting above surface irregularities and the sonar beam was too narrow to pick up pillars etc in the collapsed area around the cleft. But I wondered later if the instrument needed a gain adjustment. Dudley confirmed that it arose from using the 1500m scale. At that scale you need much higher gain to record distant objects, but you get radial "birds", which are greatly amplified artifacts. We should have used the 500m scale, and maybe the 50m or 150m scales locally along the cleft.]
17:15:25	2209	1	S	Photos (roll 1, frames 3-5): I just took my first 3 hand-held photos, of lobate flows. The sediment cover may be 50% here, with quite a bit of sediment ponding between the lobes. The surface navigator just gave us a position (11000, 11430) and told us to drive 400 m on a course of 080° to our target vents. We've been sitting on the seafloor. I've tried some video. There are many small brittle stars. In the sediment ponds I see irregularly-shaped yellow and brownish lemon drops; some appear to be broken-up. We're still in lobate terrain.
17:16:17			P	We're sitting on the seafloor, awaiting a fix. Photo (roll 1, frame 20): Older lineated lobes are slightly heaved, but a younger primary lobe in the foreground to left of center is not. Sediment ponds cover 10-15% of the surface, veneer 30-50%. Lemon drops and many brittle stars are too small to be resolved by the 24mm lens.
17:18:30			P	The first fix places us at (11000, 11430), about 400 m from the main hydrothermal vent, which from us is on a bearing of 080°. We will drive on that course.
17:19:16	2209	1	S	There are many brittle stars. I saw a striated sheetflow overlapping a lobate sheetflow. There are still many particles in the water. A fluffy little creature with many legs zigged its way through the water. Some pits occur in small flow lobes here; a few lobes are broken, and many have striations. I can't see a damn thing.
17:19:25			P	The strobes are firing now with external camera #1. Many lemon drops are here; at first they appear immobile, but some waft up around us when we gently bump the bottom. The rest of the sediment looks much as it does under the flat lighting in photos by the USGS towed camera, with the same tonal variations: Edges of sediment ponds form relatively light haloes around darker central parts. Why? Do darker granules migrate to the center? Perhaps the darker granules are more dense and settle out first, or move around less easily and remain in the center, while lighter bits move around more and settle on top.

Perhaps low-density, light-colored organic particles can settle only along edges of hollows where water motion is low. Or perhaps dark-particle formation (spalling of hydrated glass?) has declined, so that an older dark layer is buried by younger sediment. We also see small areas of glass-shard mosaic. Broad heaved lobes project from beneath smaller primary lobes; the latter seem to have extruded from the former, and spread into low areas between them. I've seen no big change yet in the amount of sediment cover, and we still kick up some clouds of sediment as we move. Sediment cover should decrease as we approach the cleft; will it do so gradually, or will we see a contact between lava flows distinctly different in age? There are many ophioroids here, and I saw one asteroid a little while ago. Now I just saw one of the bigger lemon drops so far in this dive; its diameter must have been about 3-4 cm. Now we're coming to a shallow collapse off to port; it looks like it's in a shelly lava flow. The collapse is broad, with irregular boundaries. A marker is ahead of us [at 17:21:44]; it is [0-]. We just passed our own marker, so we've not gone far yet; we've circled around.

17:19:28 2207 1 E This is the first frame with strobe illuminaton. It shows subdued lobate sheetflows with much more sediment cover (50% veneer, 15% ponds) than most places near the axial cleft. Some broad lobes are broken by small faults that appear to penetrate only a superficial crust a few cm thick. This breakage could be caused by slight inflation of the lobes. Some lobes are featureless, while others have shallow, broad, curvilinear striations.

17:20:09 2204 1 E Here is the lobate front of a rather thick (10-20 cm) flow having toes that are more robust than those shown previously. Its sediment veneer here is about 30-40%, perhaps significantly lower than on the thinner flow. [This may be a contact between flows of different age.]

17:20:36 2205 1 E A flat surface here has lineations that describe broad curves extending roughly parallel to our heading of 069°. It is flanked on both sides by overlying robust lobes; it has a sediment veneer of about 50% and sediment ponds about 10-15%. Could it be a stream axis? Is it significantly older than the robust lobes?

17:20:49 2206 1 E Here is a good photo of robust lobes 20-30 cm high and having marginal faults, a few cm high, from which a fringe of small toes has oozed. Sediment veneer is 30-50%, and sediment ponds occur. Superficially, it appears that two flows of different ages occur here, with the ooze-outs between them. But instead it is probably a single flow, inflated and faulted to form a step-like compound front.

TIME	D	A	O	OBSERVATIONS
17:20:57			S	I see what may be a coral among lobes of lava. There are quite a number of creatures floating around here. The sediment cover is still the same as before, with quite a lot of ponding. I see irregular shapes--what I assume are lemon drops. There are still a fair number of ophiuroids.
17:21:16	2205	0	E	A single lemon drop occurs in a crease between two lobes.
17:21:30	2203	1	E	Robust, sagged, shelly-looking lobes here appear older than the inflated lobes, having 50% sediment veneer and more than 20% sediment ponds.
17:21:31	2209	1	S	I see nice starfish out my window. At 17:21:44 Robin said he saw our marker [0-]. We're now over a shallow collapse pit; a white starfish is within it. I assume we've stirred up all these particles, though I'm not certain. The collapse pit forms an overhang. You can see the exact pieces of the top of the flow that fell into the pit. The pit is maybe 6 in high. I see our drop-weights to starboard. I see another collapsed lobe; this one is about 1/2 m deep. Some of the sediment does have a brown tinge. I think I see coelenterates; their stalks are pink, and they have 6 tendrils at the top.
17:21:57	2207	0	E	Now unsagged lobes nearby have only about 20-30% sediment veneer and less than 5-10% sediment ponds; it does look like flows of different ages are juxtaposed here.
17:22:10	2209	1	E	A small, shallow pit occurs in the younger lava; it looks like a collapse pit with the crust subsided intact.
17:22:24	2209	1	E	Robust lobes rimming the pit have no sediment ponds and less than 20% sediment veneer.
17:22:30	2208	1	P	Our heading is 080^{o}, and we're flying over pitted sheet flows. There may be two different flows here, one having shallow subsidence pits and one having residual inflation pits. Other evidence for small-scale inflation includes uplifted tables (4-5 cm high and several m wide) on broad lobes, smaller uplifted blocks 1/2 to 1 m wide, and tilted plates about 10 cm thick. Broad lobes (about 1/2 m thick) of a younger flow have spread discontinuously across an older pitted flow. It looks like a contact between a younger, unpitted flow and an older, shelly and pitted, broken-up, rubbly flow. (Could there be 3 flows? An older inflated flow, a shelly flow, and then an unpitted flow?) I've seen several of the funny little creatures with wave-like undulations of fringing "cilia" flying by, commonly in pairs. Less sediment seems to occur on this unpitted lobate flow than on the lava at our landing site; this lava has 5-10% sediment ponds and about 30% sediment veneer. We also see many specular reflections from its glass, though they are not prominent and you must look for them. More extensive sediment

TIME	D	A	O	OBSERVATIONS
				cover does occur on the flat tops of some broad lobes; as much as 1/2 cm of sediment may have accumulated on some of these surfaces, and the total sediment cover sometimes approaches 70%. So it's not entirely certain that these lobes are younger than the lava seen initially. Many big lemon drops, up to 4-5 cm in diameter and perhaps bigger, have begun to appear. Here is a fairly broad, very shallow pit, perhaps 1/2 to 1 m deep, with a few white asteroids along its edge.
17:22:37	2211	1	E	There may be a very intricate contact here between flows of different ages.
17:22:51	2206	0	E	Broad, pitted lobes here have much higher sediment cover (60% veneer, 15% ponds). A broader collapse seen dimly in the background shows up better in subsequent frames.
17:23:04	2210	1	E	Here is a good photo of a shallow collapsed area in which broad, thin plates of crust subsided intact and still fit together like pieces of a jigsaw puzzle.
17:23:18	2207	1	E	In the foreground of this next frame is a toe that oozed from under one of the subsided plates. The background of each frame in this sequence is shown close-up in the next.
17:23:30	2208	1	S	We're still in collapsed sheetflow terrain. There is still a light dusting of sediment on almost everything, and many ophiuroids. I see a nice shallow collapse pit; it's circular and maybe 1/2 m deep. The flows are still mainly lobate. There's a beautiful crab to starboard.
17:23:31	2205	1	E	An elongate, branching lobe has oozed out from under one subsided plate onto other subsided plates.
17:24			S	We were moving so that I had no time to photograph that crab. Some of the sediment ponds contained various discolorations. Some of the sediment is yellow and may be comprised of lemon-drops, some of which appear to be about 4 cm long. There is another big collapse in a lobe; it may be 1 m deep here in its center. I see--I guess it's a glassy sponge. I see a much larger collapse now; some little organisms seem to be living right under its rim. I do see some coral out here.
17:24:11	2206	1	E	To the right of center is a crab on a tangle of elongate, worm-like toes.
17:25:59	2207	1	E	Thin ponds of sediment cover more than 50% of a flat area (apparently a shallow sag) on this young pitted lava; this flow seems old enough to have accumulated extensive sediment locally where conditions are especially favorable.

TIME	D	A	O	OBSERVATIONS
17:26:10			P	Photo (roll 1, frame 21): asteroids on rim of shallow subsided area. The steeper wall rises 10-20 cm above a floor that slopes to a maximum depth of about 1 m. Small lobes have oozed onto the floor. I've not seen a sharp change in sediment cover. We did cross a morphologic contact, but the lavas didn't look very different in age. Small-scale morphology-related variations in sediment cover seem as great as the difference across the contact.
17:26:13	2208	1	E	This frame shows a possible contact between flows of slightly different age, with the younger lobe unbroken. But sediment cover is not obviously different.
17:26:40	2207	2	S	Faunal abundance seems to be increasing a lot. I assume the creatures are mostly corals; they're much more common now than before. We're still in lobate flows right now. I don't see much collapse, though we're over some right now. Sediment cover is maybe 30-50%; it's variable and depends on the slope of the surface. In some places there isn't as much sediment ponding as I saw before. The lava lobes are broad and striated. I see some ribbon flow. There are some very large lemon drops here, with rounded forms; many others are broken up.
17:27:10			P	Photo: Tried for a purple fish just beyond the port, but it must have escaped. Many ophiuroids [unresolved by the 24mm lens], asteroids, and worms are here, and many white, fist-sized heads of coral(?). The lava consists of lobes as wide as 5 m or more, some having collapsed centers. Sediment accumulates in the troughs of gentle wrinkles on their surfaces (10% ponds, 30% veneer). On ANGUS photos this sediment would probably be interpreted only as a veneer covering 40-50% of the surface in some places.
17:28:40	2208	1	P	I've still not seen a significant change in the lava-flow morphology. But right now we're crossing the rim of a very shallow pit, about 4 m wide and perhaps 1/2 m deep. It looks like an isolated collapse in a broad lobe, with no visible connection to any other pit. Many other lobes nearby have gently sagged tops even though they lack pits. It looks now like we've lost all signs of heaving or inflation; I've seen none of that since crossing the probable morphologic contact. All pits here seem to have been caused by subsidence. I do see various uptilted plates along the edges of some lobes, and places where the lava drained away from behind steep flow fronts. But the collapse pits are not obviously connected; it looks like collapses are local. What mechanism could produce this? Just local spreading of the liquid? Or perhaps deflation as gases were lost? If the latter, what gas could it be? The pattern does resemble that of gas loss in subaerial lava flows. But maybe the pits are connected by invisible drainage channels.

TIME	D	A	O	OBSERVATIONS
17:28:45	2207	1	S	I see no collapse pits for the moment. We're still in lobate terrain. Sediment cover is the same, maybe 30-50%. There are still many particles in the water. I don't see as many sponges now. The sediment is white but has a slightly brownish tinge. We're passing a collapse pit about 1-2 m deep. We passed over something that looked like a hollow, circular piece; I don't want to call it a chimney since this is not what we think chimneys are, but it was very angular--square--with a hole in it. It was not a basalt pillar. I see a red starfish out here.
17:30:02 to 17:30:16	2209 2205	0 1	E	Here are good photos showing the edge of a much broader collapsed area having a flat floor veneered by sediment. In the foreground of the second frame is a band of irregularly tilted, broad (1/2-1m), thin (2-10cm) plates. Some truncated (?) toes seem to have flowed over other tilted plates, suggesting some complexity here in the process of subsidence and spreading. This could be an incipient low levee around a perched lava pond. Two surges of lava may have occurred here, the toes of the second tilting up subsided plates of the first. We're swinging around to port to land on the rim; our azimuth is 076o in the first photo, and 072o in the second.
17:30:21	2206	2	S	Jim says we may be on the rim of the cleft. We'll deploy a marker. Ribbony sheetflows are below me.
17:30:54			P	We've crossed the rim of a much broader collapsed area now, and its floor consists of folded sheetflows. There is no sign of pillars here, but I think this is the edge of the outer collapsed area. We'll deploy a marker here.
17:30:56	2204	2	E	We continue to swing around (061o) over the very flat surface, which was at first featureless but now has a prominent band of lineation. The lineation is not just straight and featureless but has long, low uniform folds, closely-spaced and some having V-shaped axes.
17:31:00	2206	2	S	The sediment cover is about 95%, probably because the surface is so flat. I see one or maybe two sponges on it. The sediment is a dirty white. I see a vibrating [?] surface on the sheetflow.
17:31:23	2203	2	E	A sharp boundary occurs between the flat, lineated lava and a more irregularly-folded to dimpled or sagged, draped surface with a gentle slope. Azimuth 53o.
17:31:37	2207	2	E	This close-up view shows a small shelf along the morphologic boundary. It may be a lava-subsidence selvage, but it is discontinuous and irregular; it appears to be a fold in some places and a shelf in others.
17:31:50	2208	1	E	Here are the less regular, higher, sharper, draped folds.

TIME	D	A	O	OBSERVATIONS
17:32			S	Photo: It shows marker [3X], which is deployed.
17:32:04	2209	1	E	We have come to rest on the draped folds. Sediment is concentrated in the troughs of folds; crests have less than 10% sediment veneer while sediment ponds in the troughs cover about 10% of the total surface.
17:32:10	2208	1	P	CTFM photo: Heading 040o, 1500 m scale, useless "birds" from high amplification. We deployed marker float [3x].
17:32:17	2205	0	E	We're stationary, with our azimuth 039o; this frame may have stereoscopy with the previous one.
17:33:52	2206	1	E	We are beginning to move again; our azimuth is 069o.
17:34			P	A navigation fix here puts us at (11160, 11456). Our bearing to the main hydrothermal vent is 095o, its range is 215 m. We'll now make a careful topographic traverse of the collapsed area. Jim will fly at constant depth (unless he must climb over something), and I'll constantly read time, depth, and altitude. Ellen will make a verbal description of what she sees. We want to know if there is a gradient on this subsided surface.
17:34:32	2207	0	E	Benchmark [3X] is floating above draped folds. The floating block of syntactic foam measures 6 by 12 by 2 in.
17:34:46	2211	0	E	Here is a good view across the morphologic boundary, past draped folds in the foreground toward the lineated flat surface of the subsided flow. Some low swells may be successive fronts of lava that oozed out over foundered crusts as the lava receded. Heading 077o.
17:34:58			S	Photos (roll 1, frames 6-10): We got a video record of the [3X] marker. I also shot 5 photos here; three showed the [3X] marker, and two showed an area about 3 m to the right of it. We're still in striated sheet flows. I see something that looks like a shrimp, a pink animal lying on the floor. There are many sponges around here.
17:35:13	2206	0	E	A low mound is coming into view beyond the lineated flat surface. Scattered small bluish-white blobs probably are glass sponges; some appear cup-shaped. Heading 056o.
17:35:26	2205	1	E	Here is a good view of the top of the mound, which is broken open like a tumulus. But the tilted plates are thin and look like they have been draped onto underying irregularities; they do not look like products of inflation. Successively younger lineated surfaces are less disrupted. Heading 039o.
17:35:40	2210	0	E	The top of the mound consists of tilted plates of lobate lava, which was probably the primary spreading morphology.

TIME	D	A	O	OBSERVATIONS
17:35:53	2206	0	E	Now a small pit is visible beyond the "mound", which may really be the rim of the large subsided area; the pit must be outside it. Our heading is 032o, and we become stationary again for several frames while we get a fix.
17:36:21			S	Robin is getting a navigation fix. Our range to the target was 215 m. I'm looking at the rim of a pit, with some bathtub rings beneath. The flow seems to be draped down toward the lineated (same as striated or wrinkled, in my usage) sheetflows. Several sponges are nearby; most are white, but I see one with a kind of peach color.
17:37:14	2205	1	E	This good frame shows the morphology of a collapse pit. Most of a broad lobe has drained away, leaving a fringe of primary crust around a pit about 1 m deep. The center of the pit is littered by rubble of the primary crust; but beneath the overhanging roof, around the edge, is an inward slope that may consist of pimply-textured dregs thinly veneering older flows beneath. Heading 014o.
17:37:41			E	This frame shows better the rubbly pit floor.
17:37:56	2207	1	E	Heading 013o. The uncollapsed surface of an elongate lobe extends away from the pit. Following frames show a tangle of elongate robust lobes; a few pits reveal that they are largely hollow shells. After 17:39 our heading swings back east and averages about 95o. Though we're going east, we're no longer above a flat surface, but a robustly lobate one having scattered small pits. Is this a younger flow within the big collapsed area, or is it another uncollapsed part of the same flow? Earlier in the dive it looked to me (Robin) like we were on the edge of a broad subsided pond that we had to cross to reach the cleft. But Ellen's description and the external photo sequence suggest instead that we skirted the north side of a collapsed area, passing mostly over lobate sheetflows until we neared the cleft. I should examine this problem again using the ANGUS films; my shipboard interpretation (extensive younger overflow inside an extensive subsided area) may need revision.
17:38:28	2207	1	S	Photos (roll 1, frames 11-14): Frames 11 & 12 show what I was just saying about the draping of flows over the rim. The others show the collapse, and bathtub rings.
17:38:49			S	We're back over pitted lobate sheetflows; I see no more flat sheets. We're above a large pit 1-2 m deep. I see a light pink anemone. Sediment cover is maybe 20-30%, though often there is just a light dusting. Many particles are in the water column. There isn't as much fauna as I saw earlier; not nearly as many sponges, though I do see a few. Some sea pens are sticking up. I see a nice fish to starboard; is it a rattail?.

TIME	D	A	O	OBSERVATIONS
17:40:25	2208		S	I see a few collapse pits now. Sometimes I can see into a pit and estimate its depth at maybe 1-2 m. I still see lemon drops, and some ophiuroirds. Many lemon drops are scattered about in one sediment pond; they seem to like the depressions between separate lobes.
17:41:22	2207	1	S	We're still above lobate sheetflows. Below me are some broken sheet fragments, maybe 5 cm thick. The lobes are broad and striated. We're now driving over a nice collapse pit with bathtub rings in it. The rubble in it was very small. Now there is another huge collapse pit. There are sponges all over the bases of the bathtub rings. There is quite a bit of sediment dusting, maybe 80% sediment cover on it. Now we're passing a very large collapse pit. I'm starting to lose sight of the bottom.
17:41:31	2203	1	E	Once again we are coming to the edge of slightly chaotic broken lava around the edge of a broad collapsed area, as if a younger flow might have flooded against and tilted the broken plates along the edge of a previous subsidence depression. If so, my shipboard interpretation of multiple floods is correct, except that the second flow ponded within the depresson of the first.
17:41:58	2206	1	E	This good frame may show flows of two ages, with younger lobes oozing around rubble of an older collapsed lobate flow in the foreground. But the interpretation is not certain; this could be partial collapse of a single flow.
17:42:25	2207	1	E	Here is the edge of a deeper (more than 1 m) collapsed area, with short pillars protruding. The next frame seems to show dimly a broad subsided floor, as if we have not yet reached the deeper axial cleft. Then the seafloor recedes and is very dim for several frames.
17:42:52	2206	2	S	From here I can see some collapses and bathtub rings. A face of the wall is flooded with sponges, many of them, all over the place, both underneath and inside the pit. We're now passing over flat sheetflows, which are striated. The sediment accentuates the striations here. Sediment cover is maybe 40%. There are many particles in the water. I see the edges of the collapsed area now; the flat sheet was ponded in the middle of the collapse.
17:43:40	2206	4	P	Ahead is a wall about 2 m high.
17:43:46	2203	3	E	Pillars of an inner subsided flow project upward dimly; two generations of overflow and subsidence are obvious here. But are there more, as I thought during the dive?
17:43:59	2204	3	E	Here is a good view along the rim of a deep collapsed area, with small glass sponges clustered on the rim and wall. Only one flow generation is apparent in this view.

TIME	D	A	O	OBSERVATIONS
17:44:25			S	Now we're over lobate sheetflows. Sediment cover is maybe 40%, and there is much collapse, and broken pieces.
17:44:30	2207	1	P	Here are collapse pits.
17:45:00			S	We're above a large collapse pit again; and many sponges are attached to its walls. The pits seem to be getting deeper; this one is maybe 2 m deep. The sediment cover is maybe 1-2%; but surfaces do not look glassy. There is a big aa-like pillar with sponges all over its surface.
17:45:07			E	Here is an apparent pillar, with glass sponges, rising above a lobate surface that is also collapsed; it's a pretty good visual record of two flow-subsidence episodes.
17:45:34			E	Here is another example of the same thing, maybe showing the same sponge-colonized pillar.
17:46:00	2207	2	P	A big drop-off is ahead of us.
17:46:00			S	We've come to a huge drop-off. I can no longer see the bottom. I do see some bathtub rings. I've totally lost the bottom; I have no more view. Our altitude is rising to 8.3, 8.6, 8.9 m. Now it's 10, then 11 m at 17:46:31.
17:46:01	2208	1	E	The seafloor has gone out of view.
17:46:31	2207	15	S	I still cannot see the bottom.
17:46:40	2207	14	P	We're turning to descend the west wall of the axial cleft.
17:47			S	We're turning now so that we can take a look at the wall. We wish to drive down the wall and describe it.
17:48			S	I am preparing to slurp a sample of bottom water for Gary Massoth, into bucket 3.
17:48:16	2195 ?	12	E	Collapsed sheetflows are coming back into view, dimly.
17:48:47			S	I've turned on bucket 3, pump 12. The bottom is in view again, and I see large collapses. Sediment cover is less than 5%, maybe 1-2 %, though locally there is a sediment dusting on the collapse pieces. I see a nice pillar.
17:49:10			E	Here's an excellent view of a sharp-rimmed deep pit, with a thin vertical septum between adjacent lobes and maybe a thin plaster of younger lava on the wall of an older pit.
17:49:24			E	Here is another good view of the pit margin, with glass sponges and perhaps some rude lava-subsidence selvages up high, grading downward into a pimply-textured veneer.
17:49:37	2205	1	E	We kick up a cloud of sediment.

TIME	D	A	O	OBSERVATIONS
17:49:45	2206	3	S	We're deploying [OX]; it looks like it's in a collapsed lava tube, under an overhang. I'll photograph now. Photos (roll 1, frames 15-16): 2 views of a pillar. We're slurping bottom water now, but we've stirred up a lot of particles in moving around to photograph the [OX] marker. I've lost sight of the marker and have not been able to photograph it. As I think I said, it's lying at the bottom of a collapse pit, slightly underneath its rim.
17:49:51	2206	2	E	We rise above the pit and record the shelly lobes around.
17:50:00	2207	2	P	We thought we went down as we turned, and we decided to take a water sample here. But our depth recorders show that we're still up high. I can see one high rim above me to port; this could be a remnant of the initial unsubsided lake surface. If the surface beneath us is the subsided lake surface, then the subsidence here may have been 3-4 m. Behind us is a drop-off that may be the true west rim of the axial cleft. The lava walls around us have many subsidence selvages, while we are sitting on a primary, unsubsided, lobate sheetflow surface, with pits in it. So there has been at least one upward surge of the lava surface here after the lake's initial subsidence; then renewed subsidence produced the pits in the lava beneath us. I see many glass sponges on the rims of depressions and selvages. I do not see many specular reflections from glass, but the sediment cover is light, less than 5% ponds, 15-20% veneer. I see one large pillar out to port with many glass sponges on it.
17:51:25	2206	1	E	Here is a good close-up view of younger toes that apparently oozed over an older collapsed surface.
17:51:45			P	We've deployed marker float [OX].
17:52:33	2205	1	E	This frame shows the same view as the previous one, with a puffy lemon drop in the foreground. The next frames show the manipulator arm kicking up sediment clouds.
17:53:05			P	Photos (roll 1, frames 23-25): pit wall, showing the selvages and sponges, and many particles in the water. Many sponges hang from the bottom surfaces of projecting shelves and would not be visible on ANGUS photographs.
17:54:21	2207	2	S	We're moving to another spot to continue slurping because we've stirred up sediment here. I see the rim of a collapse pit right in front of me. [To Jim:] You might watch the side over here. We're going to hit. We hit the wall of a collapse pit. There are sponges all over it. We're now at the bottom of what I assume is a collapse pit; yes, I see some pillars. There are small bits of rubble all over the place. Sediment cover is maybe 5-10%. There are still many particles in the water.

TIME	D	A	O	OBSERVATIONS
17:54:48	2208	1	E	The thick cloud dissipates, leaving a thin cloud of lemon drops wafting around.
17:55:15	2207	1	E	Here is a good view of a collapsed inner lobate flow having lava-subsidence selvages on its wall.
17:55:18			P	After setting out the marker we found that we could not collect a water sample for Gary Massoth because we had kicked up much sediment. So we lifted up and moved a few m, crossing a collapse pit 1-2 m deep in the lobate floor of a deeper collapse pit. So we have at least three different generations of lobate surface here, each one being inside the subsidence pit of a previous one.
17:55:55			S	Photos (roll 1, frames 17-18): more views of a pillar. We're in collapsed terrain. There are many pillars all over the place. I guess we're kicking up a bit of dust beneath us again. The large particles look like a lot of bugs, or biological matter that have been kicked up. I can see much better with the light off, though there is still much sediment in the water column. Right now I'm over a flat unbroken sheetflow that looks striated . We're still slurping. I'm going to let it slurp a little longer, though I think we got quite a lot of particles in the sample of bottom water. According to the position we got at 18:00 hrs, we're not yet at the bottom of the cleft; we're still on the rim of it. I see a lot of what looks like levels of collapse, deep collapse pits in the sheets and lots of bathtub rings. Sediment cover on the top of the flows is nearly 0%, though from this view it does not look glassy at all. Some of the flows seem to be of slightly different age, or slightly different color; I don't know if that's because of surface texture.
17:56			P	A fix on our position here puts us at (11290, 11440); the main hydrothermal vent is 90 m away on a bearing of 110°. If that distance is correct we cannot be on the true east rim of the cleft yet unless the cleft is nearly 90 m wide here. Maybe the east wall goes down in a series of steps, such that it is wider here, from rim to rim. So maybe the inner cleft widens too, as well as the outer collapsed area, around the hydrothermal vent.
17:56:36	2210 ?	1	E	We're kicking up another cloud of lemon drops.
17:59:37	2208		P	We're sitting on the bottom, a few m away from [OX], taking a slurp sample of bottom water for Gary Massoth. Our depth indicates that this lobate surface lies only about 1 m below the general floor of the outer collapsed area. Our fix still places us west of the main cleft; we'll see if we go down stepwise into the cleft here.

TIME	D	A	O	OBSERVATIONS
18:00:26	2205	2	E	The cloud of lemon drops dissipates in front of us as we rise and fly away. Following frames show the seafloor only dimly; it still consists of pitted lobate flows.
18:01:25			P	We'll descend on a course of 110°, hoping to get deeper into the cleft. It looks like we're coming onto a deeper inner rim right now, a fairly high, almost vertical step downward, and I cannot see the bottom.
18:01:34	2203	1	E	We pass over a rubbly lobate rim, possibly with a detached slice pulling away from the rim of the cleft, and fly out into space. The seafloor goes out of view.
18:01:40	2207	2	S	We're coming to another rim; I cannot see the bottom below it. The edges are collapsed, with jagged pieces protruding. It's a vertical cliff. I barely see the bottom now. It doesn't quite look like there are bathtub rings, or many that I can see. But we intend to do an upward traverse, looking at the wall of the cleft; so I'll wait to say anything more. Now I've lost my view; I cannot see anything any longer.
18:02:04	2206		P	We're descending into the cleft; our altitude is 4.3 m at 18:02:04, 7.6 m at 18:02:14, 10.4 m at 18:02:25.
18:02:34	2206	15	S	We're now descending into the cleft.
18:02:35	2206	15	P	The altitude display is jumping around quite a bit right now (15.6, 14.1, 13.3, 12.8, 12.6, 15.4), perhaps because of pits or other rugged terrain beneath us.
18:03:00			S	The bottom water sample was not truly from the bottom of the cleft, but from a terrace-like step of its west wall.
18:03:34	2212	10	P	We're descending now into the cleft.
18:03:39	2213	9	S	I'm beginning to see the bottom of the cleft. It looks flat, so far as I can see now. The bottom is well in view now. It looks like a lot of broken flows, broken sheets. I would not call it rubble. Sediment cover is practically nill. I don't see very much at all. I see a few little crawling things. We've just kicked up some sediment upon hitting the bottom.
18:03:52	2213	9	P	I can see the bottom beneath us.
18:04:24	2219	3	P	We are coming down onto broken folds in front of us, and possibly lobate lava over to the port side. There is much fine golden sediment here, and many coarser lemon drops; we kick up a cloud as we hit the bottom.

TIME	D	A	O	OBSERVATIONS
18:04:29	2202 ?	18 ?	E	The seafloor is coming dimly into view. It is shelly rubble--mixed fragments of shelly lobes and folds. Small sediment ponds are common in hollows between fragments; a lot of sediment must be present for it to fill interstices and show up on a surface as rough as this.
18:05:17	2222		P	We're sitting on the bottom. We've come down about 14 m since we deployed [OX].
18:05:27	2221	1	S	We're now at the bottom of the cleft.
18:06:31	2206	2	E	We are beginning to kick up a cloud of sediment.
18:06:52			S	We're turning to look at the west wall of the cleft. I still see many broken sheets and a pillow. We're now rising slowly. Sediment cover here can be no more than 10%. It's a very thin veneer and mostly in depressions or crevices between individual flows. I can possibly see lava draping over the sides. Yes, it looks like we're going up a gradual slope. Jim says it's about 30°. There is quite a lot of draping of the flows. I don't see anything very sheer yet. Jim says the slope is about 40°. The sides really are rather smooth. Nothing sheer about them yet - or nothing jagged as far as I can see.
18:07:03			P	We're rising and turning around to make a short traverse up this scarp 12-14 m high that we've just dropped over. As soon as we start up, I'll change the framing rate of the external camera to 6 sec. Wow! You really . . . The declivity is too gentle for a wall; it looks so far like a slope going up about 30°. I'm waiting until we get a really steep slope to increase the repetition rate of the camera.
18:07:11	2219	2	E	Here is a good view of shelly rubble.
18:07:25	2226	0	E	Here is a good view of broken folds that are not entirely chaotic. This material looks like the dregs of a drained flow after several generations of crustal foundering, or regeneration and deformaton of a thin crust during rapid flow. The following frames show other varieties of non-lobate broken crust, as well as areas of apparently unbroken and possibly unsubsided lobate sheetflows.
18:08:46	2218	1	E	Here is a good view of shelly rubble and scattered lemon drops. The next frame shows a relatively unbroken shelly drapery around the base of this rubbly mound. It looks much like the islands that protruded from the subsiding flows of 8-14-71 and 9-24-71 on the eastern floor of Kilauea caldera.

TIME	D	A	O	OBSERVATIONS
18:09:07			P	I've set the repetition rate to 6 sec as we go up this slope. [We should make a mosaic of this sequence.] There is a lot of rubble on it, and a few subsidence selvages. The pilot says the ground slope now is about 40o, so it may be getting steeper as we rise up it. Much golden sediment occurs in small pockets, and floating around are some lemon drops, many of them having a pale color. The slope looks almost like a talus right now, but it's a talus composed of small blocks mixed with plates. Now ahead of us is a steeper buttress or wall having lava-subsidence selvages on it. The contact between it and the slope below is sharp. It does look like a talus had developed beneath a cliff, probably in more than one stage: Older talus further down was veneered by lava fringed with bathtub rings, and a younger post-eruption talus then developed higher up on the apex of the slope. [Later note: Alternatively, there could have been one generation of talus and a later stream of lava that flooded only the lower talus. We should test these alternatives using the external photographs.] The wall is not straight and vertical but is scalloped and very irregular, with much lava draped over the front of it, and many lava-subsidence selvages.
18:09:09	2221	0	E	The plot thickens! When viewed close-up, that surrounding "lobate" material looks like it's partly a blocky rubble, maybe having a pimply veneer on top.
18:09:15	2219	1	E	Now we see irregular fractures in the veneered rubble and those wide, shallow cracks reveal a massive (not rubbly!) substructure; the rubble itself is only a thin veneer right here. The crack walls consist of multiple planes having vertical intersections, such that the cracks follow zigzag paths. The most prominent crack seems to curve around a high area beyond the upper right corner of the view, and it seems to display fault displacement: subsidence as well as extension.
18:09:21	2216	1	E	Oh, yummy! Here is a fat pillar with no sign of an exposed axial pipe but clear signs of multiple onion-skin veneers. It protrudes from a subsided crust that is veneered by tacky lobate lobes and rubble.
18:09:27	2218	1	E	Beyond the fat pillar is the face of another fault in the veneer.
18:09:33	2216	1	E	Above the fault is an apparently unbroken ramp of pimply veneer littered by blocky rubble. This veneer may occur on top of talus that is sloping down toward the camera. In the following frames we continue to climb this slope.
18:09:53	2216	2	S	I'm going to take some photos now.

TIME	D	A	O	OBSERVATIONS
18:09:56			E	This frame shows a contact between lava-veneered talus below and a nearly vertical massive wall above. The massive appearance of the wall apparently arises from a plastered-on veneer. Some faint horizontal marks are visible on or through the veneer, and many sharper vertical ribs look like little driblets of lava that froze as they drained down the face.
18:10:02	2214	1	E	The contact is barely visible now at the bottom of the frame, and some horizontal lava-subsidence selvages are coming into view near the top.
18:10:08	2211	2	E	Multiple veneers seem to be plastered over each other on this face, with the truncated, downward-facing ends of three being exposed here!
18:10:31	2209	3	E	We're up now onto a finely fractured, hackly part of the cliff face. I'm not sure how to interpret this.
18:10:37	2208	4	E	A crude spherical form here (and in the previous frame, maybe in stereo) could be a truncated pillow partly showing through a discontinuous veneer.
18:10:53			S	Photos (roll 1, frames 19-20): two out-of-focus views of the wall; I couldn't get enough light to focus. I see some bathtub rings on the side of a collapse pit. The top of it has essentially no sediment, but maybe some occurs in the cracks. We've now risen above the cleft. I never really saw any sheer walls exposing truncated flows. It looked like everything was covered by flows that cascaded into the cleft. We're now turning and will descend again.
18:10:55	2203	6	E	Here above the massive face is a shelf, capped by rubble.
18:11:01	2203	6	E	Now the view is largely filled by rubble having many shelly plates of lobate crust. Above the rubble rises thin septa between adjacent collapsed lobes.
18:11:06	2209	4	E	Now we see the lobate surface above the rubble and septa. The pit wall is corrugated by many subsidence selvages.
18:11:12	2203	4	E	Beyond the rim is another pit in the same shelly flow.
18:11:30	2203	2	E	We leave the pitted surface behind; the seafloor fades.
18:12:13			S	I've lost bottom once again. We'll descend and search for the hydrothermal vents that Karen & Randy described.
18:12:26	2207		P	Now that we've came back up, we'll descend again on a course of 110° toward the hydrothermal vents. . . . . [Long gap] . . . as we fly out into the axial cleft.
18:12:55	2199	7	E	The framing rate is reset to 14 sec as we descend again.

TIME	D	A	O	OBSERVATIONS
18:13:19			S	We're still descending. I don't see the bottom yet. A fish is just below me, flying right outside my viewport; he seems to be just drifting with the current.
18:13:58			P	We're coming back down into the sediment cloud we kicked up earlier. I see the bottom but can't see details through the rain of fine sediment and lemon drops. Now we're coming out of the cloud, and below us is a semi-chaotic surface of broken folds; the glass is heavily tarnished, with no sign of specular reflections. The surface is a mixture of broken folds and lobes, mostly folds. Folds occur on various scales: the biggest have amplitudes of about 1 m; many have amplitudes of about 10 cm. Sitting up on top, or projecting through the top of the flow and above my viewport, are large lava masses resembling accretionary lava balls; but they may be the bases of fat pillars that haven't moved. Local relief is at least 2-3 m over a distance of 10 m. . [Long gap] . .
18:14:00	2216	4	S	I see the bottom again. We've probably kicked up much of this sediment. The particles are rather large. The bottom consists of many broken flows, with fragments of various sizes. Some flows have more sediment than do others, mostly as sediment pockets. In front of me now is a large, lobate mound, with broken flows to its side. I am losing my view because of particles in the water. [End tape side 1] . . . [Begin tape side 2] The bottom is in much better view again. Now I see lobate flows. In front of me is a large slope on which I see a large pillow and a lot of broken flows. I see no evidence of fault talus; I do see evidence of draping by flows. There is another large pillow with a bud coming out of its side. There seems to be some red staining on a piece of basalt on the wall. Yes, I can confirm that. It's sort of strange; it seems to be the only piece in the area having any sort of stain on it. We're turning. Below me are many lemon drops and some sediment ponds. We've just kicked up a lot of sediment, so I'm starting to lose my view of the bottom.
18:14			P	<u>Photos</u> (roll 1, frames 26-29): shelly, broken folds near the base of the west wall of the axial cleft, nearly opposite the Plume Site hydrothermal vents. They show much golden sediment and many lemon drops.
18:14:17	2217	2	E	Rough, chaotic rubble on the floor of the cleft is coming into view.
18:15:38	2220	1	E	Here are undisturbed elongate toes and lobes that have spread across rubble and broken folds. A flow was slowly extruded onto this area after the last flood drained away.
18:15:52	2221	0	E	Robust elongate lobes are obscuring a substrate of rubble.

TIME	D	A	O	OBSERVATIONS
18:16:06			P	We've come to some robust lobate lava that has oozed slowly onto the rough floor. One mound almost looks like a little hornito. . . . Photos: I've taken a few down here, and right now the frame counter is set on 13. Some of these robust lobes are almost like pillows, and there are big, striated, turtleback-shaped, pillow-like forms with smaller lobes that oozed from around their bases.
18:16:59	2219	1	E	A small mound of veneered rubble projects as a kipuka through elongate lobes.
18:17:26	2218	2	S	The flows look lobate as we turn. Sediment cover is maybe 5-10%. The water is clear again; there are no particles in it. As far as I can see, the slope and the eastern wall look like they are covered by lobate sheet flows. There is scarcely any sediment cover on them, the flows are unbroken as far as I can tell, and they are smooth up the wall. There are no striations on the flows. I see what looks like a hole or collapse pit in the wall. It looks like a flow may have come down the wall and then had the bottom collapse out from under it. There may be some bathtub rings, though I'm not sure. I can see lots of flows, each maybe 40-50 cm thick, piled up. Some of their edges are broken; others are rounded.
18:17:53 18:18:07 18:18:20 18:18:34	2216 2218 2219 2218	1 0 1 1	E	A sequence of frames along a chain of elongate lobes shows how one lobe feeds another, with one of the oldest links upslope having collapsed to form a shallow pit.
18:17:54	2219	1	P	We're flying over the floor of the cleft on a heading of 110°, trying to find the eastern wall. Right now we're over fairly shelly lobate sheetflows that have come out onto the rough lava from somewhere ahead of us. The slope is coming down toward us. This lobate lava must represent a late, slowly-spreading extrusion across the dregs of earlier lava that filled the cleft rapidly and then drained away. Also in this lobate flow are a few big pillows, slightly elongate downslope. Now the wall is ahead of us, and we want to move along it in some direction to find the hydrothermal vents, but I don't know which way to go.
18:19:01	2215	0	E	We now see shelly rubble, and possibly veneered rubble, along the base of the eastern wall.
18:19:14	2217	1	E	Here in close-up cross-section is shelly rubble, possibly truncated and then partly veneered by later lava. Some boxwork structures etc. are also shown on the next frame.
18:19:41	2211	2	E	The manipulator arm appears as we try to sample the rubble.

TIME	D	A	O	OBSERVATIONS
18:19:44	2217		P	We're at the base of a steep scarp near the hydrothermal vents. As we turn to port we can see that lobate lava has spilled down this scarp, built a cone at its base, and spread westward across the floor. The lava left broad, sheet-like stalactites where it flowed down across overhanging ledges of the wall. Some of these drapes are complete; others are broken. The source of this lava is somewhere higher on this scarp, or beyond its rim.
18:20:32			S	Photos (roll 1, frames 21-23): east wall. We're turning so that Robin can view the wall out of the port window.
18:20:49	2214	2	E	The cloud of debris that we kicked up is clearing.
18:20:51	2215	3	S	We're turning so that I can see the wall. Robin said I should keep my eye out for the hydrothermal vents.
18:21:02	2211	4	E	Here is a morphologic contact between back-tilted flat lava and folds along the base of the cliff. The fold axes and fractures in the flat plates probably parallel the wall and flow direction along the cleft. It looks like successive crusts formed along the edge of a lava lake, different crusts behaving differently as the flow rate subsided from a flood to a trickle.
18:21:22			S	I see lobes. I hear Robin say lobate lava; I thought it was more like sheet fragments and folded flows, ribbons that had cascaded down the scarp. Sediment cover is maybe 5% or less, very localized in depressions. There are many broken sheets and sheet fragments, but I see little evidence of bathtub rings; in fact, I see none at all. I can barely see the bottom off to starboard.
18:21:43	2209	2	E	Several frames seem to show onion-skin layering plastered against the wall. Or could it be a veneer of successive little surges atop each other as the stream rose briefly before draining finally to leave a rind of congealed, flattened tongues against the older wall veneer?
18:21:56	2218	0	E	Here's an especially good view of onion-skin structure.
18:22:50		4	E	The manipulator appears as Jim tries to sample a red (oxidised?) material that has not yet appeared in a photo.
18:23:03	2213	4	S	We're stationary as Jim tries to sample from the wall. Photos (roll 1, frames 26-28): approximate area being sampled. These frames may be out of focus because there was not enough light for me to focus. [Frames 24 & 25 are out of focus.] I'm catching glimpses of Jim's view. It looks like there's a reddish surface on a piece of the basalt. In fact, there is a reddish surface on many of the pieces here. I don't see that same color on any of the basalts outside my viewport. I see a shrimp now.

TIME	D	A	O	OBSERVATIONS
18:24	2213		P	Jim is trying to sample some very red material from a ledge on the wall. I've asked for a fix; it puts us at (11390, 11450). The hydrothermal vents should be about 50 m away on a bearing of 200° along the valley wall.
18:25:05	2209	4	E	Here is a good view of the reddish particulate material on shelly veneer of the eastern wall.
18:25:30			S	Photos (roll 1, frames 29-30): shrimp, in the same area, just to the right of Jim's sample site. x=11390, y=11450.
18:25:45	2209	4	E	A red cloud rises as we try to sample the red material.
18:31:56			P	I'm looking out the front port; Jim has sampled from the lower part of the wall drapery. Its surface is dull, but where he broke it fresh glass occurs just beneath a very thin, dull coating. Much brick-red material occurs throughout the broken mass; fracture surfaces may have been coated by a ferric hydroxide, possibly hydrothermal. There seems to be some dull-black material too; although much of the rock seems to be glass, some pieces may be thick enough to have a finely crystalline interior too.
18:32:17	2211	0	E	This good frame shows reddish material in place, reddish clouds, and bluish surfaces that may be fractured basalt.
18:33			P	Photos (roll 1, frames 30-40): frames dark; the strobe did not fire until Jim replaced the connecting cord.
18:33:00	2214	3	S	We're still at the place where Jim took the sample. We kicked up a lot of red sediment. When the basalt was broken you could see the glass beneath, but on top it looked tarnished. They're having trouble with the strobes. We're now moving from the sampling site. I can definitely see very glassy surfaces on the basalt. We put no marker at this site. We did take a scoop sample.
18:33:24 18:33:38	2215 2213	2 2	E	Two very good frames (maybe in stereo) show festooned drapery hanging from a projecting ledge near the base of the eastern wall. The festoons have longitudinal ribbing, and some are truncated. Then we kick up a cloud of debris as we move away from the cliff.
18:35:35			P	We're pulling away from the sampling site on a heading of 200° and will leave no marker. I had problems with the strobe for my hand-held camera, making several dark frames on my roll of film. But Jim changed the strobe cord for the camera, and it seems to be working again now.
18:35:53 18:36:00	2213 2207	4 5	E	These frames seem to show truncated drapes hanging along the base of the cliff, which seems to have a recess near its base. This lava must have flowed down over the cliff after subsidence of the last voluminous flow.

TIME	D	A	O	OBSERVATIONS
18:36:20	2212	6	S	We're in search of the vents again. We'll not try to slurp a sample of the red sediment; we'll go directly to the vents because we've already fallen well behind our schedule. I can't see the bottom clearly now; we're too far above it. We're back over lobate lava. Sediment cover is 5-10%. There are ponds of red sediment. The water is very clear. I see very little biota. Right in front of me is a huge wall of lava; I can't make out exactly what it is. To my right is apparently a huge collapse; I see nothing in the distance. We're moving now, approaching a wall. The external camera may have photographed a fish. The bottom has dropped again, though there did not seem to be a cliff or a wall; I guess it sloped away. The flows are unbroken; they're not at all jagged. I can't make out the bottom very well.
18:36:35			P	Photo (roll 1, frame 41): drapery on the lower face of the cliff, as we backed away. The drapery bends over a ledge and is truncated where it formerly hung vertically.
18:37:07			P	As we fly along the base of the cliff we're crossing over some fairly large pillows, perhaps of 1-2 m diameter, and then over shelly lobate sheetflows. I can see that these flows overlie chaotic, rough lava of the cleft floor. The surface slope is from the east down toward the west.
18:37:14			E	Now we see lobate lava on the cleft floor again as we move southward along the wall. Soon pillows begin to appear, sloping down off the wall from left to right.
18:37:41			P	We're crossing a contact from younger lobate lava to much more shelly, rubbly material of the cleft floor. But I see more pillows ahead, so we're not entirely beyond the younger flows; they come down at more than one place along the eastern cliff. I can see distinct streams coming down over that wall, draping it thickly with sheetflows unlike the thinner subsidence veneers on the west wall. Here are some extremely elongate pillow-like forms, and very long tubes like downspouts coming down the cliff. They have shallow pits, much like the gutters of Mauna Ulu lava that cascaded over Holei Pali.
18:38			P	Photos (roll 1, frames 42-43): long lobes and drapes near base of the east wall. Top is to right in frame 42.
18:38:08	2223	1	E	Here is a good view of some striated elongate pillows.
18:38:21	2218	2	E	After this final shot of pillows, the bottom disappears.
18:38:48			P	After crossing an especially prominent steep cone of long pillows and gutter-like tubular lobes, we're flying along the nearly vertical cliff with large, protruding, shelves partly obscured by thick mats of biogenic crud. The wall dropped down much deeper as we passed beyond the cone.

TIME	D	A	O	OBSERVATIONS
	2218	7	P	The total depth here is about 2225 m. The very heavy coat of puffy golden-yellow material may indicate that we are nearing the hydrothermal vents. This wall is nearly vertical, rough, and has some horizontal selvages. Now I see lots of worms below me. I turned a light on for a better look and saw that the entire wall is coated with a thick mat of this golden material.
18:39:06	2217	7	S	I can't make out the bottom well from this height. It looks like it's all well-sediment-dusted and flat. I heard Robin say that the sediment is golden yellow. I could not make it out as such from here; it just looks white to gray. We're descending a wall. It's not ragged at all; it's smooth sheets as far as I can see. I hear Robin saying he sees a lot of worms. The wall, as far as I can see, is well-covered by sediment, probably close to 100%. It looks like there is another break, though this time it looks like it's more of a collapse than a draping, though now again I see draping. Now worms are coming into view, very briefly. Now that I see pieces of the wall, it does look craggy and jagged. I do not see much evidence for bathtub rings. The floor below me that I see is very well-sedimented, certainly 100%. I can't estimate sediment thickness from here.
18:40:23	2224	4	P	The floor is visible, with many worms, much fibrous white material like cotton candy, and lots of golden-yellow fluffy material forming a drapery swinging in the breeze.
18:40:37	2218	4	E	The wall is at the left, partly veneered by organic mats.
18:41:21			P	<u>Photos</u> (roll 1, frames 44 & 1): material hanging from wall above hydrothermal vents; includes yellow and white fibrous mats, and entrails that may be dead worm tubes coated with bacterial mats. Below are many worms and blue-gray incrustations. We're stopping to sample.
18:41:25	2226		S	I'm looking out of the front viewport and see yellowish-orange "sediment" that I assume is bacterial mat. Robin sees worms; I don't. Is it slurpable? My view isn't very good. All of the excitement is out of the other two ports. (Sigh.) Robin sees shimmering water.
18:41:44			E	Here is a typical view of the wall, which is overhung here and is apparently coated by a featureless, tacky-looking veneer and patches of gold and white organic mats. Sulfide chimneys appear at the bottom of the next frame.
18:42:30	2227	1	S	I saw many tube worms out of Jim's port. I could see the shimmering water at Robin's side; my view is still pretty rotten. I hear them trying to use the temperature probe.
18:42:38	2231	0	E	Thick worm tubes hang from organic mats on a projection of the wall; below them are bluish-black massive-sulfides.

TIME	D	A	O	OBSERVATIONS
18:43:19	2230	0	E	A cluster of worms appears to the left. Then follows a long sequence here as we sample organisms and rocks.
18:50			P	Photos (roll 1, frames 2-9): edge of bluish-black incrustations near north end of vent field. Reddish blocks are jumbled among bluish ones, and a bacterial(?) mat blankets rocks to the left of a sharp boundary. Violet-purple palm worms are abundant on the bluish incrustations. Up is the the left in frame 7. Frame 9 is an out-of-focus close-up made with the 105mm lens. A big lemon drop is near the center of most frames. A few needle-like spires, both red and black, are visible.
18:51:56			P	I've finished my first roll of film and am starting a roll of Ektachrome 400; I hope the higher speed of this film will permit an extra f-stop (f8) to give me better depth-of-field with the 105mm lens. The first roll of Ektachrome 200 was shot almost entirely with the 24mm lens, but the last few frames were made with the 105mm. We're collecting a slurp sample now. I made photos of some typical vent features, bluish incrustations, etc.
18:53			P	We've moved around a little to port, so that now I only see thick golden mat to the left and bluish incrustation to the right, with a sharp boundary between. Shimmering water streams out from both areas.
18:53:13	229	0	E	This good view shows the lower part of main worm cluster.
18:53:47	2226	1	S	We've been slurping yellow sediment. Right now I'm looking out Jim's front viewport. I turned the pump off.
18:54:30			S	When I moved the slurp-gun nozzle I kicked up a lot of black sediment. I didn't want to mix black sediment with the yellow stuff, so I turned off the pump. I'm looking at a clump of tube worms with bacterial mats all over it. From this view I can't see any shimmering water. The red tips of the tube worms are feathery. Photos (roll 1, frames 31-34): I switched back to my own port and took 4 photos of turquoise rocks. [Black frames; no strobe.] Some of the rocks have a little turquoise-blue coating; most other coatings are kind of a dirty yellow-brown or white. I'm not sure that it's a basalt that is coated, though it certainly looks that way sometimes. Part of the block might be basalt; the other part is well-coated by the dirty-yellow sediment. Some of the sediment has more of an orange tinge to it. If I look even further down I see more of a whitish to very light blue coating on some basalt. The rocks are blocky, with fragments sticking up. There's a white, slender fish outside of my port; I'll try to capture it on photos. Photo (roll 1, frame 35): fish, still at the slurp-sampling site. That was the last frame on this roll; I'm changing film.

TIME	D	A	O	OBSERVATIONS
18:56:33	2228	0	E	This good photo shows much of the main worm cluster.
18:59:15			P	Photos (roll 2, frames 0-14): I've finished a series out of the front viewport using my camera with Ektachrome 400, f8, first with the 105mm and then the 24mm lens. These photos show the worm colony above hydrothermal vents near the north end of the vent field. Tightly clustered red heads protrude through remnants of a white and yellow fibrous bacterial(?) mat. Before I began this series I noticed out of my own viewport a tiny fish on the golden mat, nose into the mat and not moving very much. The fish was only 6-8 cm long and was white with some peculiar reddish-brown spots or splotches having unsharp edges. It may have been feeding on something in there; I tried to photograph it, but could not.
18:59:22	2228	0	E	This good photo shows much of the main worm cluster.
19:02:23	2226	2	S	We're still in the sampling area, though now I'm looking at a wall. A lot of particles are stirred up here. I see old, dead worm tubes. I took some photos. Some of the worm tubes look really bizarre. I see a stack of worms, all blackened. There is also a black precipitate on the slope. The walls are covered with bacterial mats; yellowish stuff is covering the wall, and some of the mats are white. Again, these dead worms look charred; they've had it! I just remembered to turn on the slurp gun to flush the system, though we've stirred up a bit of particulate matter and are still in the same sampling area. Just in case we come to something soon, I want to have the slurp gun flushed reasonably free of that yellow garbage we were sampling several minutes ago. We're stirring up a lot of sediment, so I can't see anything now. Jim said he got into the critter box some of the tube worms from the same area that we've been sampling for the past several minutes. We were going to try to pick up some of that blue rock, but it's very difficult right now; so we're moving toward the vent field.
19:05:12			P	Photo (roll 2, frame 15): I photographed with the 105mm lens a peculiar dome- or globe-shaped object in the yellow sediment. It's in the center of the frame. It's smaller than a golf ball and has a dark spot on top, in the center. As we get down close I can see in the golden mat some beautiful light blue rocks(?). Some other material is darkish green with irregular bands of yellow and white, much like the jade-green material I saw at Vent 3. Some material is a sky-blue, almost turquoise but without the greenish tinge, more like a baby blue; very light, lighter even than the blues we've seen on the bluish incrustations. Jim is trying to collect blue rock.
19:06:07	2225	1	E	Here is a good photo, one of 4, possibly showing a fat chimney that flares irregularly upward.

TIME	D	A	O	OBSERVATIONS
19:06:48	2225	1	E	We have rotated to port, and the fat chimney has gone out of view. Now we are looking past lemon drops at a blocky rubble having interstices filled by gold-beige deposits that look like mud in the photos but seem to be fluffy accumulations of the organic mat when viewed close-up.
19:07:55	2225	1	E	In the upper central part of this frame (shown better in next frame) an elongate pillow seems to lie at the base of blocky talus. Other pillows may occur near it. Did pillows spread over a cone of blocky talus? Or do the blocks postdate pillows? Or are the pillows and blocks interbedded? I cannot tell from these photographs alone.
19:08:36	2227	1	E	We have rotated back toward the wall and see pillows at the top of the talus slope too. But the relative age of pillows and talus still isn't clear; organic mats fill low spaces, hiding contacts between pillows and blocks.
19:08:49	2222	2	E	It does appear that the pillows here were fed by flows spreading down the wall. A narrow fringe of pillows is visible at the base of the wall, on the apex of a rubbly slope extending a few m farther down to the cleft floor. But pillows are not visible midway down the slope; they may be covered there by talus and organic mats.
19:09:03	2220	2	E	We have apparently risen and rotated enough to see only the east wall, which has a veneer of organic mats. We kick up a thick cloud of lemon drops and finer particles.
19:10:17			P	Jim couldn't sample the blue rock, so now we'll look for chimneys and hotter vents, in order to get a complete suite of samples. Jim did get some tube worms here.
19:11:18	2215	5	E	The organic cloud is clearing, but the floor is not seen.
19:11:45			P	We have deployed marker float [4/] at our sampling site, presumably at the north end of the vent field.
19:12:39	2219	7	E	The seafloor is coming into view, dimly.
19:12:40	2226	6	P	We're driving along the base of the cliff on a course of 200°, and we're sinking slowly, I think. The very heavy cover of golden mats and puffy white cotton candy accumulates especially on the less steep parts of the cliff. A lot of the cotton candy seems to adhere to the bottoms of overhangs, whereas the golden material tends to accumulate on the tops of shelves. I can see some structure to the cliff face here; it is not entirely featureless. I can see that some lava did flow down over the scarp. I've seen a few little white or gray spiders on the cliff, like those at Vent #3 except for their color. We're coming to another area of extensive blue incrustations and tubeworms.

TIME	D	A	O	OBSERVATIONS
19:13:24	2229	5	S	We're moving away from the sample site. I see a scarp covered by dull yellow sediments, with light and dark patches. The flows seem to be lobate and probably come down the scarp. Some surfaces are smooth, with nothing jagged or broken. Below me may be a sulfide mound, and small chimneys surrounded by a dark blue color. Robin sees tube worms, but I don't; I do see shimmering water.
19:13:46	227	4	E	The base of the wall is to the left, the floor dim ahead.
19:14:13	2234	0	E	Small chimneys mantled by organic material, and massive, blue-black chimney rock are at the base of the wall.
19:14:27		0	E	A mass of tube worms is on a fresh chimney to the left.
19:14:41	2231		S	I can't get a good altitude here. There are many little spires, shimmering water, and a heavy sediment mantle. I see marker [OV].
19:15:07	2230	1	E	Beyond the live worms to the left are some pencil-like projections from the wall. They look like organic stalks, but no soft body is visible, and they seem to be coated by organic mat material. We rotate slightly to the left, to sample the blue-black rock we suspect to consist of massive sulfides comprising the chimney.
19:15:11	2231	2	S	The seafloor is still thickly covered with sediment. The dark blue material looks almost like it has (everytime I've seen it) flowed down a slope. The blue is in narrow bands on the wall. I'm trying to photograph the blue encrustation; I tried one, but was too far away. Photos (roll 2, frames 2-5 at about this time): east wall of cleft, sampling site at [OV]; frame 5 shows "charred" tubeworms, which are probably dead and possibly coated by manganese. Jim has the video on. A possible black smoker is in sight. My view is not good. Jim is using the temperature probe on the smoker.
19:15:25			P	Ellen has reported marker [OV] out of her starboard viewport. I quickly took some pictures as we flew; I don't know if they will be any good.
19:18:17			E	The manipulator arm appears sometimes now as Jim works.
19:18:40	2231	3	S	Even from this position I can see marker [OV].
19:19:40			P	Photos (roll 2, frames 16-25): I've taken more photos at our second vent site near [OV] while Jim tries to sample a chimney. These photos show a colony of tubeworms near chimneys. Up is to the left on frames 20 & 25. Palm worms are numerous on a band of bluish-black rock below the tubeworms. I've changed now to the 24mm lens and will try some general views after the cloud clears.

TIME	D	A	O	OBSERVATIONS
19:21:00			S	Photo (roll 2, frame 7): I tried one of [OV]. We're still sampling and using the temperature probe.
19:21:26			P	Photos (roll 2, frames 26-28): I used the 24mm lens for some general views of this little bank of tube worms; up is to the left. The worms are hanging in a clump, rooted together. Below their dangling heads, lower on the rock face, is a horizontal band of many palm worms lined up along vertical, entrail-like bluish incrustations. The entrails could be the stalks of dead tubeworms, encrusted by some other material, and the palm worms may be growing on them. But the palm worms seem to be absent higher up where the live tubeworms are now growing, as if the two animals occupy slightly different zones or niches.
19:24:52			S	Photos (roll 2, frames 8-12): views through the pilot's port showing the temperature probe and possible sulfides. Frames 11-12 show the probe in a black smoker, where the highest temperature was measured (about $40^{o}C$).
19:25:01			E	This view shows the fresh chimney, which rises like a cylindrical pillar through the field of view.
19:25:55	2230	3	E	We have risen so that the top of the chimney is visible. Blue-black incrustations on the wall behind the chimney are concentrated along lines where hot water apparently streams out through a veneer of plastered lava.
19:26:30	2230	4	S	Photo (roll 2, frame 13): I just switched back from the pilot's port and through my port took a photo of a wall coated with dull yellow sediment. No strobe.
19:31:59			E	The manipulator grabs the narrow conical top of the chimney, and in following frames it breaks off a piece.
19:32:53			E	Wispy bluish-black smoke issues from the broken chimney.
19:35:35	2225	3	E	The manipulator is bringing a Ti water bottle to the broken chimney top in order to sample the plume.
19:40:39	2230	5	S	We're on a wall. I see much shimmering water. The whole scarp is a dull yellow, the sediment has patches of gray and light-yellow. There is now a lot of water below me, since we're partway up the wall. I cannot see basalt beneath the sediment cover. I can still see shimmering water; it's coming out of holes in the wall.
19:43:09			P	Jim cannot trigger the titanium bottles, and we don't yet have a piece of the chimney. We'll quit working here and go somewhere else to get a complete set of samples.
19:43:09	2231		S	The titanium bottles would not trigger, so we will look for another site to collect a full suite of rock samples.

TIME	D	A	O	OBSERVATIONS
19:47:04			E	The chimney recedes from view as we leave this site and move along the wall, which is dimly visible occasionally.
19:47:50	2231		S	We've left the last sample site and now are directly over marker [OV]. I don't have a clear view of the bottom. I saw a crab. The seafloor consists of lobate sheetflows. Right outside my port is a huge chimney at least 15 feet tall. It looks like the yellow-red hydrothermal stuff spalled off of the bottom of the chimney to expose a black core. The next layer is white, and the one on that is the gold-yellow. There's a smaller chimney to the left. I'm trying to get a picture. <u>Photos</u> (roll 2, frames 14-15): chimneys; frame 15 shows the huge chimney with a black core and layers. I did see some shimmering water a little beyond the base of the chimney.
19:4-:-9			P	We left [OV] and are moving along the cliff. A golden mat is all over the dead worms--some big dead chimneys are directly below me! A big chimney is right beside me.
19:48:51	2231	4	E	A dense forest of small asparagus-shaped chimneys comes into view, with many tube worms hanging above them, from bigger chimneys or projections on the wall.
19:50:26	2224	0	E	Here is a good view looking obliquely down on a cluster of medium-sized chimneys that rise up 1-2 m.
19:50:39		0	E	Gorgeous shot of an asparagus-bud top of a chimney.
19:51:13	2233		S	At the base of the large chimney is a bunch of smaller chimneys, maybe a couple m to less than 1 m high. One spire seems to be coated with a dull-black material, manganese I guess. Underneath the black coating, at the base of the chimney, is a dull yellow material. Right next to this chimney is a dark turquoise chimney, and adjacent to that is a threesome of chimneys. A spire much taller than the threesome has a fluffy yellow-white matting (bacterial?) over it. Black smoke is coming out of the chimney that I just described as coated by Mn; but the smoke is very diffuse, and not pumping much. I could see shimmering water at the base of the black chimney. The whole area around there looks like it's now being coated in black, whereas underneath the black was a dull golden-to-dull-brown color. I'm trying for some photos. We've certainly hit quite a large chimney field. On the wall I see some dead tube worms, reddish color. Many of the pieces (spires, I assume) were covered with red material, a kind of tarnished red. Some of the spires were a dark blue. <u>Photos</u> (roll 2, frames 16-25): frames 16-17 show chimneys and chimney fields; frames 18-22 show sulfides and dead tube worms on the east wall. Frames 23-25 are useless. I can no longer see anything. We were trying to sample, but we stirred up so much material that we must move. The particles look reddish brown.

TIME	D	A	O	OBSERVATIONS
19:51:47			E	We begin to kick up debris as we attempt to sample.
19:52:16			P	Jim has knocked over one of the big asparagus-shaped chimneys. It was at least 3 m high, perhaps as high as 5 m. Its stalk pinched and swelled a few times beneath the big bud on top; the swells looked like previous buds through which the narrower pipe-like stalk grew. I could see the pillar break into segments as it fell past us; then it kicked up a cloud of golden material, and I don't know if we'll be able to extract a piece from that muck. I took some pictures of this chimney. It was bluish-black and dark gray, not covered with sediment. When I got up close, I could see that it hosted thousands of little palm worms. Patches of red material on it looked like iron oxides. Photos (roll 2, frames 29-30): large, active chimney near [OV], shaped like a young asparagus. Top is to the left in frame 29. The stalk is buff-brown, and the bluish-black bud is colonized by many palm worms. Frame 30 shows disturbed water around the bud as Jim topples the chimney.
19:53:21			E	The manipulator has appeared again in the field of view, as Jim tries to continue sampling. In subsequent frames we kick up thick debris clouds, of various colors.
19:54:55	2234	2	P	Ellen gave me a view out of the starboard port, where she can see many large chimneys. The enormous one looked like it was at least 1 m in diameter and rose up quite high above us, which means it must be at least 5 m high. We broke off one pillar, but I think Jim has quit trying to collect a piece of it and is working on something else, another pillar. I want a pillar that is broken off and has something . . .
19:57:40			P	We're moving along the cliff again, trying to get out of this crud that we've kicked up, so that we can sample something else. OK, I see another . . . what is all this stuff? There's a lot of smoke coming from somewhere, but I don't think that we're kicking it up.
19:58:09	2234	2	S	I see the bottom now; it's totally covered with a wispy, cottony white material. In fact, bottom is all cotton, what everyone has been calling the white cotton candy; we're descending into it. I'll try some photos.
19:58:29			P	We're continuing on, and there are many chimneys. Here's a little black smoker right beside me on the port side, Jim. It's been broken off recently, and smoke is coming from a hole in its top. The top of the stump is flat, almost planar; it shows an internal radial structure to the chimney, and concentric rinds outside of that. I don't know if it's something you can get your probe into; it's a rather small hole, maybe 4-5 cm in diameter. I quickly snapped some photos of it. Photos (roll 2, frames 31-34): Black smoke wafting from the axial tube

TIME	D	A	O	OBSERVATIONS
				in the stump of a recently truncated large chimney, maybe the one sampled earlier by Karen and Randy. The stump appears to be about 1 m wide and looks like it has two pipes, one of them not smoking. Concentric and radial structure is visible. The tan chimney may be truncated also, and capped by the stalks of dead tube worms.
20:00:00	2234	2	S	I'm trying a filter-sweep sample of whatever we kicked up in the water column. The sediment appears reddish.
20:00:47	2228	4	E	This good frame looks obliquely down at a cluster of thin chimneys. Some parts are fresh and bluish-black; others are coated with organic mats. Then more chimneys and the manipulator appear as we attempt to sample again. But the last frames from camera #1 are fogged.
20:02:21			P	We're blinded again by stirred-up sediment. We came past a large, truncated-chimney stump with a central hole. It looked like the stump had a diameter of about 20 cm, and the axial hole a diamater of perhaps 4-5 cm. It had a flat top and a sort of acicular internal structure. I could see various crystals, including a layer of white crystals, perhaps anhydrite, lining the wall. Black smoke wafted slowly from the cavity. It could be the one that Karen and Randy sampled earlier; but I could see no accumulation of new material on the surface since they broke it. [Later note: Could it be the stump of the chimney that we broke off?] We should check the external photos from both dives to see if it's the same stump.
20:06:40			P	We're still trying to sample, and I can't see anything because of the dense cloud of suspended sediment.
20:07:43	2232		S	I'll turn off the slurp gun at about 20:10.
20:07:59			E	This is the last readable data-frame from Camera #1.
20:09			P	Jim is putting [a piece of chimney into the tray?] . . . I'm having trouble with recorder.
20:14:30			S	I've begun slurping vent water, though the water pumping out is pretty diffuse. I decided to use valve #1 which is for filtered diffuse vent water. Jim is trying to get some video of it. On the video screen I can see the bright-red encrustation on what looks like a chimney.
20:17:17	2233	17	S	We're slurping. I took three photos of the wall, though I was a bit far away; it's difficult to tell from here the color of the sediment, generally a dull yellow, with some red. <u>Photos</u> (roll 2, frames 26-28): east wall of cleft. When we're finished slurping, I'll try for some photos of the vent. The Ti bottles are not working; one may be broken. We got a sulfide chimney sample at [4V]; we'll wait to describe it.

TIME	D	A	O	OBSERVATIONS
20:17:47			P	[In high voice because of slowed-down recording] I took photos of the chimney to port, using the 24mm lens. We're hovering a little higher now, so I'm not looking anymore at the base of this chimney, but at the widened asparagus-bud top. . . Now the first side of the tape is ending, and I will change to side 2. There may have been a gap before I noticed that side 1 was used up. . . . . some sediment or smoke roiling up around the base of it.
20:19:32			P	I'm beginning side 2 of my voice tape. We're still collecting samples at the place where we dropped marker [4V], and I've just taken some pictures of a chimney, using the 24mm lens. Photos (roll 2, frames 35-37; roll 4, frames 3-4): series showing a pair of chimneys, or two buds atop the same chimney. Frame 35 is a general view, showing that the higher bud may consist of two parts, one oxidised and one not. Frames 36-37 are closer views of the lower bud, colonized by many palm worms and other creatures. Frames 3-4 are underexposed. . . . Jim has a chimney sample now, and a slurp sample, but we have no temperature or Ti water-bottle sample. . . We're preparing to leave. Jim has collected two good segments from the same chimney, a Y-shaped chimney. The two pieces share the same base, but they're from the diverging arms of the Y. One is black, and one is brown. Jim could see water streaming from both of them.
20:22:27	2234	2	S	I took a slurp sample from a diffuse vent. The sample was only 5 min long because we lost the nozzle out of the vent. We tried to reposition ourselves, but it was futile; so we decided to move to another site.
20:23:40			P	We're preparing to leave this sampling site and rise up the east wall. I've turned off camera 1 (frame counter at 916) and turned on camera 2 (frame counter at 025).
20:23:43	2231	2	E	The seafloor is only dimly visible through a white cloud of debris that we have apparently kicked up.
20:23:53			S	As I was looking out my porthole I realized we were sitting over black smoke. . . I cannot see anything in the water, below me or to the side, except this smoke and a lot of the particles that we kicked up recently.
20:24:27			P	I have set the camera 2 framing rate on 6 sec, and we're rising up to leave site [4V]. As we rise up the cliff it appears that we won't see much with the external cameras because the cliff is almost completely covered with the golden mat. Clumps of old dead worm stalks protrude from the mat in many places.
20:24:41			E	The cloud has dissipated, but the bottom is out of view.

TIME	D	A	O	OBSERVATIONS
20:24:52	2230	6	S	We're rising, having decided to abort sampling for the moment. We're going to do a traverse of the wall. The suspended particles are thinning out. Robin can see the wall. I can't see anything; I'm in darkness on this side.
20:25:34	2216	5	E	Visible obliquely to the left is the east wall, extending nearly parallel with our axis. Crude horizontal ribs are on the wall; they may be a kind of subsidence selvage, but they're rounded and poorly-defined, and obscured by organic mats. Suspended in the foreground is a very large lemon drop, probably 1/2-1 m long. It is almost in focus, and its complex sponge-like structure is visible.
20:25:39	2224	6	E	Here are excellent close-ups showing the overhanging wall draped by organic mats. It could be useful to view some of these stereoscopically, to better distinguish and interpret the draperies of lava and organic material. There may be truncated tubular lava stalactites here.
20:26:20			P	Photos (roll 3, frames 5-8): I took some pictures of the mat-encrusted cliff face as we rose and it began to fall away. Some of the pictures may be over-exposed and out-of-focus. The frames show a mixture of golden lemon drops, white fibrous cotton candy, and darker material. It flies to pieces as our turbulence arrives. Enormous clumps of golden material are drifting down; one of them must be at least a foot long, a V-shaped mass that should appear in the left-hand side of one photo, each of its arms a foot long. I see several overhangs as we rise. (Aside to Jim: They're nothing that threaten us.) They are not horizontal ledges, but are like little roof eaves, inclined obliquely down the cliff face. They could be lava drapery, but if so, they're obscured by the mat all over and hanging from them. They should show up in the photos. My golly! There's still an enormous chimney out here to port, a big asparagus rising up at least 3-4 m above our present depth. I cannot see its base; it goes down like a telephone pole into the cloud of debris through which we've ascended. Its top is like an asparagus bud about 2 m in diameter. There's another narrower one behind it. I've no idea where its base is. It may have a total height of more than 10 m. Now it looks like we're coming down onto a yellow matted surface. Here again it looks like the golden mat covers zillions of worms.
20:26:32	2217	9	E	Now some vertically-striated plates have appeared. They may be more pieces of truncated basaltic stalactites; if not, they may be some other kind of curtain-like drapery.
20:26:55	2224	0	E	Here is another variety of drapery. Some of it has a billowy, drip-like form; some appears to be truncated. Some of the rubble on the floor of the cleft must have its origin as collapsed drapery from this area.

TIME	D	A	O	OBSERVATIONS
20:27:17			S	I still cannot see anything out of my port. I turned on slurp gun valve 9/10 to flush it. I'm going to close it. We're kicking up a lot of particulate matter again.
20:27:24			E	The wall goes out of view as we rotate to port.
20:28:22	?	10	E	Something is coming into view through a cloud of debris. It looks like a very steep slope, maybe a non-vertical part of the wall, thickly draped by organic material.
20:29:15	2227	0	E	The manipulator appears in the field of view, but we see little else because of all the suspended organic debris.
20:30:01			P	We're almost stationary, hovering along the face of the cliff. Most of the material suspended in the water here is golden mat, lemon drops, and white cotton candy, but there are pieces also of a fluffy black material similar to the rest except for its color, which is like manganese.
20:30:12			S	I still have no view out my port. A lot of organic matter has been kicked up. I can't say anything. Robin has been describing a lot out of his viewport.
20:30:25	2218	9	E	The cloud is clearing as we rotate to starboard.
20:30:28			P	We've bumped something, but I can't see what or where.
20:30:48			E	The cloud reappears as we rotate back to port.
20:30:54	2226	2	P	I can see a big pillar here to port, against which we're bumping, and I think it's just gone back behind us; I think we're past the top of it. Oh, I see another cliff coming up to port now. We've bumped it. It's still covered with a mixture of white and gold material, the former commonly having a coarsely botryoidal surface texture. We're coming up again. We kick up a lot of loose debris. There are still many black patches on this fine material; it might be a manganese coating. I do see now a few pieces of light turquoise, greenish-blue in the cliff up here, which means that there may still be some hydrothermal vents at this altitude. Our altitude says only 2.0 meters because we're up over a ledge.
20:31:11	2225	0	E	A matted, overhanging cliff appears once again as we continue rotating to port. Our heading now is 153o.
20:31:29	2223	2	E	Thick organic drapery hangs down. It is like cotton candy, a mixture of white, gold, and jade colors. Some small areas of turquoise and blue-black rock are visible too, along cracks where hot water probably is issuing.
20:31:35	2224	1	E	This good frame seems to show scattered sulfide deposits on a densely matted, rough cliff. Patches of red-orange deposits occur in addition to bluish ones.

TIME	D	A	O	OBSERVATIONS
20:31:41 20:31:46	2227 2223	2 2	E	This stereo pair shows tabular blocks protruding from the cliff face; they may be basalt, maybe truncated drapes. Following frames show other truncated plates hanging down.
20:32:39	2226		P	Refractive, probably hot, water is streaming from bare, turquoise-blue areas on the cliff. We rise up and find a ledge coated with beautiful, peach-colored cotton candy.
20:33:32		12 ?	E	The wall fades from view, though suspended debris remains.
20:34:07			E	A conical chimney top may appear at the bottom of this frame.
20:34:26	2220	15	S	I still have no view out of my port.
20:34:54	2220	8	P	I've not seen the wall for some time, though much stuff is floating around. Now I can see something ahead of us.
20:35:17	2217	4	E	The wall is faintly visible again behind floating debris.
20:35:19			P	I had a brief glimpse of something, but lost it again.
20:36:09		15 ?	E	The wall fades from view once again.
20:36:58	2211		P	We've lost sight of the wall, and we're still rising. I'll switch the camera back to a 14-sec repetition rate. We are trying to find the east rim of cleft.
20:37:14	2209	16	S	We're still rising. We want to look at the lava flows outside of the cleft.
20:37:10		15 ?	E	We are rising above the cloud of organic debris.
20:38:00		15 ?	E	The wall is visible again, dimly. Or is it the east rim?
__:__:__			P	I see the edge now, rimmed by pitted lobate sheetflows, quite cavernous, with a thick cover of golden sediment. The glass is quite tarnished. The pattern of collapse is quite complex. We'll set down here to put out a target, make CTFM photos, and get a fix.
20:38:12	2209	10	S	I see the bottom again; it's thickly mantled by sediment. I see shimmering water issuing from some dull-yellow to golden material; it seems to come from some small spires. Turquoise and blue coatings are on some parts of the wall, which looks like a huge wall of sulfide. Yes, definitely there are some small spires, less than a ft to maybe a ft high, from which shimmering water emanates. Out of this port I can see a lot of shimmering water. The spires are growing on top of a collapsed lobate flow. I'm going to try for some photos of this. Photos (roll 2, frames 29-35): sulfide mounds and shimmering water in the vicinity of [5V]. Jim is trying to get a tube core from the yellow spires.

TIME	D	A	O	OBSERVATIONS
20:38:50	2202	6	E	Here is a good view of shelly lobate lava on the sharp rim of the cleft, thickly carpeted by hydrothermal sediment of various colors--white, gold, and bluish-black.
20:39			S	A surface-navigation fix places us at (11364, 11386).
20:39:15	2203	5	E	Here is an excellent view of the edge of a deep collapse pit, with shelly robust lobes in the foreground.
20:40:55	2211	0	E	The manipulator appears in the field of view, setting out benchmark [5V]. We then sit in this place and attempt to sample the hydrothermal deposits.
20:42:02			P	We've deployed marker float [5V]. There seem to be sulfide mounds here, which Ellen is photographing. All I can see is thick yellow sediment in a pond, and greenish encrusted shelly lava. CTFM photo (roll 1, frame 7): useless frame with "birds". Photos (roll 3, frames 9-10): Shelly lobate lava at [5V] with golden sediment ponds and white bacterial(?) mat on rocks. Most of the mat is on a mound to starboard; I see only the edge of it to port.
20:45:29			S	Photos (roll 2, frame 36?; roll 3, frame 1): At the end of roll 2 are a few photos of [5V]. I'll start roll 3 with a photo of this marker; it's next to a small sulfide mound maybe 30-40 cm wide. Shimmering water comes from the mound. I can see a broken tube core next to that.
20:46:24			P	We're still sitting at [5V], and Jim is trying to sample.
20:50:37	2210	1	S	Photos (roll 3, frames 2-8): I just took several photos of [5V], shimmering water, sulfide mounds, and a broken push core. In the background I see large blocks; Mn coats their lower parts. Beyond are huge sulfide pillars easily 1 m in diameter. [Later note: These may consist of lava, not sulfides.] We got a push core of the sediment. We're going to do a traverse along the rim. This is the end of my voice tape #1, side #2.
20:56:49	2210		S	[Begin tape #2, side #1] We're still over marker [5V]. I took one more photo of the sulfide mound and shimmering water. Jim just said we lost the port arm; so we'll have no more slurp samples unless we can get them without moving the slurp gun.
20:58:30			S	We're starting to move away from the mound. I'll take time, depth, and altitude while Robin looks at the wall. As we move away from it, I still see some shimmering water. There is some turquoise material. It's just a large mound; I don't think I can see basalt underneath it, but I can't say what this pile is made of. It looks like it may be built over collapse rims; I can't say for sure. Now I'll start to record altitudes for this traverse.

TIME	D	A	O	OBSERVATIONS
20:58:50			P	We're still sitting on the east rim. We'll rise and move along the east rim on a course about 200°, from Point #6 to about Point #9 of our dive plan. We've asked the surface navigator to tell us when we've gone about 400 m; at that point we'll deploy a marker float, drop down over the west wall, and go back toward the hydrothermal vent area. Ellen will gather data for a topographic profile, and I'll interpret the geology along the rim. The external camera is set on a repetition rate of 14 sec.
21:00:34	2211	0	E	The foreground drops from view as we rise from our landing spot. We fly away with the manipulator visible in the lower right corner of subsequent frames.
21:01:22			P	We're on our way; it looks like we've gone out over a high step to port.
21:01:40			S	We'e not doing the profile yet; Jim is doing something else at the moment.
21:01:55			P	No, we've not started the profile yet; Jim is still working on this equipment problem. We're having trouble with the mercury; we may have to go up early.
21:03:20			P	We're turning to our course of about 200°, for the drive along the rim. I don't see it yet.
21:08:45			P	We're coming into the wall now; we used the CTFM to find it. We'll start to move now on a course of 200°. Here's the wall; we're rising up now. It's still covered with much organic mat material; lots of lemon drops are floating around. I can see possible large worm tubes, perhaps 2-4 cm in diameter and covered with sediment.
21:08:45	2218	7	S	We've finally found the wall and will start the traverse soon. I can see the wall too; it's covered with a lot of dull-orange sediment. I see the whitish organic mats, and also a bluish-gray material beneath the mats.
21:08:54	2208	8	E	Here is an excellent view of the upper east wall near the rim of the cleft. It is steep but not vertical, and elongate lobes appear to plunge over the rim and down the cliff to form drapery or buttresses. [Later note: This suggests that the drapery on the base of the cliff may have flowed into the cleft from somewhere farther east.] But this interpretation is uncertain because of a thick mantle of sediment. Many of the toes and lobes appear to be truncated too, and this obscures the original morphology.
21:09	39		S	I'm losing sight of the wall as we turn.

TIME	D	A	O	OBSERVATIONS
21:10:00	2214	6	P	We're still rising up to the level of the rim. There is still a thick veneer of golden mat material. Ah, here's our marker float [2-], with a great big crab beside it. This float is just a few m below [5V] and to the west of it, on a ledge of the cliff face; Jim had accidentally dropped [2-] while trying to deploy it on the site where [5V] went subsequently. Photo (roll 3, frames 11- 14): Frames 11-13 are dark; I tried to photograph [2-], but was too far away. Frame 14 is a dim view of [5V] as we circle up and past it, heading south. OK, we're flying along the rim now, and pillars are below us. There is a pervasive and very complicated collapse of the lobate lava flows along the rim here. Very shelly sheetflows here have local collapses 1-3 m deep. I see some pillars that may be as much as 4 m high. It's hard to say if there has been more than one eruptive pulse (or surges) here. The big caverns go back in beneath the shelly crust for 4-5 m and are commonly 3-4 m high. In fact, some of the caverns are deeper; I see one that seems to go back 6 m. Am I overestimating dimensions? And there are many very thin natural bridges, perhaps no more than 4-6 cm thick. . . . [long gap in tape] . . .
21:10:09	2208	6	E	Here is another view of the wall that may show truncated drapery, including a prominant cylinder of basalt.
21:10:16			S	We're still rising. Robin said he just saw marker [2-] with a crab beside it.
21:10:32			S	I see a big chimney outside my window. No, I take that back. I think it's a pillar; I can see bathtub rings on its side. The pillars are covered with material that is white to yellowish gray. I see drop-weights 5 and 7. There's a huge pillar, about 1 m in diameter, with a top that is roundish, almost like a mushroom. It too is covered with a lot of sediment. A piece of lobate flow capping these pillars has been broken off. I can't tell the relationship of flows to that pillar. Small sulfide spires come out the tops of many other pillars. Shimmering water comes from one pillar with golden sediment all over it. Photo (roll 3, frame 9; time of exposure uncertain): pillar and arch.
21:10:34	2201	8	E	Rough terrain has appeared; a rugged wall is to the left and pillars may rise above a rubbly lava floor to the right. Following dim frames seem to show other pillars; this may be a collapsed area above the rim of the cleft.
21:12:15	2209	2	E	The sharp lobate rim of a collapsed area is shown to port.
21:12:31			S	I've lost sight of the bottom. We're flying very high right now; I can't see the bottom very well. It looks like a lobate sheetflow terrain.

TIME	D	A	O	OBSERVATIONS
21:13:05			E	Here is a good view of the overhung, cavernous margin of the collapsed area, which appears to be at least 2 m deep.
21:13:08			S	I can see the bottom again; it has just risen sharply. I see lobate lava here, collapse pits, and many bathtub rings. The collapse pits are maybe 3 m deep.
21:13:30			S	There isn't much sediment on top of these lobes. Now that we've risen out of that pit, I see many glassy sponges. The pillars have bathtub rings on them. Sediment cover here is 5% or less. There are some red sediment ponds in the lower areas. I think I see some lemon drops. We're going to hit a pillar on the starboard side. . . . I can see the rim of the depression out of the starboard port.
21:--:-2			P	Photos (roll 3, frames 16-19): I've tried to take some pictures showing these younger billowy lobes juxtaposed against the walls of older collapse pits having lava-subsidence selvages. I'll try to get some more photos.
21:14:45	2209	0	E	Here is a good view of a mosaic of robust elongate lobes having pillow-like striations. Other frames show extensive collapse pits.
21:14:59	2210	1	S	Here is a drop-off of several m; its rim is broken and jagged. I don't see any flows draped over the edge; if they did, they're broken off now. Right below me is orange-yellow sediment. Lemon drops are being scattered about. Some orange-yellow sediment is in ponds.
21:15:41	2210	1	S	We're going along the rim. Our altitude seems quite a bit higher now, but we're just crossing a very, very deep collapse. On top of the lobate flows now is quite a bit of dull-yellow sediment. The bottom is disappearing from my view, though I can still see a lot of sediment cover.
21:15:58			P	There are many lemon drops here yet. Lots of stuff is still flying around; we must still be close to some hydrothermal vents. But the overall sediment cover is not very great on this lava; very few sediment ponds occur up on the lobate lava surface. There is extensive sediment veneer, but it's hard to say how much is normal sedimentation and how much is of hydrothermal origin.
21:16:36	2209	5	S	I've lost my view of the bottom. . .
21:16:44			P	Some really rugged badlands-like terrain is now out to port. I see perhaps 4-5 m [overestimate?] of relief, with pillars everywhere. The pillars tend to be alined. Steps are going down ahead of us. [Robin, aside to Jim: Are you able to follow the rim of the main cleft? Jim: I'm having a hard time.]

TIME	D	A	O	OBSERVATIONS
21:16:49	2208	4	E	We fly into space, with the seafloor out of view. A few following frames faintly show ruggedly cavernous flows.
21:17:00	2209	5	S	We've been zig-zagging back and forth, because according to Jim the rim is hard to define. Below me are unbroken sheets and lobate sheets. Sediment cover is about 50%. There is a series of pillars. The floor is now covered with many broken pieces, presumably fallen lobate roof pieces of subsided sheetflows. Bathtub rings are all over the walls. I assume that some of these pillars once had hot water coming out, since I see hydrothermal deposits (the orange-yellow stuff that I described before) all over them. I've lost sight of the bottom.
21:18:09			P	We're turning back on a course of 270o. We think we've wandered away from the rim of the main cleft, off into an area of large lake collapse. We'll try to find the cleft again, if a high rim does exist here. It's possible that it has no straight boundary, but a very tortuous one.
21:18:55	2210	2	S	Our altitude is jumping between about 2 and 3 m.
21:19:14			P	We're turning, with the CTFM on, looking for the main scarp. We're kicking up sediment, which makes seeing difficult. Now we're clearing out of it. We're crossing another depression that looks like it's about 3 m deep.
	2210	4		[Overestimate?] The material that subsided . . . [gap] . . . irregular; I doubt that one would ever be able to do detailed correlations without many depth measurements and accounting for many error factors. [Later note: This last was part of a reply to Ellen's question about correlating the different levels of bathtub rings.]
21:19:21	2210	3	S	Once again we're over collapse pits. I see pillars. The terrain is very rugged. Occasionally I see a chip of glass piercing all of the sediment cover. There are many particles in the water; I assume that we've kicked up most of this sediment. In this depression I see some collapse pits in the lobes. The sediment cover is about 20%, mostly occurring as ponds in the lower depressions.
21:20:30	2211	4	S	From this altitude the sediment looks off-white or gray, and kind of dull. In the sediment I see many white spots; I don't know if they are lemon drops. Many broken pieces are scattered about. We're coming up to quite a pillar. You can see the bathtub rings on the sides of lobes. Now we're flying over broken sheets. There is a large sulfide chimney, but nothing is coming out of it; it's a bit far away but is easily 4 m high. [Later note: Could it instead be a pillar?] There are possibly 2 distinct ages of flows. No, it's not 2 distinct ages of flows, but a collapse pit in the floor. For awhile the color contrast was so large that it looked like a newer flow over the old, but it was a shadow effect.

TIME	D	A	O	OBSERVATIONS
21:21:00			P	We're flying over large folds and draped folds in a depression, with much coarse sediment and lemon drops. Once again we're coming into a place that saw 2 different episodes of lava flooding and then subsidence, the older level being higher, and the younger contained by walls of the older subsidence pit. There is no obvious difference in sediment cover on the two surfaces.
21:22:04			S	We're still in collapse terrain having pillars, arches, and bathtub rings. There is a slight red dusting over most of the flows. I've not seen much fauna recently. There are a lot of broken sheets. There are many lemon drops and yellowish sediment in some of these smaller collapses. We're now over broken lobate flows. The sediment is ponded in all of the lows, and in most ponds there are bundles of lemon drops. The lobes, on the outside, do not at all appear glassy. We're approaching the rim of the cleft. It seems like there are 2 levels here. I see a level several m below me; below, nothing.
21:21:50	2208	4	E	Billowy lobes are coming back into view, first on the port side of these frames, and then straight ahead.
21:22:47			P	We've left the big collapse pits and are flying over billowy but robust, broad lobes, generally 2-4 m wide, and longer. There are some signs of local inflation.
21:23:05	2213	0	E	Here is a good view of robust, billowy, shelly lobes having narrow vertical ridges on their sides and shallow wrinkles on their tops. Sediment veneer is less than 20%, with small lemon drops scattered along the creases between lobes. Then the seafloor becomes dim again, though pitted lobate sheetflows are still faintly visible.
21:23:36			P	Ellen says we're approaching the rim of the cleft. I still don't see very many pits where I am; the lava looks like robust, billowy sheetflows.
21:23:45	2208	3	S	There is a light red dusting over many of the flows. We are now descending. The rim looks very jagged here. Right now I'm over the rim of a small, shallow collapse, maybe 30-40 cm high. All of the roof pieces are in it, and lemon drops are all over the place. We're moving slightly away from the rim. There are lobes, some with collapse pits. Their surface is very dull, not glassy; the basalt certainly looks like it has been altered. Once again we're approaching the rim of the cleft.
21:24:48			P	We've crossed some more pits, and the surface flows are more shelly than before. But surface plates are commonly about 6 cm thick, and they break up into a rubble that is less regular than in hotter, more fluid lava lakes.

TIME	D	A	O	OBSERVATIONS
21:25:35	2216	1	E	Shelly lobes here along a high rim may have two different ages, one flow being enclosed within the subsided area of the other. Small lemon drops produce gravelly-appearing sediment ponds in the hollows.
21:25:39			P	We're flying over billowy, shelly lava that is broadly collapsed; but in some places it looks like there has been some inflation also, some heaving-up of the lobes. But the lobes also appear hollow. So the inflation must have been temporary, because the lava later drained away.
21:25:16	2209	1	S	There is definite draping of lava over the rim of the cleft, which is no longer jagged. We're now going over some jagged pieces. I've not much view anymore, so I'll give some altitudes. Robin will give the description.
21:26:03			S	Once again I can see the rim very well; it's very well defined here. Beyond it I can no longer see the bottom.
21:26:39			P	We've crossed another depression with signs of repeated spillover, ponding, and drainage, with the lobate surface of a later flow enclosed within the collapse of an earlier one. Photos (roll 3, frames 20-24): multiple overflows from the cleft. Frame 20 shows billowy lobes that have spread onto the rubbly floor of a collapsed area having pillars. Frame 24 shows two generations of overflow followed by collapse.
21:27:05			S	Now once again I can see the edge of the cleft. I do not see bathtub rings on the wall, though the top in some places is possibly a bit jagged and does suggest collapse of the rim. Once again the wall is out of view.
21:27:40			P	Now we've crossed into a patch of folds, contorted folds, possibly some broken folds, and some draped folds. I can't tell how extensive this patch is; it may just extend only another 10 m or so from our axis. And then we come to a little step up, about 1.5 m high, and we find that the previous flow was on the floor of a collapse pit, surrounded by shelly, lobate sheetflows.
21:27:42			S	I see the wall again. Some collapse pits are in the top m. [Later note: I don't really understand what I was describing: "collapse in the top meter" . . ?] I see bathtub rings. Below the bathtub rings the floors look very different. Perhaps these are flows built one on top of another at different times. We're on lobate flows now. The surface is still dull, not glassy. Sediment cover is 5%, maybe. Once again we are traversing the rim.
21:28:--			P	As we drive along it appears that some pillars and pillar chains were tilted [by lava-subsidence processes?] after the eruption; they seem to be inclined uniformly in the same direction.

TIME	D	A	O	OBSERVATIONS
21:28:06	2211	1	E	Here is a good photo of a shelly natural bridge, a thin remnant of an extensively collapsed billowy lobate surface having stacked, draped folds shoved up over the high rim of the depression bounding it.
21:28:30			P	Here is another depression with a rubbly bottom. Much golden-yellow lemon-drop sediment occurs here, with a gravelly appearance.
21:28:30			S	I no longer have a view out of my port.
21:30:43			P	We're flying along a small collapse depression right on the rim of the east wall; it can't extend more than 4-5 m in from the rim. Now I can see that there is more collapsed terrain above us, further out to port; the pillars look like they stand much higher, and . . .
21:31:01		1	E	Here is a good photograph of an elongate pillar, shaped like a flat-iron, with horizontal lava-subsidence shelves and selvages along its walls. The following frames show a very rugged, collapse topography with a relief of 2-3 m.
21:31:20	2211	2	S	I can once again see the seafloor. From here the flows look lobate. A thin veneer of sediment makes the flows look old. The flows are sediment-dusted, at the very least. It looks like there are different surge levels as we descend. I've lost view of the rim once again.
21:33:00			S	I can see the wall. It's hard to say, but I think sheets and lobate sheets can be seen in cross-section in the wall. The wall is not particularly jagged, and I don't see bathtub rings on it. A piece maybe 4-5 cm thick is standing right up; it's the rim of a collapse pit. Robin is asking Jim to try for a pillar sample.
21:33:			P	We've been told that we've only gone 100 m along the rim in 33 min since 21:00 hrs, probably because we followed a sinuous path. We've asked the surface navigators to tell us when we've gone another 100 m, and then we'll drop over the rim to do a vertical traverse of the east wall.
21:34:03	2212	2	S	I no longer have any view from my port again. Robin just said the rim is very sinuous. [Later note: No, he did not say exactly that. The principal inner rim of the axial cleft may or may not be sinuous; we could have followed the sinuous rims of shallower collapse pits above and outside of the main rim.] We cannot follow the rim; it keeps coming in and out of view. Flows are draped downhill. There are large blocks and slabs which stand up vertically. Both the blocks and the slabs are kind of rectangular. Their base is 2-3 m across and about that high. The surface navigator is giving us a position now. . . Our position is (11290, 11175)

TIME	D	A	O	OBSERVATIONS
21:34:15			P	We've crossed the cleft rim, and the face of the wall really is sinuous here; it's not at all straight. I'd like to collect a narrow pipelike pillar with a hollow interior, if we can find any, but not a massive pillar.
21:35:11	2213	1	E	Here is a close-up of the flared top of a pillar, which the manipulator tries to sample in subsequent frames.
21:37:00	2211	1	S	The rocks are lightly dusted with off-white sediment.
21:39:20			P	A good fix at 21:34 hrs placed us at (11290, 11175), about 150 m on a bearing of 010o from station 9 of our dive plan. Right now Jim is trying to get some rock samples. Then we'll drop over the rim into the cleft and make a vertical traverse up the east wall. Photos (roll 3, frames 29-30): platy lobate rubble at [1X] on the east rim of the cleft.
21:39:22	2210	1	E	Here is a close-up of a detail in the right side of the flared pillar photographed at 21:35:11. It shows the thin folded crust of a lobe margin leading down into the horn of the pillar, now exposed in cross-section.
21:42:25			S	Photos (roll 3, frames 10-16): I took three photos of marker [1X]. I'm shooting at a wall right now and we are down one ledge. The wall is stained a brownish color. It must be pretty young, since fresh glass is visbile where some basalt was broken off. I'll try for one more picture of the wall. . . . I tried for a couple of pictures of the vertical slabs [frames 15-16], which are right next to [1X]. We're now moving along the rim.
--:--:--			P	We're still in pitted lobate terrain; we'll drop down now and make a traverse here.
21:44:02	2212	1	S	I can definitely see fresh glass and what I had called a charred (dead) tube worm. I was just told that the dead tube worm was from our basket; it did not belong here.
21:44:22	2208	1	E	We break off sampling and begin to move.
21:44:48	2210	2	S	We're back over collapsed lobate sheetflows. Roof fragments are scattered about, and bathtub rings are on some walls. We've just crossed the rim, so that I've just lost my view of the wall. I can't see the bottom.
21:45:02	2210	2	P	I'm over an abyss and can see nothing, but Ellen is still describing sheetflows; we must be centered over the rim.
21:45:12	2209	3	E	The seafloor goes out of the field of view.
21:45:19	2211	8	S	We'll now go down the wall of the cleft, then turn around and come up to get a much better view of the wall.

TIME	D	A	O	OBSERVATIONS
21:45:58	2212	17	P	We've come straight out above the cleft and we'll drop.
21:47:40			E	A flat or lobate surface suddenly appears, close-up.
21:47:50	2224	3	S	We've reached some kind of ledge. There are pieces that are broken over the side. Some striations on these flows are directed downslope. I can't decide about sediment cover; there is some dusting of whitish sediment, and I see small dark patches locally. On top are flat, broken plates. I'll try to get a photo. . . I just took several photos of the slabs, and now bottom is out of view again.
21:48:05	2228	0	E	Here is a great close-up shot of this surface. It seems to be a vertical or steeply-sloping surface viewed head-on. It is a broken mosaic of big polygonal plates that have separated and moved apart slightly to leave wide, flat-bottomed cracks between them. And on the flat (and some shallow concave) crack floors are striations normal to the crack walls, showing the slip direction. Fantastic! They are something like striations beneath sliding plates on Puu Puai in Hawaii. The separated plates appear to be 1-3 cm thick. Maybe they were sliding slowly down the wall of the cleft as lava drained away rapidly.
21:48:30	2224	4	E	A white crab is shown dimly on the slabby lava; the tilted slabs rest precariously on ledges of a steep slope.
21:48:44			P	We seem to have dropped down into some sort of alcove; it may be a distinct compartment, back behind the main wall. We've just passed a little red shrimp--the first I've seen here in ALVIN--and a beautiful big crab! I tried a photograph (roll 3, frame 31): spider crab, on ridge? . . . All right, that's the wall there, isn't it? We're quite a way down below the rim, but it's still a bottomless pit below me right now.
21:48:55	2227	3	E	We pass beyond a ledge, out into space again.
21:49:36	2221	8	S	I can barely see the bottom.
21:49:37	2221	8	P	I cannot see the bottom right now. We came out of that alcove, up over a little rim with a big crab on it, and then the bottom dropped away.
21:51:26			E	A vertical wall is coming into view; it has crude vertical ribbing.
21:51:46	2227	16	S	We're still descending. I've no view out of my porthole. Many particles are in the water; I assume that we're stirring them up. The cliff is thickly mantled by a dull yellow-gray sediment. Some flows seem to be draping down into the cleft. It's all going out of my view.

TIME	D	A	O	OBSERVATIONS
21:52:05	2229	16	P	We're still going down at a pretty good clip. I still cannot see the bottom, and we're going to come up this wall. There is still quite a bit of sediment on the wall, though I think it's not as thick and pervasive as it was where we went up above the main vent area.
21:52:16	2222	9	E	Here are more vertically ribbed structures that look like crude lava stalactites but could be hanging organic drapes.
21:52:41	2223	8	E	One more frame shows what looks like vertical drip-like ribbing and truncated drapes on a lava-veneered surface, but could instead be a drapery of organic material.
21:53:06		7	E	A last frame shows some sort of drapery, and then the wall goes out of view in a cloud of fine organic debris.
21:53:23		6	P	We're still going down, and I can't see the botton, perhaps because of all the sediment we're kicking up.
21:56:07			S	We've scraped against the wall. I saw bright red rims through some very thin, small cracks in the wall. In getting a closer look, some of this red material looks grainy--small grains. The wall itself is draped; the sheets are standing on end. I've lost sight of the bottom again.
21:56:46	2238	3	S	I turned on the slurp gun, valve #6, to get a sample of the stuff we've been stirring up. I have no view. . .
21:57:12	2238	2	P	I can see the bottom now; it's fairly flat, and littered with blocks surrounded by abundant golden sediment, like many ANGUS photos we've seen. We'll approach the wall at a place slightly different from where we descended, and try to record the cliff using our external camera.
21:57:16	2240	1	E	The cleft floor is visible through a clearing debris cloud. It consists of blocky rubble or possibly lobate flows having extensive gravelly-sandy deposits of lemon drops and other organic debris. Following frames show that some of the surface consists of flat sheetflows littered by rubble.
21:57:45			S	I see the bottom again; low areas look thickly mantled by fluffy sediment, which we are stirring up. The slurp gun is still on. Robin will document the wall as we go up it.
21:58:02			P	We're going up now, with camera #2 firing every 6 sec.
21:58:22	2237	2	E	The seafloor is fading behind a cloud of fine debris.
21:58:57	2233	2	E	A few frames faintly show the wall beyond the debris. A featureless veneer appears to be broken into polygonal plates by sharp-edged cracks a few cm deep and wide.

TIME	D	A	O	OBSERVATIONS
21:59:08	2231	3	E	The wall is disappearing again, becoming only faintly visible and having no decipherable details.
21:59:40			S	We can't see very much so we're changing course to look for more vents. We'll descend. I'll slurp for awhile more until the water clears again.
21:59:43	2223	7	E	We veer off away from the wall into the dark void.
22:00:00	2222		P	There's too much material in the water and on the cliff to get useful photos, so we'll break off this traverse to go back down and drive along the base of the east wall toward the hydrothermal vents. If we have any time left when we reach the vents, we'll collect more samples.
22:03:30	2217	6	E	A cloud of suspended fine debris is coming into view again.
22:03:37	2225	6	P	I can see the seafloor. It consists of lineated sheetflows, perhaps gently folded, and I can see one pillow by itself out there in the middle of them. The lineations seem to parallel the contour, and then as we come across we see . . . a pond surface of fif . . . [significant gap in tape]. . .
22:03:59	2229	0	E	A strongly lineated flat surface is coming into view on the floor of the cleft. Following frames show the same place successively closer-up.
22:04:02	2230	3	S	I see lineated sheetflows. There is some of that fluffy sediment in between. Robin has called it a thick pond surface. . . We just threw up a lot of sediment so that I can't see anymore. It looked like these sheets were thick and sagged under their own weight to break into huge blocks. I'm waiting for my view to clear.
22:04:17	2231	1	E	Here is a good close-up of the lineated surface, which is broken into polygonal plates that are gently tilted. Several of the fractures tend to follow the lineations, but other less-straight fractures cut across them. This looks like a sagged pond surface. About 30% is covered by sediment veneer, mostly in the troughs, and a litter of small lemon drops, less than 1-2 cm wide.
22:04:29	2231	1	E	We rise slightly and begin to move along the lineations, which trend sub-parallel to our heading of 038°. The lineations probably trend about 020°-025°.
22:04:40	2230	1	E	Smaller lineated plates ahead are tilted more steeply in various directions; but the overall slope is down to port, and the port observer could see the center of the sagged pond off to port.

TIME	D	A	O	OBSERVATIONS
22:04:50			S	Here again I can see the lineated sheetflows, which are broken. The lineations pointing upward on one broken plate were truncated by another plate that was draped across it horizontally. I see some small pieces of rubble and dark sand. The floor is mantled by sediment. I'm losing sight of the bottom.
22:04:54	2232	0	E	Here is a good close-up of the tilted, lineated plates. Then the following frames get dimmer, though we can still see strong lineations trending about 025°.
22:05:27	2231	1	E	The surface is very dim here, but it appears now to be less regular. It could be a lobate sheetflow, or perhaps lineated plates are smaller and tilted more irregularly.
22:05:39	2231	2	E	In this vague view, the surface still seems to consist of gently tilted plates with little sediment cover and small lemon drops concentrated along the troughs between plates.
22:05:55			S	I can't see the bottom; many particles are in the water.
22:06:02	2231	2	E	We are approaching a cloud of fine suspended debris; this is probably the cloud that we stirred up when we reached the bottom earlier (at 21:57); it must take a long time for this fluffy material to settle.
22:06:54	2235	4	E	We are suddenly beyond the cloud and find a rough surface of tilted plates. Some are still lineated, but many are lobate. This looks like the jumbled margin of a lava lake, with lava toes oozing from beneath tilted remnants of its previous generation of crust.
22:07:00	2234	2	E	This good view seems to show a chaotic lake margin at the base of a cliff. Lineated plates are tilted sharply to port and have pulled away from a rind still attached to the wall. Angular rubble fills the crack. Some of the jumbled plates in the background are lineated. Following frames also show this jumbled pond surface.
22:07:10			P	We've come through this debris and have crashed into some other rock consisting of drapes and steeply tilted plates. They look like they're draped over over talus along the base of the cliff. This area in here looks like a deeply subsided lava lake. The tilted plates of lineated lava are amazingly thick--like the thick plates in Kileuea Iki; some are at least 15-20 cm thick, and I may not have seen their bases.
22:07:12		2	E	One plate has lineations that appear slightly curved, like pahoehoe ropes. It is shown also on the next frame.
22:07:20			S	I can't see the bottom; particles are still in the water.

TIME	D	A	O	OBSERVATIONS
22:07:35	2231	2	E	The bottom has gone from view. The last frames suggested that we had passed beyond the pond onto lobate sheetflows, or maybe onto a transition having mixed lobes and plates.
22:08:00			S	The bottom is back in view. There are sheetflows again, broken into large plates and draped, sloping in various directions. In the distance I could see another large drop-off. Sediment veneer is slight. Flow surfaces are dull. I'm starting to lose the bottom on this side--no, it's either a very deep collapse or . . can't see . . .
22:08:13			P	We're flying along some of these steeply inclined, draped, lineated plates, and down to port I can see the fairly flat floor of the depression; it looks like it's partly filled with golden-yellow sediment. Then we get back over plates that are a little more shelly, a little less regular in shape, and not so strongly lineated as the earlier ones. They are thinner (8-10 cm), and the surface topography is much more hummocky than it was before. Right now we're flying over a little depression that is almost conical, a flat cone or inverted pyramid formed by big polygonal plates inclined down toward a common apex, much like some draped depressions in the neck of the Kilanea Iki lava lake. There is an old paint can over there. Wow! Something black is down in the bottom of that pyramidal depression; I can't tell if it was extruded upward through the crust or fell down onto the crust. Its shape is irregular; it could be a very large boulder that tumbled down from the cliff. Photo (roll 3, frames 32-33): thick, lineated plates of a lake surface dropped down and draped over underlying terrain to produce a hummocky, jigsaw-puzzle mosaic.
22:08:16	2236	1	E	The bottom appears again; it seems to be a mixture of small, broken plates and subdued lobes.
22:08:28	2233	1	E	A sharp rim ahead faces away from us; this and a few following frames seem to show low swells on the rim.
22:08:34			E	The rim is not quite normal to our heading of 337°; it may trend about 090°. That is an odd direction; could the depression ahead be a crater in the floor of the cleft?
22:08:45	2233	2	E	The last good views of the rim suggest that it is not a sharp break but a sort of warp, a crest, with no deep pit beyond. And as we fly ahead, the altimeter does not show a deep depression; instead we seem to rise up a few m.
22:09:25			S	I've lost the bottom again. We've gone over another rim.

TIME	D	A	O	OBSERVATIONS
22:09:45	2233	4	P	I can still see the bottom to port, though Ellen has lost it to starboard. [Later note: Did we skim past a deeper pit to starboard?] A big rattail fish down there may be 1.5 m long. It still looks here like an originally flat, thick lake surface was warped and broken as it dropped down onto an underlying terrain. It also looks like there may have been some localized channels within it; I can see some relatively flat areas bordered by lineated areas, as if flow continued longer in some places and perhaps was slightly channelized as crustal foundering occurred. It might be possible to map a drainage network if this were true. Some plates are thin, and others are thick; they could represent crusts of different generations, with only some parts of the older generations having foundered.
22:10:16			S	I still see no bottom.
22:10:56			P	Now it looks like we may be flying over more irregular, rugged, rough terrain; but it's hard to tell. Now we're coming in to hit a wall; we're going to crash. Did that wall suddenly change its direction? Right now we're heading 070°, so this must be the east wall. We changed course; it didn't. This wall is heavily coated with some kind of sediment. It doesn't look like the loose, fluffy material of the golden mat we've seen; it looks more dense, like a more normal sediment, and it's draped all over this wall.
22:10:59	2224	9	E	The bottom is coming into view again.
22:10:58	2231	9	S	I can see the bottom; it's heavily mantled by sediment. We're heading 070°. Jim says this must be the east wall. I see flat-lying sheets in the wall, maybe 1-1.5 ft thick. There are several layers; I can easily count 5. Sediment drapes the flow thickly. Above it I see flows kind of "putting icing" on those flat-lying sheets; I mean that flows seem to have dripped down the walls. Along the walls are many orange and yellow bacterial mats. Beneath them is something dull gray, nearly black. <u>Photos</u> (roll 3, frames 21-28): I'm taking quite a number of photos of sulfides and bacterial mats on the east wall; the last one should show a depression full of lemon drops [frame 28]. The wall itself has a dull orange stain, though the stain looks like it's on top of the bacterial mats. I don't know what it is. It looks like the flows have come down the walls. They're fairly smooth where I can see them. The flows definitely are draping the wall. I see no layering, nor pillow pieces, in the walls. The walls are multi-colored: patches of dull black to gray, orange, and off-white. I guess these are bacterial mats. The mats are all over the place and are kind of fluffy, not grainy at all (which is why I called them bacterial mats). Now I've come to a part of the wall where there is sheetflow upon sheetflow,

TIME	D	A	O	OBSERVATIONS
				averaging about 1 m or more in thickness. Some of the flows are horizontal, others look like they're draping downhill a bit. Shimmering water is coming out of these walls. Photos (roll 3, frames 29-31): shimmering water along the wall. Now the wall is completely blanketed by a dull orange sediment. It looks fairly grainy, though I can't tell for sure. We're stopped at the moment.
22:11:17	2222	9	E	The base of the wall here appears to consist of several steep, narrow steps that are discontinuous along strike, each step being thickly mantled by organic mats. These steps could be successive flow lobes piled up and exposed now in cross-section. They could represent old pre-cleft flows exposed in the base of the wall, but their stepped character suggests that they are instead lava-subsidence terraces or other features of young lava flows confined within the cleft.
22:11:40	2231	4	E	Some fine, sharp, vertical drip-like ridges occur on the risers of some steps; they look like flow structures on a thin veneer. This supports the idea that the steps are not old flows in the wall. Maybe the steps are some sort of veneered debris.
22:12:09 22:12:15	2226 2230	4 4	E	Here are some very good shots looking obliquely along the base of the wall. High, narrow vertical steps are plainly seen; the steps are too steep to be a veneered talus. Thick organic mats cover much of the surface.
22:12:21	2229	4	E	The steep wall ends abruptly downward at a blocky rubble that appears to slope down to port; it may be a talus, heavily veneered by organic debris.
22:12:24			P	We came into this wall at about 070°, and now we're rotating out counterclockwise. I'm getting out over the void now. We'll resume driving parallel to the wall. I can just barely see the slope or ledges going down below
	2229	4		me, and mostly my view is of the void. Our altitude is
		13		jumping around; is this a reflection of high relief below
		16		us? Oh yes, we've flown over irregularities in these
		4		ledges below me. Right now I can't see anything below me,
		2		although we're recording an altitude of only 3.3 m.
22:12:27	2229	4	E	We are rotating to port away from the wall, and the steep talus(?) slope extends dowm into the darkness, mantled thickly by organic sediment.
22:12:33			E	Aha! That steep talus had merely accumulated on a shelf, and now another vertical step is visible below it. A very thick blanket of sediment covers everything.
22:13:47			P	We're still moving, and I can see nothing. The counter of my camera is on frame #34, and the last photos I made were of the thick, tilted lineated plates awhile ago.

TIME	D	A	O	OBSERVATIONS
22:14:07	2229	11	P	The bottom is really dropping down now, according to the altimeter. But I do see the bottom; I don't really think we're that high. But we're getting into some sort of narrower inner depression because I can see a wall now out to port, converging with us. It's not a tight situation yet; it's just out there. There's a lot of sediment on the floor here, with a few blocks protruding through it. Almost everything I see now is sediment. In fact, now I see some bluish-gray sulfide(?), and then below, nothing at all but sediment. We may be coming up into a box canyon here. There is a thick accumulation of lemon drops. Now we're running up against a little scarp, perhaps at the head of a box canyon.
22:14:29	2231	6	E	A few more frames show the wall, vertical and in some places overhanging, to starboard. A second wall facing it is not yet visible to port in these frames.
22:15:05	2233	2	E	The wall has gone out of view.
22:15:16			E	Suddenly we see close-up a flat surface of thick sediment.
22:15:28	2233	1	E	We begin to kick up the sediment.
22:15:36	2231	2	S	We're now getting a lot of sediment in the water, so that I'm losing sight of the wall. My last series of photos was taken within the last few minutes. Now I can see the wall. Flows have definitely draped the wall. There is some dull reddish-orange encrustation on the wall. Quite a lot of sediment is at the base; much of it is fluffy white. I can see a lobate flow draping downhill. There is a field of dead tube worms beneath this orange and yellow sediment. We are flying low.
22:15:37	2231		P	Our altitude is "something or other" [giggles in background].
22:16:50	2227	4	E	We've gone up or around the sediment cloud, and ahead we see a few rounded blocks projecting from thick sediment.
22:17:13			P	We've come up over a little saddleback and are flying on again. Off to port I can see mixed rubble (a sort of blocky talus), some pillows (pillow talus?), and thick banks of sediment still sloping down along the base of the wall. There must be a lot of hydrothermal activity nearby. Goodness! We've crashed into something, and cascades of sediment are falling below us. We're flying along a very coarse, blocky talus; much of it is pillow(!) talus; I'm not sure if it's primary flow talus or some sort of fault talus. Most of it looks like it's pillow talus, and I'd guess that it's from a flow that cascaded down the wall of the cleft here. Down below us it looks like there are mixed robust lobes and pillows, and they may have been fed by this stuff coming over the edge.

TIME	D	A	O	OBSERVATIONS
22:17:19	2220	4	E	A wall or chimney appears to starboard with a thick sediment slope beyond it.
22:17:48	2223	2	E	A chain of elongate lobes or pillows seems to impart a convex profile to blocky talus ahead of us.
22:17:54	2221	2	E	A closer view shows a continuous ridge of lava that seems to be a chain of elongate lobes extending downslope atop the talus. The next frame shows rounded blocks that may be pillow talus, and then the seafloor goes out of view.
22:18:05	2225	3	S	I'm losing sight of the bottom.
22:18:22	2225	5	S	I've totally lost sight of the bottom.
22:18:27	2225	7	P	I can barely make out the bottom; it looks like a rubbly surface. The rubble may consist of broken folds; if so, they're loose, broken folds--or maybe broken lobes. Many sediment ponds cover about 40% of the area. A few elongate pillows are lying around; I can't tell if they were extruded here or rolled down from somewhere above.
22:18:40	2225	9	S	I don't see the bottom.
22:19:06		10	S	I've turned on the slurp gun to flush it but don't know how well it will flush with this sediment in the water.
22:19:30	2230	4	S	I still can't see the bottom.
22:19:30			P	A big rattail fish is visible to port. There are still lobate sheetflows on the floor of the cleft. Some of the flows up here appear to be tilted back toward the center of the cleft. Now we're coming to a vent area; I can see dead worms. We're setting down on pillows. I see dead worms, and some fairly dark sediment; this might be good to sample, this dark, sandy stuff. But our scoop is full.
22:19:39	2233	3	E	A rubble slope appears on the port side; heading 027°.
22:19:43	2232	2	S	I still don't see the bottom, though I hear Robin describing it. We might try to slurp some of the dark sediment. No! No port arm. It also looks like a rock fragment got caught in the slurp tubing, so I might not be able to do it anyway. I see a large sulfide chimney; yes, we're in a field of large sulfide chimneys. One huge one is knocked down. Many are several m high, but small thin ones also occur. The floor is totally covered by sediment. There are many small spires; it looks like the spires are built along a linear ridge, so a fracture must run across there. I'm trying to take photos. . . Photos (roll 3, frames 32-36): small sufide spires and shimmering water near [OV]; only frames 33 & 36 are good.

TIME	D	A	O	OBSERVATIONS
22:19:51	2231	1	E	Some of this rubble to port appears to be veneered by something smooth, and it could have a bluish color; is it a sulfide incrustation? If so, there are no organisms on it, and it is littered with fresh angular blocks.
22:20:28			P	We passed over the dark sediment; we've no way to sample it; we're losing all of our sampling tools. [Ellen: We're in a field of large sulfide chimneys. Oh, boy! Thrill! etc. etc.]
22:20:43	2234	2	E	Blocky rubble is dimly visible in the left foreground, mantled by thick sediment. Some blocks appear rounded and could be pillow fragments. Or their outlines could be softened by sediment or hydrothermal incrustations.
22:21:01		1	E	This frame shows well the setting for float [OV], which is in the background near the foot of a rubbly slope.
22:21:06	2234	1	E	The float is shown better here, but the coarser rubble is out of view to the left.
22:21:24	2235	0	E	Fresh bluish hydrothermal incrustations and a dense stand of tiny spires are coming into view.
22:21:32			P	We've come to [OV], and I see lots of shimmering water and bluish deposits. Oh crud! Crud, Crud, Crud! [Background chatter about sampling and what to do, etc.] I photographed some miniature chimneys out of Ellen's viewport.
22:21:36	2233	1	E	Squat chimneys here are patchily covered by thin golden organic mats.
22:21:39			S	We're back at marker [OV]. Shimmering water is coming out of the chimney. Jim said [OV] is an ALVIN's length behind us. I just finished my third roll of film on small sulfide spires, 30-40 cm high, near [OV]. Shimmering water is coming from them. Sediment around the spires is dull orange on one side; in the background it looks more like a dull blue-gray. I see shimmering water issuing horizontally from some place in the wall. It's a wall full of sulfide and shimmering water.
22:21:59	2234	1	E	We are beginning to kick up a cloud of debris.
22:23:32	2236	1	E	The manipulator appears in the field of view, in front of some small chimneys.
22:27:14			E	This is the last frame illuminated by the strobe.
22:28:52			P	Photos (roll 3, frames 34-37): unsharp close-ups with the 105mm lens showing little spires out of the starboard viewport. I've finished my film, and we're sitting here, getting ourselves reorganized; we'll go up soon.

TIME	D	A	O	OBSERVATIONS
22:29:09	2235	2	S	We're not moving. We'll be leaving the bottom shortly. I've decided not to shoot any photos on my last roll of film, which is roll #4.
22:31:53	2230	6	S	We are now leaving the bottom.