DEPARTMENT OF THE INTERIOR

U.S. GEOLOGICAL SURVEY

DIVE REPORT: ALVIN DIVE #1456

Sept. 17, 1984 (JD 261)

Vent 3 Area, Southern Juan de Fuca Rift

by

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Abstract

Dive 1456, the second of eight dives during a cruise of the Atlantis II in September 1984, mapped volcanic and hydrothermal features and collected samples of sulfide deposits at the Vent 3 area. All nine of the visited hydrothermal vents were in a cleft along the axis of the southern Juan de Fuca rift valley. Vents in two areas more than 50 m long were emitting shimmering water, producing hydrothermal minerals, and supporting extensive communities of hydrothermal organisms. Two samples of sulfide were collected from one of these areas, and four samples of water and sediment were collected at or near the other. Three other vent areas 20-40 m long were active enough to support tubeworms and other macroscopic organisms. One vent area more than 50 m long seemed to be in decay. Three areas 5-10 m long seemed to be producing only small patches of golden-yellow sediment, though small clam shells were observed at one.

The cleft here is about 40 m wide and in most places seems to contain an inner trough 10-20 m wide. It is about 12 m deep in the south and deepens northward to about 25 m. No faults were observed to displace the youngest lava, which drained away to leave a thin veneer strewn by rubble derived mainly from the quenched surface of the flow. Most of this lava seems to have flowed along the cleft (from south to north), but some of it spilled over onto the main valley floor, with the extent of lateral spillage being greater around some of the larger hydrothermal vent sites. This enhanced spillage, and the occurrence of slightly younger pillowed flows and lobate sheetflows on the floor of the cleft near some hydrothermal vents, suggest that the hydrothermal vents coincide with the sites of volcanic eruption.

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Introduction. This was the second of eight dives made by DSV ALVIN along the southern Juan de Fuca Ridge in September 1984 (U.S.G.S. Juan de Fuca Study Group, 1983). This dive was focused on the Vent 3 segment photographed previously using deep-towed camera systems (Normark and others, 1983). We traversed the 1-km length of this segment, locating the main vent areas, establishing the general nature of their setting, and collecting a few preliminary samples. This dive was followed by another (Dive #1460; R. Brett, observer) that concentrated on a smaller part of the area.

The traverse is summarized in Table 1; it is shown in map view on Figure 1 and in profile on Figure 2. We dropped onto the valley floor about 100 m west of the axial cleft, 600 m southwest of Vent 3, and about 1000 m NNE of the acoustic ranging beacon in the vicinity of Vent 2. We began the traverse by going east across the cleft in order to construct a transverse profile. We then returned to the floor of the cleft and went NNE, zigzagging up the cleft from one wall to another toward Vent 3. We traversed the length of Vent 3, stopping twice to sample, then continued about 100 m before rising to deploy a marker float on the west rim of the cleft. We then returned to one of the main vent areas, where we spent the remainder of the dive collecting samples.

Navigation. Because the central cleft is narrow and deep in this area, ALVIN was frequently shadowed from the bottom transponders during the dive. Reliable three-range transponder fixes were obtained outside the central cleft and at a few locations within the cleft. A fix position was obtained for each of the sampling sites and marker floats. (Locations of floats Circle 2, Circle 3, and Circle + are indicated on the maps and profiles.) These fixes have a precision of better than 10 m. The navigation track was supplemented with heading information from divers' observations and the data frame of the external camera. The data logger in ALVIN did not work during this dive, so heading information was generally not recorded when the external camera was not in use. The navigation track (Fig. 1) for the last part of the dive is dashed because there were no reliable fixes and little heading information during this time. A three-range transponder fix was obtained shortly after the submersible left the bottom, giving a position for the end of the dive and the last sampling site. The depth-versus-time plot (Fig. 2) was made using depth and altitude values recorded by the divers and the data frame of the external camera. In this plot too, the last part of the dive is poorly constrained; it is based largely on verbal recordings by the observers.

Some confusion during the dive arose from navigation uncertainties, the real-time surface navigation generally placing ALVIN several dekameters east of the position inferred by the divers from seafloor topography. This uncertainty arose from two conditions: an imperfect match between the transponder net of 1984 and the nets of earlier years, and acoustic shadowing between the relay transponder on ALVIN and bottom transponders west of the cleft. Because this was an early dive in the series, the 1984 net was not yet located as well as it was later; it was rotated slightly with respect to the earlier nets. The effects of rotation were amplified in this dive because it was at an extremity of the net. Though our locations were well constrained along the cleft by the acoustic beacon, they were uncertain transverse to the cleft. Fortunately, this confusion was minimized by the depth and narrowness of the cleft here; most of the time we were confident enough of our location to understand then the general structural setting of our surroundings. However, the nature of structural details, such as the inner trough within the cleft, were inferred only later during the post-dive analysis.

Axial cleft. The cleft was crossed completely at the south end of the traverse, and its west wall was examined in two other places. During most of the traverse we zigzagged along its narrow floor. As a result we gained a fairly good understanding of its general nature. In most places here the cleft seems to contain an inner trough about 10-20 m wide, bordered by terraces that are also 10-20 m wide (Fig. 4). Its depth increases from about 12 m in the south to about 25 m in the north (Fig. 5). At the south end of the traverse, the cleft seems to have a symmetrical profile (Fig. 4A), while at the north end it seems to be asymmetric, with a terrace on the west side only (Fig. 4C). It appears to be a nested graben structure formed by en echelon faults. The relative ages of the various faults are not known; all of them seem to predate the latest lavas, which are draped unbroken over the fault scarps in every place that we observed.

Uncertainty remains about structural details, especially near the north end of the area; various data suggest that the structure here is more complex than a continuous symmetrical trough. SeaMARC II sidescan imagery shows that the cleft here splays or is offset by en echelon segments. In addition, the 1983 deep-towed photographs suggest that the east wall steps progressively westward in two left-stepping offsets. Finally, the navigation fix for station Circle 3 indicates that the west rim is farther west than expected from extrapolation of the west wall crossed farther to the south. In drawing the interpretive Figures 6 and 7, an attempt was made to fit these observations to a simple array of faults. In this interpretation, slices of rock 10-20 m wide form ramps leading gradually from the rim of the cleft to its floor. This interpretation is one of several that are possible; later dive data and restudy of deep-towed photographs may permit testing of the hypotheses.

Hydrothermal vents and samples. We visited at least nine distinct vent areas during the dive, with one and probably two areas late in the dive being the same as vents visited earlier (Table 2). All of these vents are on the floor of the axial cleft. Before and during the dive we thought that some vents lay along the edges of the cleft because they seemed to occur in talus at the base of steep slopes. But the post-dive analysis suggests instead that all of the vents occur within the inner trough. Some may occur along the walls of this trough, or all may occur in its center, with the steep slopes and talus being features of mounds of hydrothermal origin.

The vent areas are generally less than 10 m wide and range in length from about 5 to 100 m. These sizes are inferred from the extent of fluffy white and golden-yellow hydrothermal "sediment", which is thought to consist of bacterial growths; because this material is highly mobile, the areas of hydrothermal outflow may be much smaller. Even in the longest vent area, the area of sulfide deposition may be much less than 100 m^2. The thicknesses of the sulfide deposits are not known; in most places they may be no more than a few cm thick. Alternatively, the mounds may consist of sulfide incrustations and chimney rubble that have accumulated to thicknesses of a few m or more.

The observed vents vary widely in fauna and mineralization, and their degree of development generally correlates with their size. Two vent areas less than 5 m long (observed between 17:55 and 18:00 Z) possess only small patches of golden-yellow sediment. At a vent area 10 m long (encountered at 20:15 Z) small dead clams were seen in addition to the yellow sediment. A vent area 40 m long near the south end of the traverse (seen at 17:38-17:47)

small clumps of living tubeworms were observed in addition to thicker, more extensive sediment. Another vent area 40 m long but nearer the center of the Vent 3 chain (observed at 18:05-18:07) possesses velvety dark gray or black coatings on rocks; similar development was observed also in a smaller vent area at the north end of the chain (visited at 21:06-21:10 and perhaps at 21:57-21:59). The three vent areas more than 50 m long showed more extensive signs of mineralization, including blue, black and red incrustations, chimneys and mounds. Pervasive diffuse outflow of shimmering water was seen at the largest and most central vent in the chain (visited at 18:15-20:03). The vent area observed at 20:20-20:25 had signs of inactivity and decay.

Especially notable in the larger vent areas near Circle 2 and Circle + was the large amount of very fluffy sediment that floated up easily when disturbed even slightly. The thick clouds of this sediment made it difficult to collect rock samples, and as ALVIN moved away from the Circle 2 marker float, a thick cascade of disturbed sediment covered the top of the marker.

A few samples were collected to evaluate the prospects for additional dives (Table 3). Two samples of type B sulfide (Koski and others, 1984) were collected from the largest vent area; when one of these was taken from the top of an apparently inactive chimney, a dark plume began to issue from the chimney remnant. Four pump samples of water and sediment were collected in and near another large vent area near the north end of the chain; the sediment proved difficult to sample and to have very low density.

Lava on the main valley floor. Information about lava west of the cleft is derived mainly from our dive observations, while information east of the cleft comes mainly from earlier deep-towed photographs. The lava outside the cleft seems to include at least three different flows erupted in at least two different intervals. Included are at least two lobate sheetflows and one rough sheetflow. A second rough-surfaced flow may be a subsided facies of a third lobate flow that was not observed.

We saw only one lobate overflow from the cleft along its west rim near Circle 3 (at 21:17 to 21:45). Compared with lobate surfaces elsewhere along the rim, this one seems to be older, about 60% of it being covered by sediment (50% by thin sediment veneer and 10% by sediment ponds). The flow is thin and discontinuous, enclosing kipukas of a broken-surfaced older flow (Fig. 7); it seems to have spread only a few dekameters beyond the cleft and then drained back into it. Within the subsided area we saw only lava-subsidence shelves and selvages; we saw no pitted lobate forms or lava-resurgence shelves of a younger flow, though narrow resurgence selvages might have escaped our notice. An older lobate surface could occur farther west of Circle 3, with the broken surface of the kipukas being its subsided facies. Alternatively, the broken surface in the kipukas may represent an aa-like flow that spread onto this area instead of draining away from it.

Two lobate overflows occur on the west rim of the cleft near Circle 2, with the shelly (Swanson, 1973) surface of one being confined within the subsided part of the other (Figs. 2, 4; observed at 20:04-20:05 and 20:10-21:11). These two overflows could represent surging during a single eruption, but differences in their sediment cover suggest that they were produced by different eruptions. On the outer flow, about 60% of the surface is covered by thin sediment veneer and about 10% by small sediment ponds (similar to the flow at Circle 3); on the inner flow only about 20% of the surface is veneered by sediment, and sediment ponds seem to be lacking.

Relationships between flows are less clear near the west rim at the south end of our traverse. Here, after crossing eastward (at 17:21) from the lobate part into the subsided part of an overflow, we crossed (shortly before 17:23) a second low scarp without encountering another lobate surface. The second scarp was rimmed by broken folds and rubble of the subsided surface, and it did not trend NNE like the cleft-related faults. We interpret this scarp as the edge of an earlier lava-subsidence depression now mantled by the dregs of a later subsided flow, the younger flow having spread beyond the older depression instead of being confined by it. The two overflows could represent surges during a single eruption, but variations in sediment cover suggest that two eruptions are represented. Though we did not notice a sharp boundary between lobate flows of distinctly different age, sediment cover was greater at our touchdown site than it was nearer the cleft. About 100 m west of the cleft (observed at 17:16), sediment covers about 60% of the surface (50% by thin veneer and 10% by small sediment ponds in the hollows between lobes). But about 30 m from the cleft (17:20) sediment veneers only about 20% of the surface, and sediment ponds are absent. We think it likely that there are two flows of different ages, that the unsubsided part of the younger flow is thin and narrow, and that the unsubsided part of the older flow extends farther west to form the sediment-ponded surface around our touchdown site.

These variations in sediment cover can be used to infer the distribution of overflows (Fig. 6). Based on ANGUS photographs (tracks shown in Fig. 1) and our traverse observations outside the cleft, we infer the youngest lava to extend about 75 m beyond the cleft in the south, less than 10 m beyond it in the vicinity of Circle 2 and not at all near Circle 3. We infer an older overflow to extend farther from the rim everywhere along the cleft; though the location of its margin is unknown, its thinness and lack of continuity near Circle 3 suggest that it may extend little more than 40 m beyond the rim in that area (Fig. 7).

We observed the east rim of the cleft only at the south end of our traverse, where the lava seems similar to that observed on the west rim. Deep-towed photographs made in 1983, however, suggest that at least three different flows occur east of the cleft (Fig. 6). Two are lobate sheetflows similar to the two observed west of the cleft, differing from each other in their sediment cover. The younger lobate flow is narrow to the south but extends 50 m beyond the rim near Circle 2 and more than 150 m beyond the rim around Circle +. The subsided part of the younger lobate flow is about 50 m wide east of Circle +, but even here it is narrow compared with the subsided parts of flows around the Plume Site and Vent 1. We correlate these two flows east of the cleft with the two similar flows west of the cleft (Fig. 6). But if this correlation is correct, it poses a problem of asymmetry: Why does the younger flow extend so much farther east of the cleft than it does west of the cleft? Could the west rim have risen relative to the east rim before the younger flow was erupted?

In addition to the lobate sheetflows, a large area east of the Vent 3 is surfaced by a chaotically rough aa-like flow that seems to have spread NNE parallel to the cleft. It appears to overlap the older lobate flow (Fig. 6). Though it is shown on Figure 6 to overlap the younger lobate flow also, its true relationship to that flow is not known; their relative ages could be reversed, or they could be coeval. It is possible that the rough lava is the distal facies of a cleft overflow that occurred farther south and was not able to flow back into the cleft because the cleft occupies the crest of a gentle swell along the axis of the main valley floor.

Lava within the cleft. The lava within the cleft is quite different from that outside of it. Few lobate forms occur within the cleft; most of the lava consists of veneer, broken folds, and other dregs of a lava stream that once filled the cleft.

Everywhere we examined them, the cleft walls are coated by an apparently thin veneer. Though on the SeaMARC II image the walls appear to be faults, we saw no sign of older lava truncated by them. (However, some of the features interpreted as lava-subsidence selvages, as at 17:26:24, might alternatively be interpreted as older flows truncated by the walls of the cleft.) Much of the wall material is smooth, but much of it has a bumpy/pebbly/pimply texture, and in at least one place (wall west of Circle 2, observed at 20:04-20:05, photographed at 20:04:28) it has sharply-defined vertical striations. The most prominent features, though, are horizontal rings left by successive crusts on the subsiding stream of lava.

Many lava-subsidence rings occur on the walls everywhere that we examined them, as well as on the walls of some sheetflow pits outside the cleft (eg, 17:20:40). In most places they occur as stubby selvages a few cm thick projecting a few cm, or less, from the wall. Though in some places the spacing seems to be greater, they commonly occur at intervals of a few to several centimeters up the wall; where the cleft is more than 20 m deep, as many as a few hundred selvages may occur, one above another. Though they are most prominent on the nearly vertical walls (eg, upper wall west of Circle 2, observed at 20:04-20:05), they also occur on nonvertical slopes, among plates of subsided crust. The terrace west of Circle 2 (observed at 20:03-20:04) seems to possess rubble of two generations, one coated by veneer having selvages, and the other sitting atop the veneer (Fig. 4B). In most places, the selvages are thin and narrow, but near the base of the wall (eg, 17:26-17:27) they are much thicker and wider, with a ramp of lava commonly leading up toward them from the sagged floor of the cleft. They appear similar to shelves along the edges of subsided subaerial lava ponds, whose variations in thickness arise from changes in the rate of subsidence.

The floor of the cleft has a variety of flow forms that form a mosaic having cells commonly a few m wide. The main components of the mosaic are a pervasive veneer that coats the floor, and rubble of various kinds that occurs in patches atop the veneer.

The veneer occurs alone in many places (eg, 17:24:55, 17:51:00), and in other places it is the substrate for loose-spaced rubble (eg, 17:51:03). In other places it seems to extend as a substrate beneath thicker, close-spaced rubble (eg, 18:02:24). The veneer in most places has a distinctive texture, which in our dive notes is described variously as bumpy/pimply/pebbly/hackly, depending on lighting conditions, viewing distance, and observer predilection. It commonly resembles a pavement of pebbles welded together (eg, 17:51:03). Though it is glassy, tiny reflections from it are generally not seen except when viewed at very close range (eg, 20:15:07). From a distance it appears dark, smooth, and featureless; it is difficult to photograph, and though it is widespread it completely escaped recognition on the earlier deep-towed photos. But it is obvious when viewed stereoscopically through ALVIN's ports. Strong sidelighting can give it a rough, almost spiny appearance. The veneer seems to coat various surfaces, including older rubble and at least one expanse of cobble-sized rubble to form a "coated-cobblestone pavement" (17:58:07). In one place near a hydrothermal vent (20:36:12) a flat crust appears to have

been coated early by pimply veneer. It was then broken into plates 5-10 cm thick as it subsided onto an irregular underlying topography. The broken plates are now tilted but still fit together like pieces of a jigsaw puzzle.

Much of the floor is littered by rubble of various kinds. The rubble commonly seems to be more abundant on flatter areas and sparser on sloping areas. In a few places near the bases of scarps, the rubble includes prismatic blocks (eg, 21:05, 21:09:10, 22:00) that are probably talus derived from the interiors of lava flows. But these blocks merely form scattered litter instead of talus cones, and most of the rubble consists of platy or contorted pieces of flow crust. Broken, glassy pieces of all flow-surface types occur, including lobate, flat, and lineated forms--even a few pillow fragments--but much of it consists of broken folds (eg, 17:31:29). Fragments of a single flow type tend to dominate in any one area, giving a locally homogeneous appearance, but the dominant type commonly changes over distances of just a few to several m (eg, 17:53:10, 18:03:05). Compared with other kinds of rubble, the rough expanses of broken folds commonly have more relief, typically being about 1 m over distances of 5 m and 2-3 m over distances of 10 m or more (eg, 17:45:52). In some places among the broken folds, larger clots or clumps resemble rude lava coils 1 m or so in diameter (eg, 17:59:42). In many places the rubble is irregular or even chaotic, but in some places it appears less disrupted, with adjacent fragments fitting together almost like pieces of a jigsaw puzzle, as if broad open folds were only slightly broken and jumbled (eg, 18:00:30, 18:01:21). Platy rubble in some places seems to have an imbricate structure (eg, 17:38:46). In some places, the fragments differ from typical surface types, having a nonglassy, smooth or spiny clotlike appearance almost like aa clinkers (eg, 17:23:28, 18:01:56). Some of these clinkers may be older pieces of rubble that are coated by the pebbly veneer, but some may have been derived from thicker accumulations of that substrate.

Though the pebbly veneer generally underlies loose sharp-edged rubble (eg, 17:31:29), their superposition relationships are commonly more complex. In some places, pieces of rubble have rounded shapes and edges and a pebbly texture (eg, 18:00:30), as if they are coated by the veneer. In a few places sharp-edged, prismatic blocks appear to be embedded in the veneer (eg, 17:52:03, 20:39:21), as if they had fallen onto it from above when it was still plastic. In still other places two generations of rubble seem to be present, with the older one being veneered and the younger one littering the veneer (eg, 17:52:30, 17:53:10, 18:02:24, 21:09:36).

A less chaotic lava-flow morphology occurs on the marginal terrace of the cleft in the northern part of the Vent 3 area, below the Circle 3 station (observed at 21:14-21:16 and 21:47-21:50). The surface here consists of strongly lineated flat sheetflows (Fig. 7). The lineations are shallow and look like wrinkly folds. Though the lineations tend to parallel the trend of the cleft, the surface in some places is broken into wide plates a few cm thick, and some detached plates are rotated so that their lineations extend in various directions other than the dominant trend. Many of the plates are tilted, as if draped onto an irregular surface beneath them. The separations between plates reveal beneath them a substrate that is irregular and cavernous on a small scale, resembling shelly pahoehoe or foundered crusts in subaerial lava lakes (photographed at 21:15:24). Rising between the separated plates are blocks covered with veneer having lava-subsidence selvages (Fig. 4C).

Small clusters and chains of lobate forms and pillows were observed at four places (18:03-18:04, 20:20-20:21, 20:28:53, 21:05-21:09) along the floor of the cleft. In each case these flow forms lacked veneer and sat atop the rubble and pebbly veneer. In some cases they were seen to form narrow chains, but none of the chains extended beyond the inner trough or more than a few dekameters along it; all seemed to have been extruded locally through the rubble or pebbly veneer. Each occurs very close to a hydrothermal vent area, and some may extend beneath the vent deposits.

Volcanic interpretation. Many features of the lava-flow morphology indicate clearly that lava overflowed the axial cleft onto the main valley floor in this area and then drained away northward along the cleft. It appears that at least two different eruptions filled the cleft and caused it to overflow, with subsidence after each leaving fringes of pitted lobate flows along the rims of the cleft, lava-subsidence selvages along its walls, and complex dregs on its floor.

We interpret the veneer and rubble on the floor of the cleft as two parts of a subsided flow--the upper and lower crusts--between which the fluid central part drained away, dropping the broken upper crust onto the basal dregs. Crusts floating on the last dregs of the subsiding flow accumulated against low obstructions and in shallow depressions, leaving other areas free of rubble. The origin of two rubble generations remains undetermined. It is possible that they represent two different lava floods, with the ghostly surface rubble of one showing through the basal veneer of another. Alternatively, it is possible that only one flow is represented, with the veneered rubble being pieces that sank or foundered while others floated or fell onto the surface at a later time.

Neither the source area nor the final resting place of the drained lava is known with any certainty. The source of at least some of the lava must be to the south, possibly as far south as Vent 1, because the upward slope continues at least as far as that before reversing. The cleft in the Vent 3 area could have acted merely as a channelway for lava erupted farther upslope. But some lava could have been erupted locally in the Vent 3 area too, as suggested by widening of the overflows and subsidence depressions around some of the principal hydrothermal vent areas. The lobate forms and pillows on the cleft floor probably represent the most recent eruptions, and they support the suggestion that lava has erupted locally at Vent 3. Here, as at the other major vent areas, the sites of present hydrothermal vents appear to coincide with the sites of the most recent volcanic vents.

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TABLE 1: TIMED SUMMARY OF SEAFLOOR TRAVERSE

FROM	TO	ACTIVITY
17:05	17:14	Adjusting buoyancy at touchdown site about 100 m west of cleft.
17:14	17:29	Moving east from touchdown site across cleft to its east rim.
17:29	17:31	Turning and descending into cleft.
17:31	17:33	Sitting on terrace along east wall of cleft.
17:33	17:49	Moving north across floor of cleft, crossing axis at 17:44.
17:49	17:53	Swerving NE into axial trough in floor of cleft.
17:53	18:08	Slaloming along axial trough in floor of cleft.
18:08	18:13	Sitting at north end of fourth vent area, 1600 m from beacon.
18:13	18:16	Moving NNE along axis of cleft.
18:16	19:59	Sitting at Circle 2 station, collecting samples 1R and 2R.
19:59	20:08	Moving WNW, up and out of cleft and beyond its west rim.
20:08	20:15	Moving NE, descending again into axis of cleft.
20:15	20:40	Moving NNE along axis of cleft.
20:40	20:48	Rising above cleft for a fix, then descending again.
20:48	21:02	Sitting on floor of cleft, collecting water sample 3P4.
21:02	21:15	Moving NNE along floor of cleft.
21:15	21:18	Rising up west wall of cleft to its west rim.
21:18	21:33	Sitting on west rim at station Circle 3.
21:33	21:41	Moving west away from rim of cleft, onto main valley floor.
21:41	21:45	Moving east back to rim of cleft.
21:45	21:47	Descending into cleft.
21:47	22:00	Moving south along floor of cleft.
22:00	22:24	Sitting near Circle +, collecting samples 4P3, 5P1, and 6P2.
22:24	22:26	Obtaining fix and dropping Circle + marker shortly after dropping descent weights and leaving the seafloor.

TABLE 2: HYDROTHERMAL VENT AREAS, LISTED BY TRAVERSE TIMES

FROM	TO	LENGTH*	COMMENTS	SAMPLES
17:38	17:47	40 m	Thick sediment, colored yellow to orange, with small clumps of tubeworms.	
17:57	17:58	5 m	Small patches of golden-yellow sediment.	
17:59	18:00	5 m	Small patches of golden-yellow sediment.	
18:05	18:07	40 m	Thick yellow sediment; clumps of tubeworms, dead clams; velvety dark coating on rocks.	
18:15	20:03	100 m	Extensive thick deposits of yellow, cottony white, and greenish-white material; fish, shrimp, crabs, clumps of tubeworms, and many small spiders, chitons, palm worms and other worms; pervasive emission of shimmering water; extensive incrustations, mounds, and chimneys of light blue, blue-black, and reddish-brown; Circle 2 marker is near center of vent area.	1R 2R
20:15	20:16	10 m	Patches of yellow sediment, small dead clams.	
20:20	20:25	60 m	Locally thick golden sediment, mottled light and dark, with eroded appearance; fish, crabs, many brittle stars; clam shells and recumbent worm stalks; fuzzy yellow coatings and possible mounds and fat chimneys of sulfides.	
21:06 and	21:10	20 m	Patches of thick yellow and cottony white sediment; fish and recumbent worms; velvety dark coatings on rocks.	
21:57 (same area?)	21:59	20 m	Small patches of golden sediment and dark sand; reddish staining on rocks.	
20:29 and 22:00	20:34 22:24	60 m	Thick gold and fluffy white sediment; crabs, clam shells, tube worms, spiders; mounds and velvety coatings. 3P4 taken north of vent; others taken near its center, near Circle +.	3P4 4P3 5P1 6P2

*Estimated from durations of submersible and towed camera traverses.

TABLE 3: SAMPLES COLLECTED DURING ALVIN DIVE 1456

SAMPLE	TIME	X	Y	MARKER	COMMENT
1R	19:17	12752	15623	2	1.4 kg of porous type B Zn sulfide from inactive chimney; started a small black smoker when it was removed.
2R	19:43	12752	15623	2	0.8 kg type B massive sulfide with oxidized surface; 90% sphalerite and wurtzite; somewhat banded; from same site as 1R.
3P4	20:50 to 20:56	12850	15997	near +	Ambient bottom water in vicinity of vent; 4-liter bucket.
4P3	22:12 to 22:15	12860	15976	+	Yellow hydrothermal sediment; unfiltered sample in 4-liter bucket.
5P1	22:15	12860	15976	+	Yellow hydrothermal sediment; filter sample from same site as 4P3.
6P2	22:21	12860	15976	+	Yellow hydrothermal sediment; filter sample from same site as 4P3.

ILLUSTRATIONS

Figure 1. Map of the Vent 3 area, showing traverse of Dive #1456 (heavy line, with times noted in hours:minutes GMT) and 1983 tracks of the ANGUS and USGS deep-towed camera systems (fine lines). Numbers along the margins indicate coordinates of our survey net; distances (km) are indicated north and east from an arbitrary origin. Also shown are distances (meters) from the 1984 acoustic ranging beacon. Relative locations along the dive track are known to within about 10 meters, but these locations with respect to the earlier camera tracks are known with less precision. Circled symbols identify markers deployed in this dive, at points indicated on dive track.

Figure 2. Explanation of symbols used on maps and profiles of Figs. 3, 4, 6.

Figure 3. Plot of seafloor depth vs time during ALVIN dive #1456. Depths were obtained by adding ALVIN depth (from pressure measurement) to ALVIN altitude (acoustic) recorded at intervals of several seconds during the dive, with apparently spurious values removed. Because the data logger did not operate, the values used here were those recorded in verbal notes and the data frame of the external camera; the profile is dashed after 21:31 Z because there are no external photos and few verbal records of depth. Intervals when ALVIN was stationary are indicated by breaks in the profile and time axis. This plot can be interpreted as a topographic profile along the dive track, with an approximate horizontal scale of 1:5000 if a constant speed of 25 cm/sec is assumed. However, it is not a faithful record of topographic details because of speed variations and lack of continuous data. Locations of marker floats and collected samples are indicated by codes in boldface; other symbols are explained in Fig. 3.

Figure 4. Transverse profiles of the axial cleft at three places, constructed by adding verbal and photographic records of scarps and other features (Appendix) to the depth records of Fig. 2: A, southern (traverse time 17:20-17:30); B, central (18:15-20:15); C, northern (21:05-22:00). Symbols are explained in Fig. 2. Numbered features: 1, outer low scarp produced by lava-flow subsidence; 2, low debris-littered scarp interpreted as an earlier lava-subsidence scarp veneered by the younger flow; 3, principal rim of the axial cleft about 40 m wide; 4, rim of an inner trough about 20 m wide; 5, lava-subsidence scarp of older flow confining the margin of the younger flow; 6, rubble of two ages, with the older rubble thinly veneered by lava; 7, lava-veneered blocks of rubble projecting above tilted plates of subsided lineated crust. ALVIN is sketched to scale (1:500) on these profiles, which have no vertical exaggeration (V.E. = 1).

Figure 5. Longitudinal profiles in the vicinity of Vent 3, showing the outer valley floor, the main floor or terrace of the axial cleft, and the floor of the inner cleft. The outer valley floor is easily identified, and its gradient is well-defined; the other features are more interpretive, as discussed in the text.

Figure 6. General geologic map showing principal lava flows, scarps, and vent areas inferred from deep-towed camera tracks and ALVIN dive #1456.

Figure 7. Detailed map of the northern Vent 3 area. Symbols for vent features and lava-flow morphology, explained in Fig. 2, are shown only along the dive track.

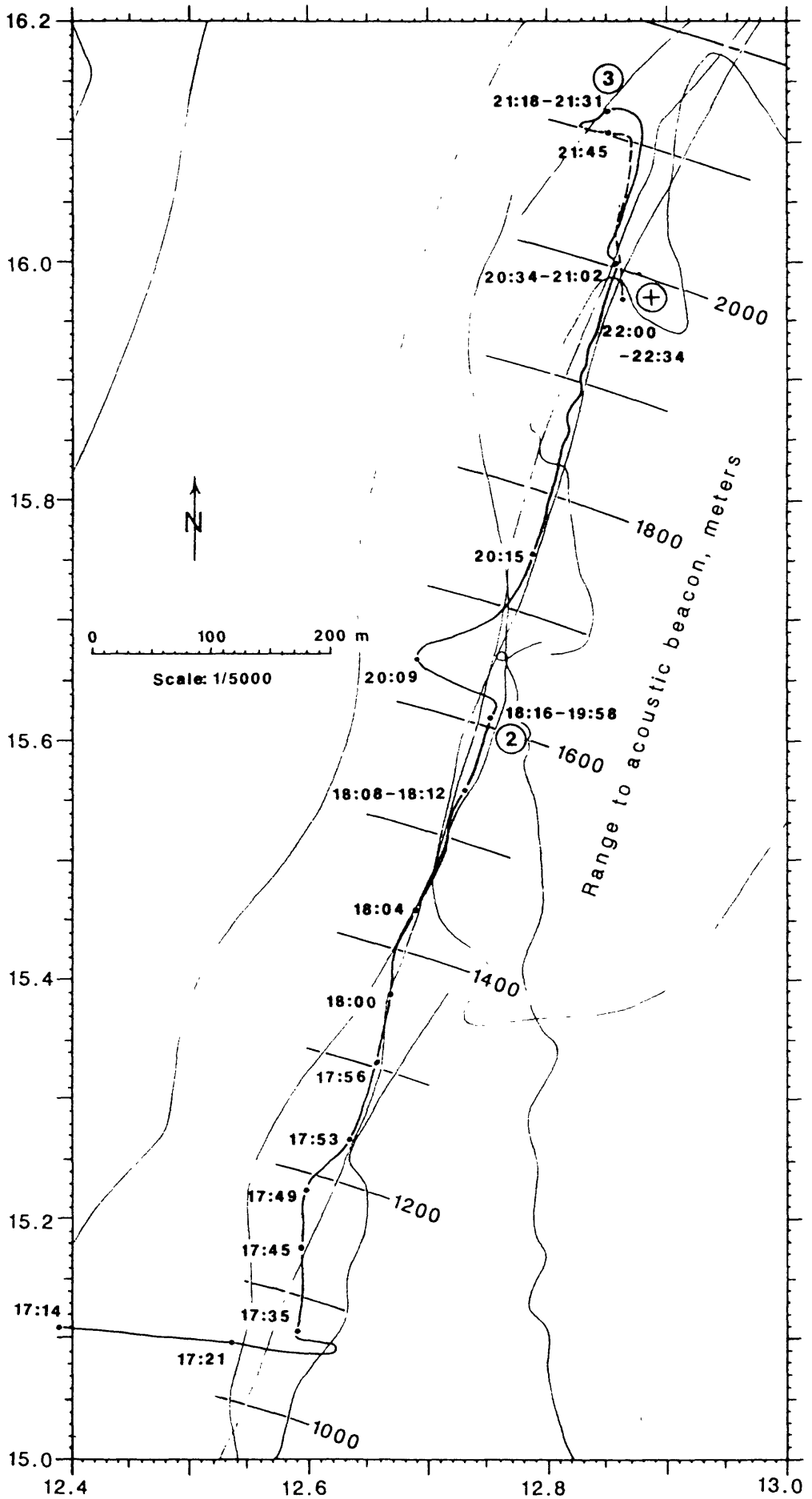

16.2
16.0
15.8
15.6
15.4
15.2
15.0
12.4
12.6
12.8
13.0
21:18-21:31
21:45
20:34-21:02
22:00
-22:34
20:15
20:09
18:16-19:58
18:08-18:12
18:04
18:00
17:56
17:53
17:49
17:45
17:35
17:21
17:14
2000
1800
1600
1400
1200
1000
N
0 100 200 m
Scale: 1/5000
Range to acoustic beacon, meters

Figure 1

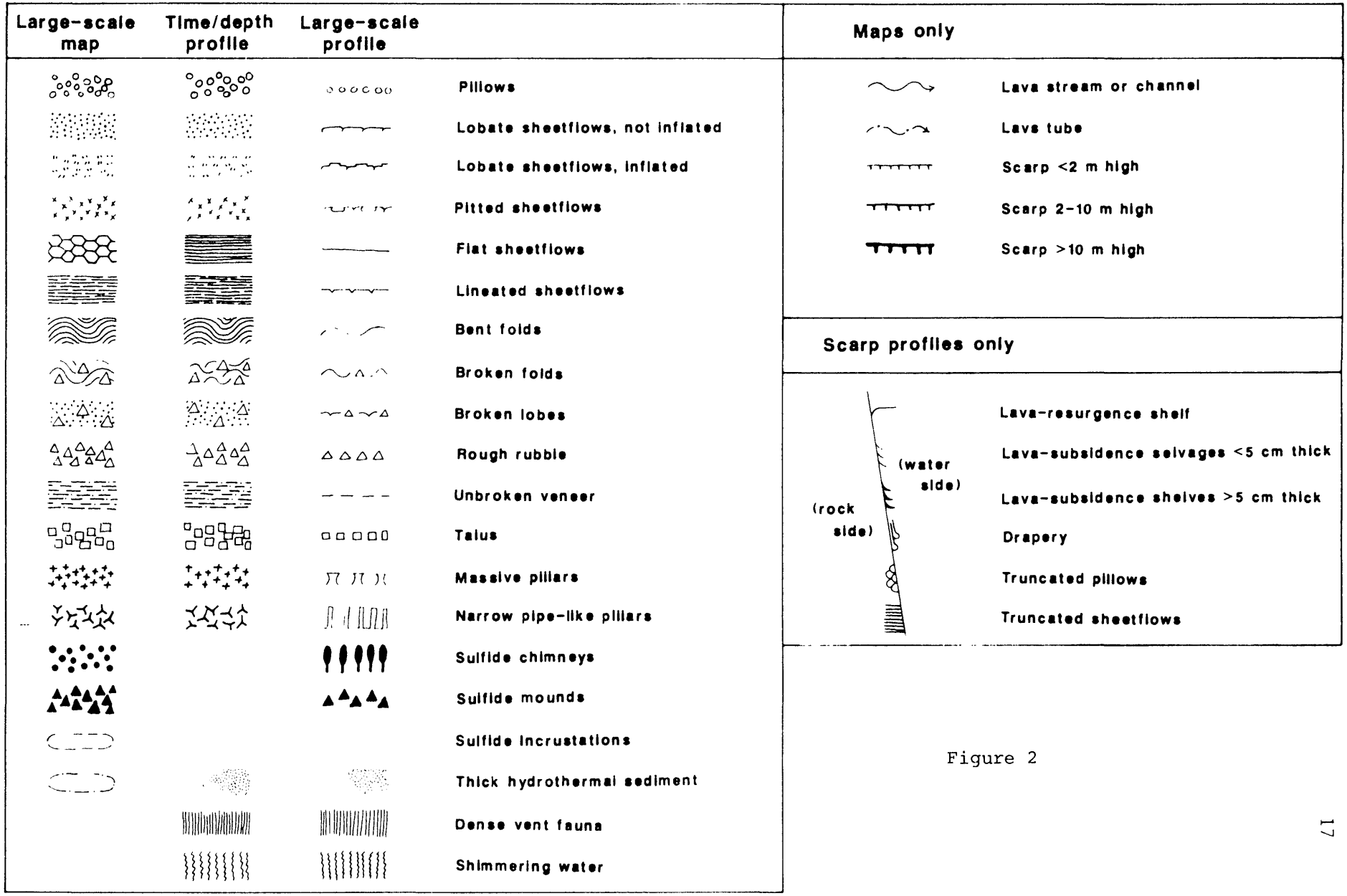

Large-scale map
Time/depth profile
Large-scale profile
Pillows
Lobate sheetflows, not inflated
Lobate sheetflows, inflated
Pitted sheetflows
Flat sheetflows
Lineated sheetflows
Bent folds
Broken folds
Broken lobes
Rough rubble
Unbroken veneer
Talus
Massive pillars
Narrow pipe-like pillars
Sulfide chimneys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

Figure 2

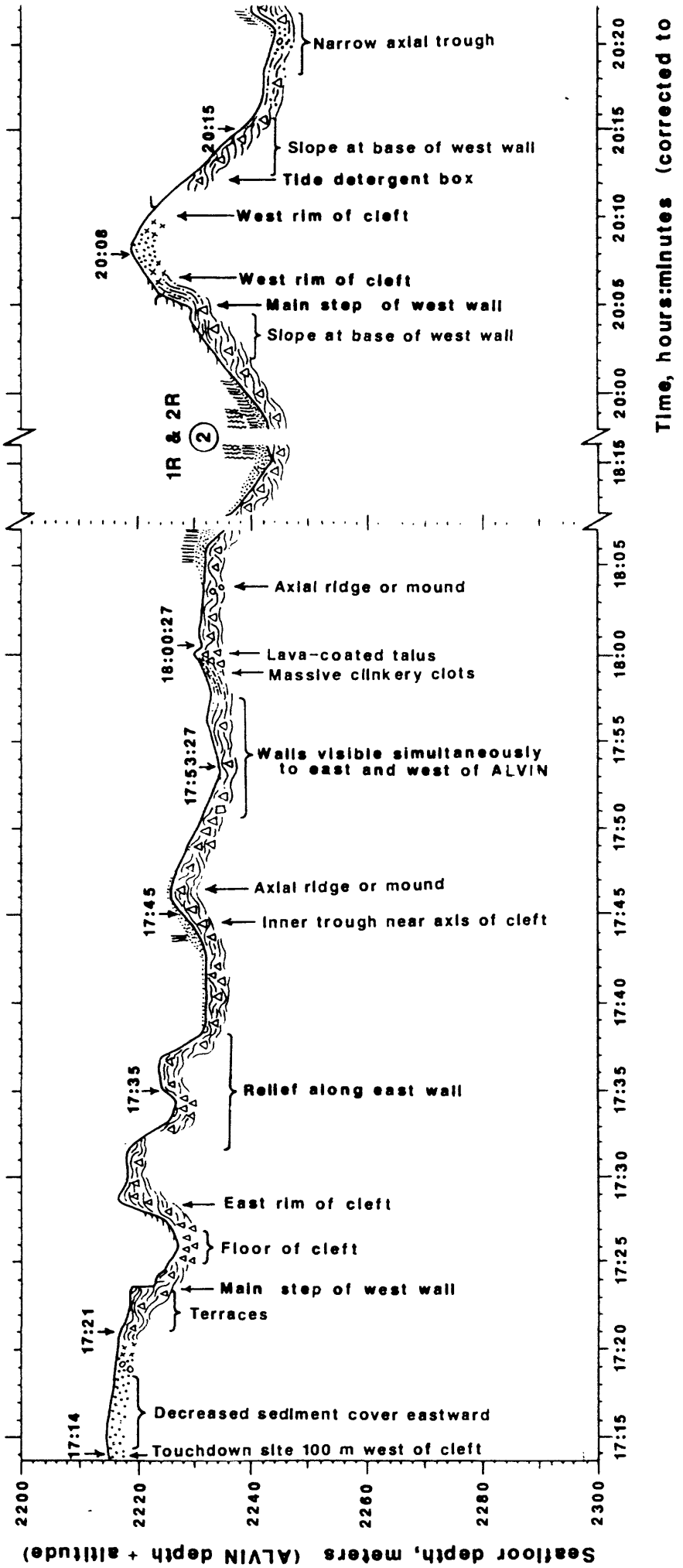


Figure 3, southern part

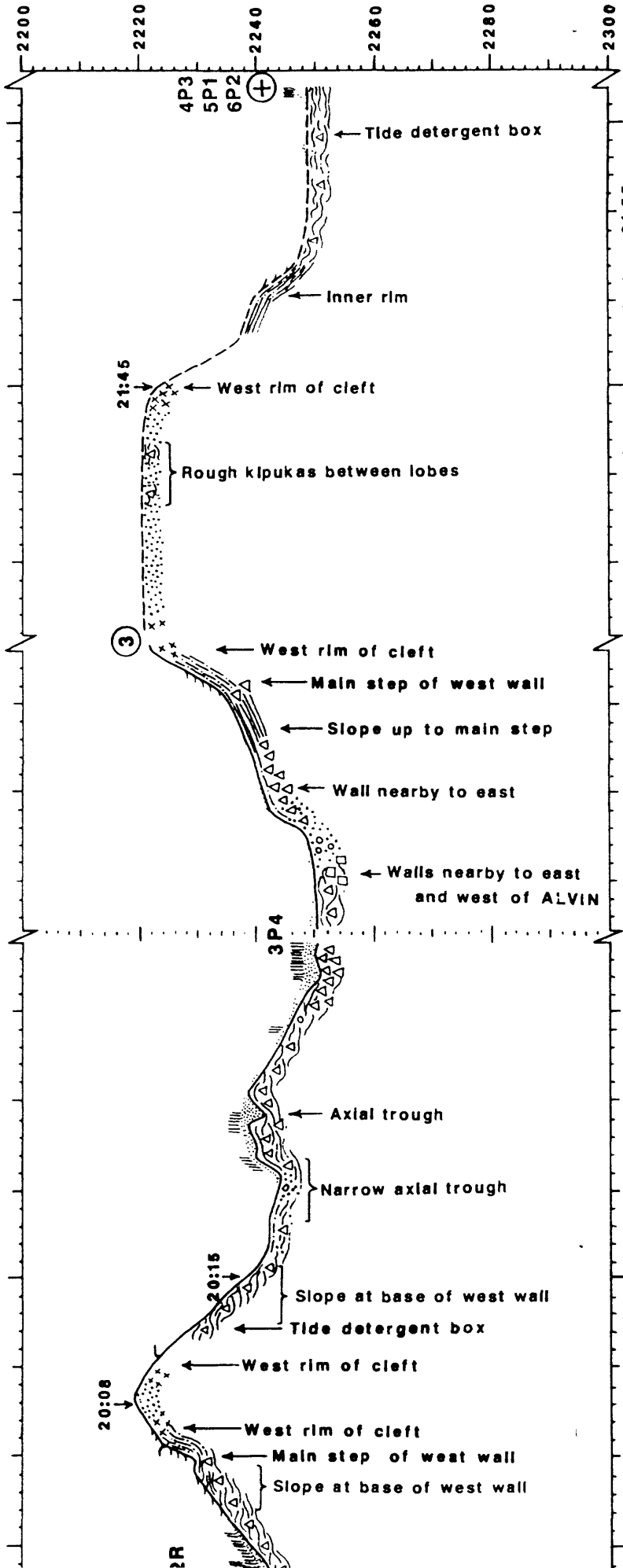


Figure 3, northern part

Figure 4

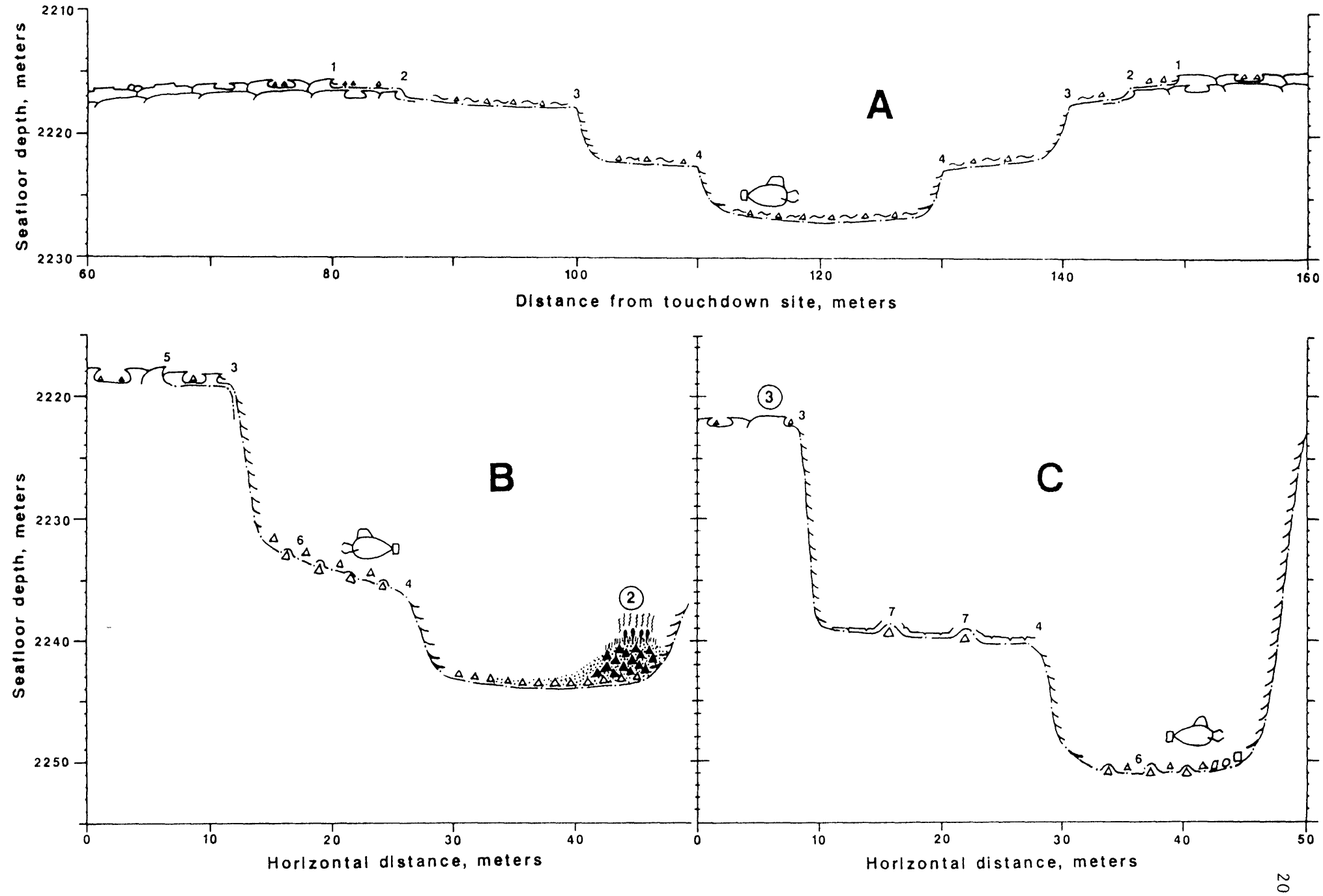
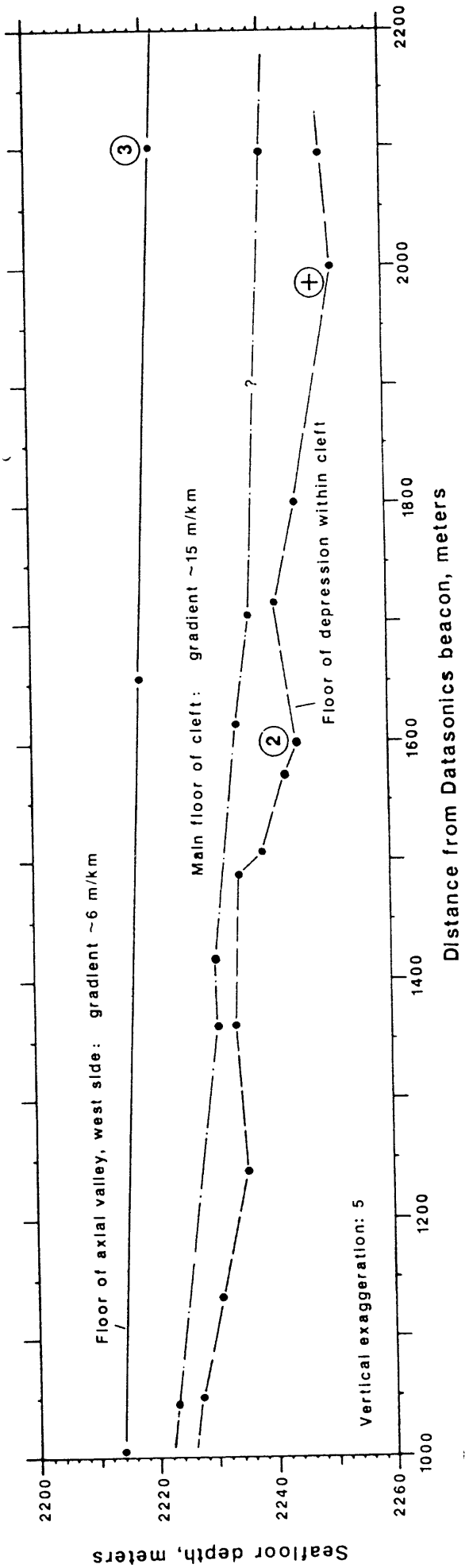

A
B
C
Seafloor depth, meters
2210
2220
2230
2240
2250
60
80
100
120
140
160
Distance from touchdown site, meters
0
10
20
30
40
50
Horizontal distance, meters
Horizontal distance, meters

Figure 5


Seafloor depth, meters
2200
2220
2240
2260
1000
1200
1400
1600
1800
2000
2200
Distance from Datasonics beacon, meters
Floor of axial valley, west side: gradient ~6 m/km
Main floor of cleft: gradient ~15 m/km
Floor of depression within cleft
Vertical exaggeration: 5
3
2
+
?

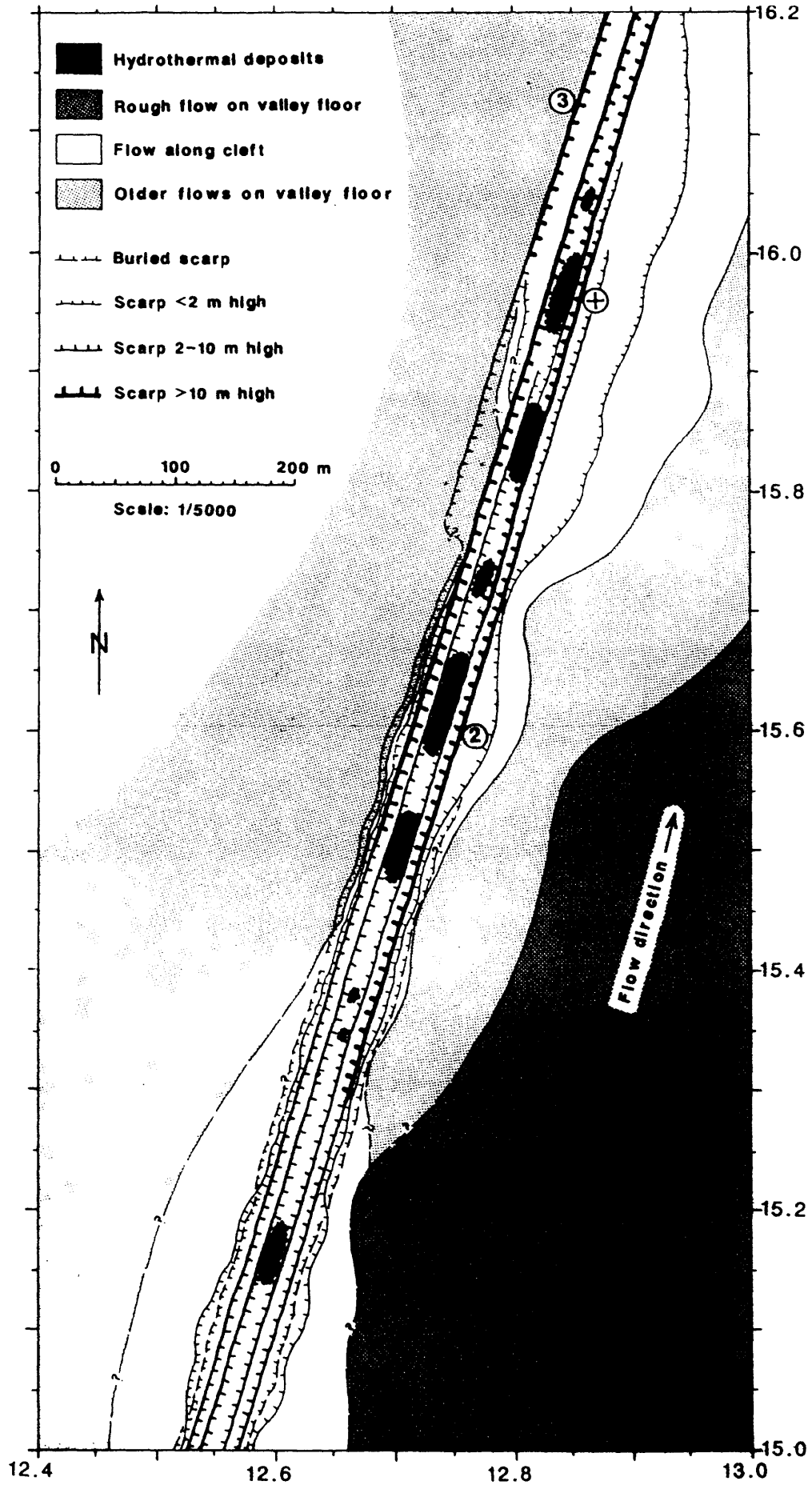

Hydrothermal deposits
Rough flow on valley floor
Flow along cleft
Older flows on valley floor
Buried scarp
Scarp <2 m high
Scarp 2-10 m high
Scarp >10 m high
0
100
200 m
Scale: 1/5000
N
Flow direction
16.2
16.0
15.8
15.6
15.4
15.2
15.0
12.4
12.6
12.8
13.0

Figure 6

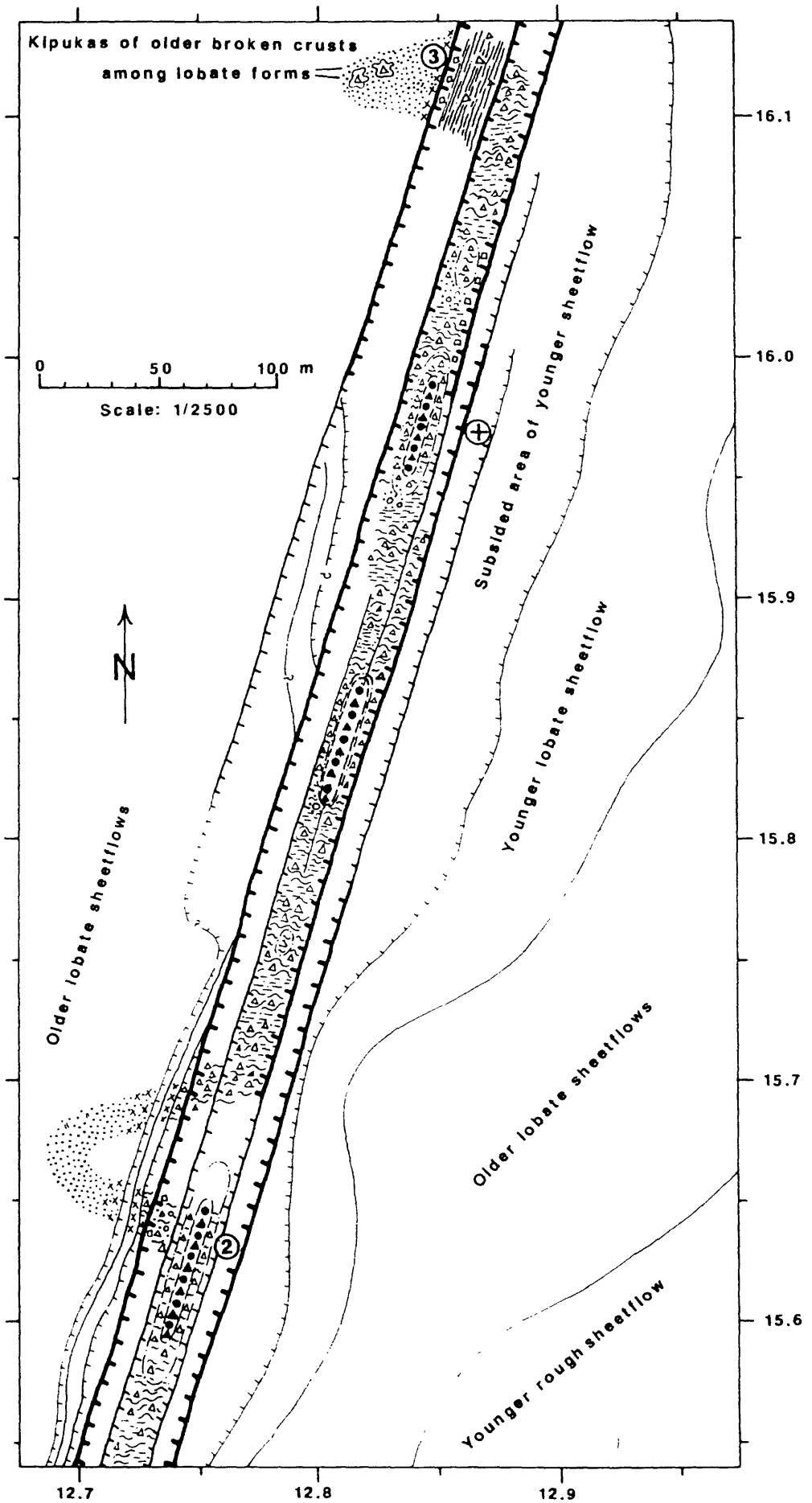

Kipukas of older broken crusts
among lobate forms
3
0
50
100 m
Scale: 1/2500
N
Subsided area of younger sheetflow
Younger lobate sheetflow
Older lobate sheetflows
Older lobate sheetflows
Younger rough sheetflow
2
16.1
16.0
15.9
15.8
15.7
15.6
12.7
12.8
12.9

Figure 7

APPENDIX: 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; see observation at 15:51 hrs.
Column D is depth, in meters, from pressure measurement.
Column A is altitude, in meters, measured by sonar altimeter.
Column O indicates observer: P, port observer; S, starboard observer; E, external camera.
Abbreviations: m, meters; km, kilometers; ft, feet; in, inches.

TIME	D	A	O	OBSERVATIONS
15:51			P	We're descending. The video isn't operating today. The clock is reading 1 hr behind GMT; I'll add 1 hr to the display time, but sometimes I may forget and give an erroneous time. [Later note: We learned later that ALVIN's clock was correct, and that the Atlantis II clock was off by 1 hr. The times given in this report are true GMT as indicated by the ALVIN clock.]
16:48	2178		P	We're approaching the seafloor.
17:05:30	2215	2	S	The seafloor is in view. I see lobate sheetflows, some with swirly texture on their surface. Sediment covers low areas; it's whitish-gray and easily stirred up. Brittle stars in the sediment appear to be only about 2-3 in across. Are they as large as those photographed earlier (5-6 in)? If so, I'm underestimating the scale of close objects. [Added note: Later in the dive I decided that I'm probably not underestimating scale.] Our landing site is on the axial valley floor, west of the central cleft; our range to the beacon is about 1 km. We can see both valley walls on the CTFM sonar. The target for the start of the dive is 1000 m NNE of the ranging beacon, along the cleft (about 500 m south of the south end of Vent 3).
17:05:35	2210		P	The seafloor is in view, surfaced by lobate sheetflows having broad lobes with wrinkled surfaces. The wrinkles are fairly contorted. There are some signs (small faults 1-2 cm high, etc.) of very local small-scale inflation of individual lobes. As we approach to within 1 m of the bottom, some sediment is entrained and flies up around the port. Sediment thinly veneers about 50% of the surface, and some very small ponds between lava lobes cover 10-20% of the surface. These may be overestimates; it's hard to estimate sediment cover in a manner consistent with estimates from ANGUS photos because my eye is so close to

TIME	D	A	O	OBSERVATIONS
				the surface. These "sediment ponds" might show up only as a part of the veneer on the ANGUS photographs. Many little brittle stars are scattered around on the sediment; they're too small to be resolved often on ANGUS photos. Most broad lava lobes are slightly inflated; overall this lava resembles typical tube-fed pahoehoe from Mauna Ulu (Hawaii) where it has spread 2-4 km from the vent to the top of Poliokeawe Pali. We're coming down to adjust ballast to neutral buoyancy.
17:10:10			P	CTFM photo (roll 5, frames 5A & 6A, 50 m full-scale, heading 190o): We took some photos of the CTFM screen and then of its time display. I made another photo just before this but discovered that the camera was aimed improperly, so the first frame will include only a part of the CTFM displays. As we move over this surface we see very good evidence for small-scale inflation and heaving of this flow. There are many small, broadly heaved tumuli typical of tube-fed flows. Would this small degree of inflation show up on the ANGUS photos?
17:11			S	Our fix from the surface at touchdown is x = 12407, y = 15065, which is 100 m due west of the targeted drop site.
17:14			S	We've settled back near the bottom and have begun going east toward the cleft. We're over lineated sheetflows with some lobate forms. I see a 5-pointed starfish.
17:14:28			P	We're moving eastward now. A rattail fish is just below us. The lava is still in the form of lobate sheetflows.
17:15:38	2213	1	E	Globular small lobes or toes occur together with broader but robust lobes. Some of the broad lobes have apparently sagged. Broader lobes are commonly broken by cracks, and some are separated into detached fragments. Sediment ponds are variable; commonly little ponds run along cracks between lobes and comprise less than 5-10% of surface; but there are some larger ponds scattered about also, in which sediment forms a continuous layer atop relatively low-standing lobes forming the floors of small depressions. But these latter ponds also must comprise less than 5% of the total surface. Their origin is unclear; they could by kipukas, or they could represent some redistribution process that deposits sediment in the lowest hollows.
17:15:50			P	I've turned on External Camera 1. The surface here is composed of lobate sheetflows. The lobes are fairly robust, with many small, broad tumuli protruding between chains of younger robust lobes and toes. From close-up I can see many small specular reflections from pristine, unaltered glass. But the sediment cover is substantial: Coverage by very thin sediment veneer appears to be about

TIME	D	A	O	OBSERVATIONS
				50%, varying from about 20% to about 75% over short distances (a few meters). All of the inflated broad lobes have gentle undulations and wrinkles on their broadly domed surfaces; these small-scale deformations probably are primary features developed while the skin was very young and fresh [less than one minute old?], while the broader doming and heaving occurred later [over intervals of an hour or more after the surface solidified?]. The inflated, fault-bounded tables here generally rise up 4-5 cm above their fringing toes and are cut by shallow primary fissures 4-5 cm deep and as wide.
17:16:18	2214	1	E	Sediment veneer is 50-60%, and sediment ponds about 10%.
17:16:32	2214	1	E	Here is a good view of a broad lobe broken into polygonal plates by shallow cracks a few cm wide. Some cracks seem to follow the axes of bent folds, but others cross the folds and are commonly normal to them; the cracking followed closely after the surface wrinkling. It may not be a product of inflation, as was thought during the dive; instead it may be a product of brittle fracture as the lava ceased to spread. But there is some evidence here of sagging of a broad lobe under the weight of later lobes.
17:17			S	Photo (roll 1, frame 2, no strobe): Swirly sheetflows have striations 3-6 in wide, and the low areas are filled with fluffy gray sediment. Widths of lobes range up to about 3 m. No fractures are visible. Flow surfaces are dull; not much fresh glass is seen.
17:19			P	As we drive east we are getting out of the inflated lavas, and we cross a nice little cluster of pillows right here
17:19:28				(at 17:19:28) among robustly lobate sheetflows that are not inflated. Small corals are growing on this, and I saw one conispiral snail and a couple of rattail fish so far.
17:19:30			S	I see more lobate forms here and possibly some pillows, with breadcrust structure on some surfaces. The bottom relief is about 1 m. We're over a collapsed lobate flow with a crust a couple of inches thick. We're coming to several small collapse pits. Collapse pits are about 2 m wide. The flows are now quite glassy, and there is much less sediment cover now--just a light dusting of about 10-20%. The flows have lobate forms.
17:19:59			P	We're getting into pitted sheetflows that are glassy and have a sediment veneer of only about 20%. We may have crossed an age boundary. (But do the pits act as sediment traps to give this lava an artificially youthful appearance?) This lava appears to have been much more fluid and spread more rapidly. It's very shelly with many broad, shallow, non-contiguous pits in it, and the flow surface appears to have more glistening glass than the inflated sheetflows we crossed initially.

TIME	D	A	O	OBSERVATIONS
17:20:20	2214	1	E	The sediment cover does seem to be decreasing, but an obvious contact has not been seen.
17:20:32	2216	1	E	This is the first frame showing a small pit, which apparently occurs in a single lobe.
17:20:40			P	Here is a bigger pit now, about 1/2 m deep, and we're beginning to see subsidence shelves or selvages along the pit walls. And now we're crossing into a much bigger pit about 4 m across and 3-4 m deep. [Pilot: Is that estimate too deep?] Its floor contains a marginal rubble surrounding folds and broken folds. Surface relief locally is 20 cm or so, but then we cross another shelf and drop down another few m. It looks like we may have been on a broad shelf; I can't tell if it was formed by multiple eruptive pulses, or multiple collapses, or draping of this flow onto an underlying stepped topography. [Pilot: OK, we've gone down 3 meters]. The surface below us now in the pit looks like broken folds, not completely chaotic, but it might correspond to the surface type I have called "rough lava" and "broken folds" on the ANGUS photographs. I think that in the past few minutes we have dropped over the west rim of the central cleft and have come down now onto its floor. If so, the cleft here does not have a sharp-rimmed high wall but a more gradual, step-like ramp, at least on the west side. The rough floor here has a local relief of a couple of meters.
17:20:47	2214	1	E	This frame shows the edge of a pit, which is at least several m wide but not more than 40-50 cm deep. Selvages are not visible along the wall because it faces away from us. The next frames show a floor of platy rubble, a litter of small plates. Much of the rubble looks vaguely like pieces of a lobate surface that has been broken, perhaps while subsiding; it does not look like a later lobate flow that flooded a subsidence depression. Some of the plates seem to consist of draped folds that were dropped down almost intact.
17:21:30			S	Photo (roll 1, frame 3): Floor of a large collapse pit littered by broken folds. Our depth is about 3 m greater than at the start of the dive. [Later note: The pilot meant that we had gone down 3 m into this depression, responding to the slightly earlier depth estimate for the depression; that may or may not be the same as total subsidence since reaching the main valley floor.]
17:22:30			S	We're still over the collapse pit and moving east, having gone about 100 m since landing. The pit floor consists of broken folds of sheetflows with very glassy surfaces. We're approaching a straight rim; I can't see the bottom beyond. We're crossing the rim obliquely. There are broken folds to the edge of the rim, then a steep drop-off.

TIME	D	A	O	OBSERVATIONS
17:22:35	2220	1	E	The rubbly subsided surface here forms a rim, with a slope falling off sharply to the right. The forward-looking camera has not yet seen a wall facing it, so it cannot yet confirm the presence of lava-subsidence selvages on these walls, which were reported visually at 17:20:40. This surface is not the kind that we previously called "rough lava", but it may consist partly of "broken folds". Of the subaerial varieties, this lava looks most nearly like shelly pahoehoe. The rim shown here appears to parallel our camera axis, which should be 085o; but shouldn't the rim be nearly normal to our track?.
17:23:18			S	Photo (roll 1, frame 4, no strobe): Steep slope, just below the rim at the western edge of the central cleft. The first slope is about 5 m high. The CTFM shows a wall about 20 m to the east. We're still heading 090o. We cross broken folds at the base of the slope and come to a sharp rim; this looks like the main depression.
17:23:28	2216	0	E	Here is another rim ahead of us, this one may be a few to several m high. An indistinct rim of a low bench also seems to occur in the left foreground. Below the high rim a slope may continue down toward the right background, but that surface could instead be flat. On that surface there appear to be a few equant blocks; they do not appear to be flat plates. Everything visible here is "rough lava" that is almost spiny, like some varieties of subaerial aa.
17:23:42	2215	1	E	The seafloor goes out of clear view now until 17:25:43, except for frame at 17:24:49 in which the slope seems to be going down steeply ahead and to left.
17:23:45	2219	5	P	We're crossing into some deeper pits, and it seems to get quite deep ahead of us now, at least several m deeper. We have come down 9 m since we first reached the seafloor. Maybe this is the rim of the axial cleft, and we've still been crossing intermediate steps. [Pilot: There is a wall about 20 m away.] The flow morphology here consists of folds and broken folds. . . . Now there's a sharp rim and a really deep depression up ahead, maybe this is the axial cleft. We're still heading east.
17:24:55	2222	4	P	We're crossing the rim of something deeper, but the wall isn't vertical; it's just a steep slope with broken folds draped on it, as if a folded surface were dropped onto an underlying topography. I don't know how much deeper it goes, but it looks like we're still stepping down to the east. [Pilot: The altimeter said it was about 5 m, and the CTFM says it's about 40 m wide.] We've come down 12 m, and are flying 3-4 m above the bottom. Then we come to a steep slope up ahead of us, and out of the front port I can see a nice lava-subsidence shelf. It looks like the subsidence was rapid, leaving a long stretch of pimply-rough veneer on the surface beneath the truncated shelf.

TIME	D	A	O	OBSERVATIONS
17:25:15			S	The altimeter shows that the bottom drops about 5 m. We are crossing the rim and down a steep slope. The CTFM shows the width of the depression is 40 m. Photo (roll 1, frame 5): large fish.
17:25:43	2222	4	E	The seafloor has gradually come into view in the last few frames. It appears rough but has a very crude lineation oblique to our track.
17:25:57	2225	4	E	This may be our first photo of the "pimply" kind of surface. Jan's description of it as "pebbly" is apt. Sediment veneer is about 20-30%, with no sediment ponds.
17:26			S	At the base of the slope is broken rubble, with blocks ranging in size from a few inches to 1 ft. Except for the rubble, the bottom looks fairly smooth. A drop-off occurs to my right. We're going east. Now we're going up over a small ridge. We're over folded, broken sheetflows. We've reached the top of the slope; there's a subsidence rim near the top. It's craggy on top. It's levelling out at the top of the ridge. I see glassy broken folds of sheet flows, with some small collapse pits. We think we're out of the central depression on the east side. The depression is narrow, about 40-50 m wide. Fresh lobate flows are seen immediately after leaving depression, and 1 or 2 shallow collapse pits. We'll turn west and get back into the depression, then drive north along the depression.
17:26:24	2223	3	E	Here is a beautiful shot looking down obliquely on a thick lava-subsidence selvage ahead of us. It appears to be at least several cm thick, probably arising from a slowing of subsidence. I see no obvious sign that the selvage projects beyond a lower pebbly-textured wall, as reported visually, but it might; stereo viewing might confirm that observation. There is stereo coverage in the following frames (17:25:57, 26:10, 26:24, 26:37, 26:51). A ramp may lead up from the foreground toward the base of the selvage.
17:26:52			P	We're on the floor of the cleft, sitting beside the east wall. The wall is a steep slope draped by lava that is fairly smooth but interrupted at intervals by thick projecting lava-subsidence shelves. We're rising up now to see how high this slope goes. We're going up a series of steps like those we came down on the west side. A rubble of broken folds litters the surfaces of the steps, while the risers (some of them, anyway) possess successive truncated selvages. The lava is glassy but possesses some sediment veneer, and because this rough lava soaks up a lot of sediment this flow cannot be especially young unless there is a high rate of sedimentation here.
17:27:04	2227	4	E	The material above the ledge is distinctly more rubbly, and small plates can be seen. But a pimply substrate may occur beneath the rubble.

TIME	D	A	O	OBSERVATIONS
17:27:18	2221	4	E	A short fissure or scarp seems to face away from us, with broken folds beyond. Interpretation of this is uncertain.
17:28:12	2213	2	E	We've been continuing across a mosaic of pimply veneer and rubble, but no more selvages are seen in the photos. Now we're coming to a drop-off facing away from us, or a decrease in upward slope, toward the right background.
17:28:12			P	We're still crossing up a slope littered with broken folds. Now we're at the top, and the flow morphology reverts to lobate sheetflows.
17:28:25	2219	0	E	Broken folds in the left foreground seem to rise above unbroken lobate forms in background. The interpretation of this is uncertain; is the lobate flow filling the cavity of a previously subsided flow?
17:29:04			P	We've lifted up over the east rim of a depression 40-50 m wide and again are in lobate sheetflows with small pits. I see a rattail fish, but not many organisms growing on this lava. I think we've crossed the inner cleft; if so, its morphology is intermediate between the sharp-rimmed cleft expected at Vent 3 and the vaguely-defined hollow observed at Vent 1 during Dive 1455. We'll now return to the axis of this cleft and begin to follow it NNE.
17:29:32		0	E	Views of lobate lava have become successively less distinct; then the bottom fades from view as we rise and turn around.
17:31:29			P	We've set down lightly on broken folds on the rim of the cleft. [Or are we on a marginal step inside the rim?] The clots of broken folds resemble aa clinkers and just sit loosely on the surface; they move and crumble as we set down onto them, kicking up a small amount of sediment.
17:33	2227		S	We're in the cleft. Its width is 40 m; our course is NW. The floor consists of broken rubble having a relief of 1-2 m. [Later note: At this point we may not yet be back on the floor of the cleft, but on an intermediate shelf of the east wall.] The basalt is glassy, and sediment cover is a light dusting, about 10-20%. The relief here is greater than the relief outside the cleft.
17:33:14	2224	3	P	We're beginning to drive NNE.
17:33:22	2227		E	Here's a good frame in a succession increasingly closer to the rim, showing a subdued, perhaps pimply, surface grading into a lobate rubble along the rim. Close-up, the "lobes" seem have rougher, perhaps more pimply, surfaces.
17:33:35	2224	3	E	These frames comprise a stereo triplet showing the rim
17:33:49	2227	2		morphology, close-up. [Note: Robin thought we were on
17:34:02	2226	2		the east rim, but Jan thought we were on the floor of the cleft.]

TIME	D	A	O	OBSERVATIONS
17:34:07			P	We're just above the bottom, which here consists of broken folds and plates littering an underlying fine-scale rough or pimply/pebbly/hackly surface somewhat like the surface on Puu Puai (Kilauea Iki, Hawaii) and other places where tacky, nearly frozen material has been pulled apart or has had a surficial component slowly flow away. I imagine that we see here two parts of a flow—the upper and lower crusts—between which a more fluid central part has ebbed away, dropping chunks of its broken upper crust onto its basal dregs. In some places nearby the surface appears to consist almost entirely of subsided broken plates of the upper crust; in some other places the surface contains only a few of these plates, the remainder consisting of the hackly surface. This is something I did not pick up on the ANGUS photos; it shows the value of close-up views from ALVIN.
17:35:56			P	CTFM photos (roll 5, frames 7A & 8A, heading 060°): We're above the axial cleft now, and the screen shows its two walls. The strongest return comes from the east wall, which is ahead and oblique to our course.
17:37			S	Our course is 020°. We're in the depression over low, folded sheetflows and some rubble of broken folds.
17:37:11			P	We're driving NNE along the valley axis. The floor is still a mosaic of broken folds and hackly dregs. Piles of broken plates litter the hackly surface in some places. [Later note: Why do these variations occur? Hypothesis: Hackly surfaces are (high? steep?) areas from which lava drained quickly, leaving just a rind; littered surfaces occur where the underlying surface was flat and/or drainage was slow, and floating plates of surface crust grounded and came to rest; continuous broken folds are in depressions where surficial plates accumulated. We should carefully check this hypothesis in future dives.] There is quite a bit of bottom relief here, perhaps 3-5 m (overestimate?) over distances of 30-60 m along the cleft, with the highs and lows being distributed irregularly. [Or at least no systematic pattern is obvious as we cruise by. It might be useful to examine this in some detail to see if an integrated drainage network shows up in the topography. If it does, most of the drainage was probably lateral, along the surface. But if not, there may have been many local sinks along the cleft, with the lava draining back down into the plumbing system].
17:38:05	2227	2	E	This is an interesting but puzzling frame. It seems to show a succession of low steps going down to the right, like a series of flow fronts stacked up. But they aren't globular toes; they're more like elongate surge overflows along a lava channel. But there is no other sign of a channel here. Do they really consist of basalt, or something else? Fine rubble occurs on and around them.

TIME	D	A	O	OBSERVATIONS
17:38:19	2228	4	E	Small patches of yellow sediment appear in cracks and around pieces of rubble, and much of the rubble seems to have a layer of coarse black sand perched on top.
17:38:30	2224		S	Orange sediment occurs on a steep slope ahead and to my left. To the right is orange sediment on a low (1-2 m) scarp. Two hackly ledges protrude along the scarp.
17:38:46	2224	4	E	More yellow sediment occurs now, and the platy rubble is stacked to form an imbricate structure, with the last-laid-down plates to the left. Or is this an illusion caused by the lighting?
17:38:50			P	Photos (roll 1, frames 0-2, no strobe): little pockets of golden-yellow sediment that are fairly thick and extensive.
17:39:13 to 17:40:07	2223	4	E	Several frames here show a cluster of upturned broken folds, with yellow sediment. These frames may provide some stereoscopic coverage.
17:42:21			P	Here are little patches of golden-yellow sediment, then bigger patches. We're crossing an area of extensive, thick sediment on rough lava. I can see worm fecal tracks on the sediment, which consists of granules mostly in the size range of fine gravel to coarse sand, with some larger pebble-sized pieces of material of a golden color. [All of these could be aggregates of finer particles adhering to each other.] In some places there may be some dark gray material mixed in with it. The flow surface still consists of broken folds, broken lobes and broken plates. Where the breakage seems fresh, glass is showing through; but most surfaces seem tarnished or coated.
17:42:30			S	The seafloor is rough here. I see the edge of some yellow-orange sediment; Jim sees more of it ahead. Yellow sediment covers a hackly, rough surface. The underlying rock is reddish. Now we've passed the sediment and are over folded-sheetflow rubble. There are talus blocks 1-2 ft across; broken surfaces are brown, broken plates are a few in thick. The floor is rough with lots of rubble.
17:43:16		2	E	Now we see some significantly thick ponds of a pale yellowish sediment on broken folds and plates.
17:43:30	2225	1	E	Scattered yellow-white globules, no more than a few cm wide, occur on the sediment ponds; these globules may consist of the puffy, cotton-like material, but it's difficult to say for sure.

TIME	D	A	O	OBSERVATIONS
17:43:49			P	Here are some little clumps of tube worms in thick, almost continuous sediment cover (probably at least 2 cm thick), with some broken folds protruding through it. [If this flow has the normal relief of rough lava, the average sediment thickness should be at least several cm.] Golden sediment here probably covers 60-70% of the surface. Some lemon drops drift by as we move; just a little movement by the submersible is sufficient to entrain these puffballs, which seem to be as light and puffy as cotton candy.
17:44:37	1		E	The deepest sediment pond seems to occupy the floor of a trough parallel to our track, with highs along both sides. The protruding material has varied: some looks like draped folds and some like rubble of basalt; some may be rubble of something else.
17:45:30			S	Sediment cover is heavy; it covers 100% of the surface in low areas. Hackly blocks 1-2 m wide protrude.
17:45:52			P	We're lifting up a little, and we're just now crossing out of the sediment deposits across a very glassy rubble that appears to range from broken folds to rough lava. We'll slalom back and forth along this depression; right now I think we're heading obliquely toward the west wall. The local relief on this rough lava looks like it's at least 1 m over distances of 5 m, and 2-3 m over distances of 10 m or more. Here are more little patches of golden-yellow sediment, and other patches of paler sediment are nearby. This spatial association of two kinds of sediment ponds suggests that they may be related genetically. [Later note: Are the latter ponds earlier deposits of the same material, now bleached? If so, Jim Bischoff thinks the material must be organic; if it were notronite it would oxidize to a red instead of turning white or colorless.] Then we go over an area having no sediment ponds at all.
17:46			S	Photos (roll 1, frames 6 & 7): thick yellow-orange sediment with broken blocks of basalt. The surface navigation says we're east of the target, so we'll drive west. But we think that we're in the central depression. We go over a small ridge and down 1-2 m. There is a steep drop-off to the east, with a sharp rim. I see lots of fresh glass and broken folds, but not much loose rubble. The floor is rough with many glassy ropes. There is a gentle slope down to my right. The floor at the base of the slope looks smoother, but it's only faintly visible. We seem to be on a ridge with steep drop-offs to both east and west; we'll go down the eastern side.
17:48			P	Photo (roll 1, frames 3 & 4): large spider crab in rubble of broken (lobate?) plates. We're still above broken rubble, in another area with little patches of hackly material beneath a discontinuous cover of broken plates.

TIME	D	A	O	OBSERVATIONS
17:48:00	2229	2	E	Sediment-free rubble here has many specular reflections from unaltered glass. The surface has low relief (less than 20 cm?) and seems to consist mostly of broken folds.
17:49:04			P	Now we'll swerve back east toward the east wall of this depression. There may also be a separate depression to the west, and when we slalom back to this side next time we may try going into it too. There may be two or more parallel trenches in the floor here, with a ridge between.
17:49:51			P	We're still flying over broken rubble, and patches of hackly material. There are a few small and scattered patches of golden-yellow material, but most of the sediment is a pale greenish yellow.
17:50:45			S	We're in a hole a couple m deep with a broken, rough floor consisting of small blocks a few in wide, and a thicker sediment cover. Sediment dusting is nearly 100%; sediment fills low places. The sediment has a brownish cast. Many angular fragments of basalt have a reddish-brown staining along cracks. I now have a close-up view of orange sediment; it has a light texture. There is less sediment now. We're over a rubbly talus slope now with blocks 1-2 ft wide; some are as wide as 1 m. A smooth surface seems to lie beneath the rubble, but rubble covers nearly 100%.
17:51:03			P	We're flying over a depression that must be fairly narrow because its walls are visible on both sides. The hackly surface is extensive here; it resembles a pavement of pebbles welded together. Blocks and fist-sized rubble are scattered over it. There are also a few larger boulder-sized blocks; one here is about 1 m wide and 2 m long.
17:51:36	2235	1	E	A few blocks of denser material have appeared.
17:51:49	2234	1	E	Now the blocks are numerous, littering the surface. They tend to be equant prisms. This looks almost like a talus; but it seems to have a solid or continuous substrate. And a few globular forms seem to rise around some blocks.
17:52:03	2234	1	E	Two angular blocks seem to be embedded in lava; did they fall from an overhanging wall while the flow was still subsiding? The transcript says we're very close to a wall here, within a narrow depression having both walls visible at the same time. Material probably fell from the walls onto the dregs of the flow as it subsided. Some angular blocks never subsided entirely into the lava, while earlier ones on the underlying floor were coated by lava to form rounded masses. If so, the lava must form only a very thin veneer here on the floor of the cleft.
17:52:30	2235	1	E	Now a boulder-sized mass appears, having relief of 1 m or more; both rounded and angular blocks litter it.

TIME	D	A	O	OBSERVATIONS
17:52:53	2233	1	P	We've come up against a wall to the east and will swing back to the west again. Seafloor depth is 2234 m.
17:53	2234		S	We're in the depression; we can see both sides of it on the CTFM. We're in the middle of the depression and following it to the north of a course of 015° to 020°.
17:53:10	2233	2	E	Platy debris here looks like broken folds; equant blocks are not visible. But then the next frame (17:53:24) shows more blocks, most of them apparently having rounded edges. Following frames show more broken folds and pebbly textures. Evidently the different surface types here are mixed over distances of just a few to several meters.
17:53:45			P	CTFM photos (roll 5, frames 9A & 10A, image truncated because camera was disturbed): the two walls of the cleft running parallel or subparallel to our course, which is generally 015° to 020°. We're still moving at low altitude over rubbly material, which right now is a mixture of fine pebbles and coarser boulder-sized pieces, with a few scattered patches of the hackly/pebbly/pimply substrate. A few lemon drops are scattered around, and also some fecal tracks, and some little, translucent, wormlike organisms. As we get close to the surface we can see brittle stars, especially on the hackly material where it has a little sediment veneer.
17:54:18	2238	1	E	This frame is dominated by angular pieces of rubble a few to several cm across. They look like plates a few cm thick, broken into tabular pieces.
17:54:30			S	The depression is floored by folded sheetflows and some broken folds, but no large rubble blocks. The surface is glassy. There is some rubble consisting of small blocks. The surface has low relief, a few cm locally, but it's not as smooth as the sheetflows outside the depression. Small angular pieces, possibly loose, form an angular mosaic. Sediment has collected between the fragments. It looks like what we called a "brecciated surface" or "glass-shard mosaic" in the earlier bottom photos. The seafloor now has a platy appearance. I see a rattail (?) fish and a large black fish.
17:54:31	2235	0	E	Now larger pieces of angular rubble appear, many of them having wrinkles and folds, then more fine rubble.
17:56:30			S	A steep wall is on my right; a band of light-colored staining (?) crosses it. There is a rubble pile at its base and large pieces of broken flows on its face. My view is mostly down toward a talus pile at the base of the wall. The pilot reports "bathtub rings" on the face of the wall. I now see the bathtub rings; they're lighter-colored than their background.

TIME	D	A	O	OBSERVATIONS
17:56:46	2234	1	E	Fine rubble consists of tabular pieces, one of them having small rope-like folds. Yellowish sediment and a few lemon drop occur in the interstices between fragments.
17:57:00	2233	0	E	Canary-yellow sediment is suddenly more abundant (15-20% of surface) in protected places between pieces of rubble.
17:57:13	2233	2	E	The yellow sediment is now sparse again (less than 5%) among a dense litter of small blocks.
17:57:20			P	We're coming into another area of golden sediment. So far there are just small, discontinuous patches, with lemon drops mixed intimately with them, almost floating and ready to lift off at the least disturbance.
17:57:27	2231	1	E	A deeper depression appears ahead, slightly to the right. A sharp rim is not visible; the slope may merely steepen.
17:57:40	2232	1	E	Now a sharp rim does appear partway down the slope ahead. It looks like a narrow shelf, maybe 1 m wide; it could be a lava-subsidence shelf. The foreground slope above it is rubbly.
17:57:48			P	Now we're past the golden patches; they're not extensive.
17:57:58			P	We're coming over a small rim into a sharper, deeper depression. It looks like a pit with an overhanging projection, like a natural bridge. From the ANGUS photos I didn't get an accurate idea of the relief in here.
17:58:07	2231	2	E	Apparently shown now is a fairly featureless flat floor at the base of the scarp. A pimply material seems to coat an underlying surface having cobble-sized undulations--a coated-cobblestone instead of coated-pebble pavement. Then more platy rubble occurs in following frames.
17:59:42	2229	2	E	Here is angular rubble of broken folds; a clump in the foreground may be a rude lava coil 1/2 to 1 m wide.
17:59:47			P	We're moving over rough lava dominated by broken folds. "Clinkers" range from the size of large cobbles to small boulders and are typically 10-20 cm wide.
17:59:56 18:00:09	2228 2230	0 1	E	Patches of canary-yellow sediment are concentrated in an area 1-2 m wide, surrounded by an aureole a few m wide.
18:00:00 and 18:00:05			P	More patches of golden-yellow sediment occur below us at these times. More sediment ponds occur nearby.
18:00:30			S	We're moving 1-2 m above very broken folds. The bottom here is rugged, with 1-2 m of relief. The floor consists of ropy folds, which mostly appear to be in place, but some cobble- to boulder-sized blocks are loose. The surface is glassy, with a light dusting of gray sediment filling a few low areas. I occasionally see thicker

TIME	D	A	O	OBSERVATIONS
	2230			patches of brownish sediment. Our heading is generally NE in a depression 30 m wide. The basalt surface has swirls and striations in many directions. The material is not as broken here as at the edge of the scarp we saw earlier. Flow tops are rugged. Loose blocks range from fist-size to 1-2 m wide. They do not have sharp, angular corners, but a rough, hackly surface. They lie on a smoother, mottled surface that looks similar to some bottom photos. [See the 17:54:30 comment.] I see a pale-colored fish.
18:01:21			P	We're still flying across broken folds and a fairly chaotic surface. In some places it looks like a surface of fairly broad open folds was broken; in other places it looks like the surface consisted of massive clots that were broken apart, more like aa clinkers.
18:01:30	2230	1	E	A few bent, broken folds appear among pieces of rubble, most of them apparently having rounded corners.
18:01:56			P	Rubble of the massive-clinker type is below us now. Though some clots are fairly smooth, they appear to be derived from the hackly substrate instead of lobes or toes. [How could this substrate be incorporated into the mobile part of the flow? Were the clots perhaps <u>not</u> remobilized but pulled apart <u>in situ</u> so as to merely resemble pieces transported from afar?] The clots are littered with pebble-sized angular fragments. Sediment veneer is about 30-50%, and many fecal tracks and pellets occur among the fragments. The broken folds are much more glassy and have much less sediment; sediment ponds cover only about 10%, except where thick golden sediment occurs.
18:02:24	2229	1	E	Now we see the distinct edge of a rubble or talus on a surface that looks like lava-coated rubble. The larger loose pieces are blocky, with planar or curviplanar faces.
18:02:38	2230	1	E	Now we see coarser blocks that may be either unconnected or coated thinly by lava to form an agglomerate.
18:02:51	2231		E	Again we see finer rubble with rounded clot-like forms.
18:03:05	2230	1	E	Bigger clots occur again, with coarser masses overlying a generally flat pimply-textured surface. Overall in this area there seem to be distinctly different though locally homogeneous clusters of rubble whose clasts change in character every few m. It is possible that younger lobate sheetflows or pillows have spread discontinuously across the dregs of the subsided flow. But there is no obvious change in sediment cover, which is light everywhere.
18:03:18	2229	1	E	Large globular masses could be pillow fragments or intact pillows, but they seem to lack striations and ridges.
18:03:34			P	We're crossing broken pillows, or pillow chains extruded across a rough flow, at first, and then across extensive

TIME	D	A	O	OBSERVATIONS
				hackly surfaces. [Later note: In future dives I should systematically photograph some of these surface types, especially the hackly surfaces that don't show up on ANGUS photos.] We're passing over a large spider crab.
18:03:59	2232	1	E	Peculiar ridged, blocky masses appear to project from a shelly rubble of broken folds.
18:04:13			S	There's a rim to the right, at the edge of my view. It's a sharp rim, but I can't see it well. Directly below are rugged, broken, folded sheetflows. The seafloor drops off steeply to the right, and also to the left ahead, according to the pilot. But there is a wall less than 20 m to the right, according to the CTFM sonar. We seem to be above a raised area near the center of the depression. We're passing over a cluster of tube worms and a thick patch of sediment. I see worms directly below, on the rim of a steep drop-off. The pilot also reports tube worms. The sediment is loose and fluffy; we stir it up easily. There is a steep slope below my side.
18:04:16			P	I see more patches of broken folds.
18:05:33		2	E	A fish is prominent in front of some nearly invisible worms. To the right are gravelly pavements of white and yellow lemon drops between cobble-sized lava clots.
18:05:40			P	The pilot exclaims over more tube worms.
18:05:47	2231	1	E	A broken clot of draped folds projects about 1 m above the surface. It is thinly veneered by finely granular yellow material, and clumps of lemon drops occur in the interstices. Tube worms are abundant; some are alone, but most are in tangled clumps beyond the foreground lava clot.
18:05:59			P	I see many tube worms and sediment patches, and a large depression ahead of us. Much sediment is spread over the surface; much of it is dark, almost black. A few dead clam shells occur. Rocks seem to be coated with something.
18:06			S	Photo (roll 1, frame 8): ratty-looking (dead?) tube worms and sediment. I get a quick glimpse of "iron filing" projections [that form the dark velvety coatings seen earlier in deep-towed photographs].
18:06:00	2232	0	E	Sharply-focussed tube worms occur in clumps against a background of yellow sediment on the sharp rim of a scarp that drops off steeply ahead and to the right. Then the seafloor goes out of view for a few frames.
18:06:54			P	We're emerging from the vent area, and setting down on more of the rough, rubbly, glassy surface [Pilot: Shall we follow this on to the north?]

TIME	D	A	O	OBSERVATIONS
18:06:56			S	We've passed beyond the thick sediment and tube worms. We will try to get a fix from the surface.
18:07:08	2238	1	E	The slope goes down steeply to the right and ahead, with stubby ledges protruding along it. The pimply surface is well shown in the left foreground, with a fish for scale. On the steep slope beyond there is much coarser rubble, apparently coated thinly by pimply lava. Then we slow down and come to rest on this pimply-veneered rubble surface. A few scattered lemon drops are visible in subsequent frames.
18:08:15	2236	1	E	Many pimples here appear sharper when viewed close-up, almost giving a spiny-aa appearance to the surface.
18:08:20-18:10:57	2238	1	E	We strike the bottom and stir up a sediment cloud that dissipates into scattered suspended lemon drops.
18:09:20			P	CTFM photos (roll 5, frames 11A & 12A, heading 004o, image truncated because camera was disturbed): We're sitting on the bottom, headed nearly due north. Our range to the beacon is 1600 m, which puts us at the southern end of our first hydrothermal target of Vent 3.
18:10			S	We have no fix yet from the surface, but our range to the beacon is 1600 m. We are just north of the tube worms.
18:12:43			P	The vents right here look fairly dead or inactive, so we'll lift up and move a little. We won't sample here or wait for a fix; we should soon find something much better. We're still flying over pretty rugged, rough lava. Some of it is broken folds; some of it includes other kinds of pieces. Lots of lemon drops are here. There are many lemon drops and much golden sediment; but it does not form ponds, just a veneer over 30-40% of the surface.
18:12:50			S	We're continuing north along the depression and passing over rubble that is mostly fist- or cobble-sized with some boulder-sized pieces. There is a light cover of typical grayish sediment. I see a large black fish (about 2 m long?). There are loose, flocculent globs. Is this globular yellow material what Robin calls "lemon drops"? The globs are loose and float up as we drive past; some are up to 4-5 in across. We're getting into fluffy yellow sediment. I see dead clams. We've settled down in heavy yellow sediment. Our motion stirs up big sediment clots.
18:13:13	2241	1	E	A flat-surfaced pond, 1-2 m long, is composed of white and yellow gravel-sized lemon drops.
18:13:40	2243	1	E	Here is a good view of lemon drops and gravelly ponds in a mosaic of blocky rubble and pimply veneer.

TIME	D	A	O	OBSERVATIONS
18:13:53	2240	0	E	This photo is similar to the previous frame, but some clots of broken folds also occur in the rubble.
18:14:07	2242	1	E	Here is a nice view of lemon drops in a gravelly pond.
18:14:12			P	The pilot says that there are many dead clam shells straight ahead, but I don't see them yet.
18:15:01	2239	2	E	A black fish is above yellow sediment at the lower left.
18:15:14			E	This is a good view of a gravelly sediment pond having an irregular, patchy segration of lemon drops by sizes.
18:15:18			P	We're getting into good zone B sediment ponds again, fairly continuous. I see rattail fish, many lemon drops, and to port an extensive field of golden sediment. [Pilot: It's all over the place here!] A white puffy material occurs also, commonly showing through the golden sediment as if it's a substrate. A big ray is swimming just beneath us. Now I see shimmering water! It's all over, though we cannot yet see a specific vent; it may be coming up pervasively instead of from a restricted vent.
18:15:40			S	I see mostly small cobbles of basalt here, and some larger pieces of broken folds. There is thick yellow sediment. White "cotton ball" material coats yellow sediment; is it some type of bacteria? Robin sees shimmering water. Photo (roll 1, frames 9, 10): yellow sediment with white "cotton ball" material.
18:15:41	2241	1	E	A thick blanket of yellow sediment is draped over mounds about 1 m high, so that only the jagged tips of the mounds protrude. Greenish-white material is visible along the contact with bare rock, as if it is a substrate for the yellow sediment. A ray is partly hidden in the background.
18:16			S	We've settled down here. Photo (roll 1, frame 11): yellow sediment and white material coating rocks. The cottony white material has a woven appearance. "Iron filing" projections, 1-3 cm long, composed of yellow sediment or white material, form small projections on pieces of basalt. Photo (roll 1, frame 12): "iron filings".
18:16:22	2243	2	E	Whitish clots show through the yellow sediment; together they form a coat up to several cm thick on the rocks.
18:16:43			P	We're in a hollow, with almost continuous golden sediment around us and tube worms to the left. Right here below some rocks are a few little tube worms, apparently dead. A boxwork-like incrustation could consist of sulfides.

TIME	D	A	O	OBSERVATIONS
18:17:29	2244	1	E	A few tube worms are seen, recumbent on thick yellow sediment, as we move ahead slowly.
18:17:56	2240	1	E	We are beginning to kick up sediment.
18:18:42			P	We're inching ahead slowly, but we can't see the bottom because of sediment clouds enveloping us.
18:19:04	2241	1	E	Here is a good view of thick sediment and sparse worms on a slope, with a black rattail fish for scale.
18:19:07			S	I see fish, small shrimp (?), and small dead (?) tube worms about 6-18 in long with narrow bodies (diameter less than about 1/2 in). We're still in an area of thick yellow sediment with cobbles and small basalt boulders. The basalt is stained. We're moving slowly north. Photo (roll 1, frame 13): large crab. There is much loose basalt rubble having "iron filing" projections. Blocks are a few in to 1 ft wide, and have dull surfaces. There is red brown sediment and red brown staining on some basalt. Photo (roll 1, frame 14): basalt rubble and sediment. A large rattail fish swims past. Photo (roll 1, frame 15): rattail fish. There are some bare patches showing material colored pale blue to turquoise, but most areas are covered by orange sediment.
	2240			
18:19:44			P	We're moving ahead now, beyond the sediment. We've seen some recumbent worms, possibly dead. There is much puffy white material among much granular, coarse-sand-sized material. The lava is still of the rough variety, generally consisting of broken clots. Surfaces are not glassy and commonly seem to have a greenish incrustation. The basic flow morphology seems to remain unchanged; it's just covered deeply by sediment here. [Pilot: There is shimmering water right below us . . very good view of some very low mounds right in front of us. Oh, it's coming out all over this darn mound!] I see a peculiar light-green incrustation, almost like some kind of chalcedony, and now I can see lots of water coming out through this stuff.
18:20:38	.	1	E	After several frames of sharp-edged rubble protruding through the sediment, we now see larger rounded cobbles that may be plastered by lava and/or younger sulfides, with a discontinuous mat of gold and white sediment over all. Fish can be seen in almost every frame; there is more than one individual because one frame shows two fish.
18:21:05	2242	1	E	This is a good view of a steep slope up to the right ahead, with a variety of colors: yellow granular sediment with white puffballs showing through, and then a jade-like green material, and some turquoise rinds on rocks that may be shelly dregs of a lava flow draping a scarp.
18:21:32	2237	0	E	This frame is a good close-up of mixed yellow and white mats, with the white fraction overexposed.

TIME	D	A	O	OBSERVATIONS
18:21:46-18:22:13		1	E	We kick up some sediment.
18:22			S	Photos (roll 1, frames 16-18): white and yellow coating and underlying light blue material; the third frame is zoomed in. A large black fish is in view.
18:22:26			E	A clump of miniature chimneys or spires appears in the foreground, and isolated spires occur farther ahead.
18:22:32			P	We're setting down in shimmering water and thick orange sediment. [Pilot: I'll put out a marker.] We see some chimneys and a lot of bluish-gray incrustation. I see a rattail fish, but few other signs of life. This bluish incrustation is beautiful, like azurite or turquoise. [Pilot: I'm getting heavy right now, and will settle down here.] It would be nice to sample one of those chimneys.
18:23:07-18:23:48			E	These frames show fairy castles coated with sediment, then some fresh bluish-black chimneys in the right foreground. Chimney surfaces appear spiny, but details are not resolved. These frames may have good stereoscopy.
18:23:30			S	We'll sample and deploy a benchmark. We're still in an area of heavy yellow sediment. The pilot reports dead chimneys out the front port. Dead chimneys have white streaks (anhydrite?) and an unidentified blue material. The outside temperature is up 0.1°. I see shimmering water and lots of fluffy white material coating yellow sediment; it doesn't stir up like the yellow sediment does.
18:24:55-18:30:06	2238	1	E	We stir up sediment as we try to land. Then there is a black frame as we turn off the camera.
18:28:30			S	We're settling down to sample at a dead chimney area.
18:30:45			S	We're sitting on the seafloor at the vent, waiting for the stirred-up sediment to settle. The temperature is up 0.2°, from 1.7° to 1.9°C.
18:32:25			S	We're still waiting for the sediment to settle. We've risen off the bottom a little. To the right is a large mound nearly covered by yellow-orange sediment and white "cotton ball" material. Is the yellow-orange part a weathered sulfide? We've risen a few m and are turning to approach the sampling target from another direction. Only a few boulders protrude from sediment. Irregular white ledges protrude from sediment about 2 m above the bottom. The bottom drops off steeply to my right, and ledges protrude from the steep slope. Is this vent area located on a mound or ridge in the center of the depression? There is a lot of shimmering water, with diffuse flow; the temperature is up about 0.5°. [Pilot: Shimmering water is leaking out of the entire face.]

TIME	D	A	O	OBSERVATIONS
18:34:06	2234		P	We're a few m above the ground, flying back from whence we came. I see the thick sediment below us, partly mantling a rough surface. The rubble now consists mostly of equant blocks instead of broken folds. A chimney lies to port now as we rotate. I want to get more pictures anyway.
18:36:40	2240	2	E	The camera is on again, and is recording many small sediment-covered spires protruding through sediment.
18:36:53-18:40:15	2240	1	E	We are kicking up sediment again.
18:38:34			P	We're sitting on the ground in the same general area, with chimneys in front of us. We'll deploy a marker and try to collect some of a chimney. We won't use the slurp gun now though, because there's so much sediment; the first sample for Gary Massoth is supposed to be free of sediment.
18:40:33			P	Marker 2 on the right-hand side of the tray is being set out; it's a circle with a 2 on it. A big ray is swimming around; it should be photographed by the external camera.
18:41			S	We've settled down on an area of shimmering water and diffuse flow, and will deploy the first benchmark. We've requested a navigation fix. The benchmark is circular, yellow on bottom, white on top, and marked with number 2. Shimmering warm water is coming out diffusely everywhere.
18:45 (approx.)			P	Photos (roll 1, frames 5-7): golden-yellow sediment near Circle 2, taken as the float was being deployed. Frames 5 & 6 are stereoscopic. They also show the white material that commonly occurs as a substrate where golden material is thick. The white material commonly appears fibrous and puffy, and it could be an older, bleached facies of the golden sediment. But some of the white material looks dense, and waxy or lustrous, like an amorphous silica.
18:46			S	Jim has deployed the benchmark. Photo (roll 1, frames 19 & 20): Pilot's view of Circle 2 benchmark in very thick, fluffy sediment. We've stirred up the sediment. There is much diffuse flow everywhere. The substrate, where you can see it, is dark--blackish in places. Its texture looks like sulfide, not basalt. But I see it clearly in few places, as it is almost entirely covered by fluffy yellow sediment and cottony white material. Shimmering water flows from many cracks. Small spires about 6 in tall protrude from yellow sediment. There is a slight current here. The pilot recommends approaching sites like this one from the north; it makes it easier for him. I see a gap in the yellow sediment. The substrate is dull-black and rough on a few-inch scale; it's probably sulfide, not a basaltic texture. It looks blue-black in places. Despite all of the shimmering water, there aren't any animals. [Later note: There are no large animals here, but Robin did describe and photograph small ones.]

TIME	D	A	O	OBSERVATIONS
18:47:16-18:48:19	2240		E 0	These frames are views of Circle 2 benchmark; the first one is the best. Then the camera is turned off.
18:48:28			P	Benchmark Circle 2 is deployed in front of a vent on a slope. Shimmering water is emitting from many other vents further up the slope. To port not much water is venting, and the sediment feathers out about 10 m away.
18:50:00			P	Photos (roll 1, frames 8-11): views of Circle 2 as we moved away from it to the sampling site. The marker is nearly buried by sediment that cascaded downslope onto it. Much of this sediment beneath the golden-yellow surface looks dark. This mound may be composed of sulfides beneath a surficial veneer of sediment. In these frames, note the little chimneys about 10 cm high, and the rugged, knobby protrusions from the steeper protrusions and buttresses; these look like some sort of non-basaltic solid rock beneath the fluffy sediment. Frames 9 & 10 should be stereoscopic. We're sitting on the bottom and preparing to collect some samples. Right now we're getting the slurp gun ready in case we want to use it.
18:53:20			S	Photos (roll 1, frames 21 & 22): When the cloud cleared enough to see, I took two pictures of yellow sediment and underlying rock. We'll try to sample the top of a dead chimney. We may have covered the benchmark with sediment; perhaps we should have sampled first and then set out the marker.
18:56			S	I see a hint of a dead chimney, but it's still mostly in a cloud of sediment. The chimney consists of dark material with a webbing of white material (anhydrite?). I can't see it any more. The sediment cloud is clearing now. The dead chimney is coated with yellow sediment about halfway up. It's black and has growth rings and white streaks on the outside. Yellow sediment forms finger-like projections on top of the chimney. A mound with dead chimneys stands high above the surrounding area. It looks like the yellow-orange mushroom shaped objects that we photographed at the Plume Site. [End side 1, tape 1.]
19:00:00			P	We're sitting on the bottom, waiting for the sediment cloud to clear before collecting a piece of the chimney.
19:00:50			S	[Begin side 2, tape 1.] We're sitting on the bottom, trying to sample a dead chimney. Orange material forms small stalagmites 6-12 in tall and a few in diameter. [Later note: The orange material may only coat the stalagmites]
19:04			S	Photos (roll 1, frames 23-26): Close-ups of "stalagmites" or orange sediment and dead chimney.
19:06:30			S	Photos (roll 1, frames 27-28): Dead chimney and yellow brown sediment at sample site 1R; we moved back a bit.

TIME	D	A	O	OBSERVATIONS
19:08:			P	Photos (roll 1, frames 12-14): 24 mm views of baby-blue to indigo-blue incrustations with brick-red spires protruding like miniature chimneys. Also present are recumbent forms that look like worms or worm tubes.
19:19:21			P	Photos (roll 1, frames 15-37): more views of deposits near Circle 2. Frames 15-17 are 24 mm general views. Frames 18-20 show tiny chimneys covered with golden material; the tallest chimney has a hole in the top, and others may too. Frame 21 is a 105 mm view centered on a little spire. Frames 22-23 are 105 mm views of golden-yellow coatings mixed with white puffballs. Jim started a black smoker when he broke a piece from the chimney. I'm looking at the surficial mat close-up, and I see more of those little chitons, also some things that look like tiny reddish-brown spiders, or possibly brittle stars with knobby skins or coated with crud. No, I think they're spiders; I can see them walking, so they must be alive and naturally robust and reddish-brown. There is a fauna here, but the creatures are small. As I peer around carefully at the mat and rocks close before me, I see many funny-looking little palm worms waving their arms. They are reddish-purple, less than 1 cm wide, and have several (8-10) fat arms, like those of a crinoid, but thicker. Photos (roll 1, frames 24-37): Frames 24-34 are 105 mm close-ups of tiny chimneys and spines protruding a few cm from a bluish-black incrustation; many spiders, chitons, palm worms, and pink worms are too small to be resolved among the blurs. The 24 mm views of frames 35-36 encompass most of the close-up frames, the top of 35 overlapping the bottom of 36; note the sharp contrast between reddish and bluish-black patches in frame 36. Frame 37 is a 105 mm view of a tiny chiton (the blurry tan bean-shaped object) crawling among small red palm worms.
19:20:20	2238	0	E	This single frame is a good view of the sharp boundary between bluish rock and yellow mats; it shows several thin spires capped by pale-gold or whitish puffballs.
19:20:30			S	We've taken our first rock sample (1R) from beside a dead chimney, in an area of shimmering water. Jim said it started a small black smoker when it came away. Photos (roll 1, frames 29-35): views by pilot through the front porthole, of sample 1R and its provenance; and the resulting smoker. Frame 30 is a good view of sample 1R in the manipulator; frames 33-35 show the chimney that 1R came from, and the resulting smoker, and the tiny chimneys next to it Sample 1R is in basket K.
19:25			S	We started small smokers. We'll measure temperature and maybe take a water sample. Jim sees another smoker starting on the mound in front of us.

TIME	D	A	O	OBSERVATIONS
19:32			S	We're trying to measure temperature, but it looks like we won't succeed with the high-temperature probe. We've seen a slight indication, but the maximum so far is about 1.02o, if the scale reads out with 3 places to the right of the decimal. The maximum is about 1.1o [Later: Back on board we learned that the high temperature probe reads with only 1 place to the right of the decimal; so the water was at least 110o. I think it was up to 140o, but we have no record as the data logger didn't work.]
19:34			S	Photo (roll 1, frame 36): view through the front port, of the vent where we tried to measure temperature.
19:34			P	Photos (roll 2, frames 1-19): I've taken another series, first 105 mm views of some little stalks, like tees with golf balls on top of them, and then a 24 mm view of the bank behind, which has a lot of green incrustations on it. Frames 16-19 are general views of an overhanging bank or boulder face surfaced by a greenish material. Though much of it looks dark in photos, it was a lighter, translucent greenish white when viewed. Dark areas may be thinly veneered basalt, and lighter areas may be thicker deposits of this stuff. Parts of the surface appear to have a botryoidal texture. Golden material adheres to some parts. Note the "golf ball on tee" at the bottom, and the big lemon drop floating from left to right in frames 16-18. Frames 1, 7, 10, 14, and 15 are close-up views of the "golf ball" in the general view. It looks like a little chimney with small clots of the "sediment" forming knobs along its sides. The larger clot on top is a mixture of golden-yellow and white materials, like the lemon drops and the sediment blanketing this area. Is this the source of the lemon drops? Are they bacterial colonies and their precipitates? Note the botryoidal material on the wall. Frames 11-13 show more little "golf balls" and sediment. Frame 2 shows a hole in the sediment blanket, through which a bluish substrate is visible; the hole seems to be kept clear by warm, refractive water streaming through it, which accentuates the blur in the upper center of the frame (though all of the view is unsharp). Frames 3-6 show more creatures on the bluish-black substrate; on frames 3 & 5 a chiton crawls to the right of the spine in the center, frame 4 has several palm worms, and on frame 6 both the chiton and the palm worm can be seen. Frame 3 is slightly sharper than frame 6.
19:49			P	We're still sampling at Circle 2. I've replaced the cartridge in the VCR and finished my second roll of film. Photos (roll 2, frames 21-37): Frames 20-22 show the first golf ball recorded earlier, and 23-25 show others. Frames 26-28 show wormy stalactites on the "green wall".

TIME	D	A	O	OBSERVATIONS
				Frames 31-37 are more views of the bluish incrustation recorded earlier. The cobble-sized chunk in frames 31 & 33 occurs to left of center in frame 36 of roll 1. Frame 31 is fairly sharp, though dark because the lens was stopped down. Frame 35 is the best of this series.
19:52			P	I've made another close-up series (105 mm lens) of various little spines and fauna growing on the dark, bluish-black rock. This material is literally crawling with little creatures, including spiders and the little purple palm worms whose many arms wave around in the current. There are also other little worms that I cannot identify. Photos (roll 3, frames 0-22): More views of the bluish incrustations at Circle 2. Frames 0-9 are 105 mm views; frames 5 & 6 are acceptably sharp views of the block. Frames 10-13 are general 24 mm views. Frames 14-22 are blurry 105 mm close-ups of small spines and palm worms.
19:54:11	2242	1	E	Here is another good view of vent materials, with a big-eyed fish, and a part of the manipulator arm for scale.
19:58:37	2238	0	E	This rather dark single frame shows puffs of wispy black smoke wafting obliquely from the broken stump of a blue-black chimney whose top was removed in sampling.
19:58:33			P	We're lifting off the bottom and will head west or NW to see if we intersect the axial cleft. The navigators place us in the outer collapsed area about 40 m east of the cleft. If so, we should descend into the cleft by driving NW. When we find it, or become sure that we've already been in it, we'll go NNE again. I've started the external camera again at a 14-second repetition rate; I took a few pictures with it manually while we were at Circle 2.
19:58:51	2237	4	E	The camera is on again as we rise off the seafloor.
19:59:31	2237	0	E	Protruding through the sediment are blocks that have peculiar striping in raised relief, like the relief produced by differential weathering of a layered rock. But here the striping may be a product of accretion by sulfide minerals or small organisms on lava-subsidence selvages. The selvages could be in place, or occur on blocks that tumbled down from the high rim of the cleft.
20:01			S	I've begun my film roll #2. We're leaving the first sampling site. We'll head NW to see if we're east of the axial clef, as our fix position indicates, or if we're already within the cleft. Then we'll turn and head north along the cleft. As we leave the sampling site we see more of the yellowish sediment, but it's getting thinner. We're over rubbly, broken basalt. There is still a lot of the white, fluffy material on top of the yellow sediment.

TIME	D	A	O	OBSERVATIONS
20:01:19	2225 ?	2	E	From here on a prominent elongate shadow appears in the lower left of all frames; it is probably the shadow of the manipulator arm, positioned in front of the light.
20:02:00	2232	2	E	This frame is a smashing view of a male ray swimming away over bluish-black incrustations and mounds.
20:02:13	2232	0	E	Herr is another smashing view of the ray, banking around a fat chimney having bulbous protrusions (some fresh, some weathered) and clumps of tube worms hanging down from some of the fresh, blue-black protrusions.
20:02:27	2229		E	The ray tail is visible to the right of the chimney, which has accumulated mats on a cluster of at least 4 distinct knobs. The next frame is a blurry view of the critter alone, and we lift out of view.
20:02:30			P	We're turning above a scarp that goes down to the left and has clumps of worms like bunch grass and some old chimneys coated with a lot of golden sediment.
20:03			S	We're driving WNW. We just left a thick sediment cloud and now I see the bottom clearly. We're over broken, folded basalt with angular edges. This area has rough topography, mostly rubble with a couple of m of relief.
	2225			Sediment cover is thin, just a light dusting over about 10% of the surface. We're still rising along a scarp. To my right I see broken edges, bathtub rings, large projection, and a possible pillar.
	2220			We've reached the top of the scarp and are driving over the rim onto an area of rough, broken folds. I see an arch to my right below. We go over the rim, then the seafloor drops again steeply; there are lobate forms on top, then a steep drop. I see many collapse features, bathtub rings, and pillars a couple of m tall. Lobate forms here look like thin shells, 1-2 in thick, hollow underneath, and quite glassy. I see several arches. Photos (roll 2, frames 0-2): lobate flows with small collapse pits. The floors of small pits are covered by rubble broken from the roofs of the bubbles. It looks like the type of area we put the rock drill on. I see ledges, a large collapse ledge, hollow underneath and several m wide. I can see bathtub rings underneath the ledge. The small pits are 1-2 m deep; the skin is 1-6 in thick. Lobes occasionally have a swirly appearance.
20:03:40			P	We're climbing up a very smooth slope with hundreds (overestimate?) of little lava-subsidence shelves or selvages. The subsided crust here is draped onto the slope and broken to form a sort of platy rubble.

TIME	D	A	O	OBSERVATIONS
20:03:48	2228	3	E	The seafloor now is mostly blocky/platy rubble, with sizes ranging mostly from fists to small boulders. Some small rounded forms may be lobes in place; some others may be older rubble coated with a pimply rind. Scattered lemon drops occur, and pale sediment coats small dimples comprising less than 10% of surface.
20:04:15	2228	3	E	We're at the base of the steep west wall. A few broken edges of lava-subsidence selvages may be present, but they are not obvious so far in these photos. Two big whitish blobs look to Robin like out-of-focus lemon drops; but to Janet they look like a garbage bag.
20:04:28	2226	4	E	This frame seems to show 3-4 lava-subsidence selvages on a nearly vertical wall, slightly inclined to the frame. but they are subtle because of flat lighting. Small but well-defined vertical striations occur also, like slickensides on pasty subaerial lava, as at Puu Puai where layers of agglutinated tephra slump on steep slopes.
20:04:36			P	We're rising up a very steep scarp, almost vertical, and it has many lava-subsidence selvages.
20:04:42	2224	5	E	More selvages are faintly visible in the lower half of this frame. Above them is platy, tabular rubble that may occur on a convex slope near the rim of the scarp.
20:04:53			P	Now we're at the top of the scarp, and we go right into complicated alcoves and other collapse features having many little selvages. Oh, we've gone up over one shelf, and it looks like there's more higher ground ahead of us. Now we're definitely coming into lobate flows that are collapsed, with little caverns going back into them.
20:04:55	2220	7	E	A pillar rises in foreground, and others dimly in the background. We are evidently in an area of lava-flow subidence, but it's not clear if this area is the uppermost subsided flow; it could be a subsided younger flow down in a deeply subsided part of an older flow.
20:05:36	2221	3	E	Here is the lobate but cavernous surface of a subsided flow. Successive frames show small pits in it. Pale sediment veneers about 20% of the surface, and a few scattered small lemon drops occur.
20:05:50			P	We're beginning to cross pitted lobate flows. We've come about 75-80 m [less?]. We're continuing west, and quickly we pass beyond the pits onto robust lobate sheetflows. I do see scattered big pits though, off to port. [Pilot: Yeah, we're going over a pretty big one right now.]
20:06:03	2221	1	E	The lobate surface in this view has no sign of collapse.
20:06:43	2221		E	Pits do occur; they are apparently about 1-2 m deep.

TIME	D	A	O	OBSERVATIONS
20:06:55			P	We've crossed the rim of another large pit with a rubbly floor, 1-2 m deep or perhaps a little deeper. So we're still in a pitted terrane here, in lobate sheetflows, not rough or ponded surface types. We all agree that we've gone beyond the west rim of the axial cleft and that the navigation up on top erred in putting us east of the cleft.
20:07:51	2221	1	E	This frame is a good view of robust lobate sheetflows. An elongate chain of lobes sits atop a cracked, probably slightly heaved, broader lobe having more extensive sediment veneer (about 60% vs about 30%).
20:08			S	We believe that we're out of the cleft on the west side and that the navigation erred in showing us east of it. We think the first sampling site was within the cleft. We'll turn NE and drive back to the cleft. We're now over good lobate forms; there aren't as many signs of collapse right here. The basalt has glassy reflections and a light sediment dusting. Photo (frame 3): typical lobate forms and small collapse pits. We're now in an area that is much more broken; there are large blocks, lots of collapse and big pieces of roof rubble. We're still over lobate flows, but they have much more collapse. Big plates have broken and fallen in; it looks like there was heaving and folding. The material is fresh and glassy. Now I can see a rim directly below me, a steep drop-off which goes down a couple of m. I also see a large crab. A cliff goes down in two steps. It has dropped off below us several m, and I see another steep drop-off ahead. The floor is faintly visible and consists of striated sheet flows.
20:08:04	2217 ?	1	E	Lobate lava here has wrinkles, a higher sediment cover (60-70% veneer, 10% ponds), and a few lemon drops.
20:08:16			P	We'll turn around and go back. Right now we're in lobate sheetflows, with some signs of inflation. The big, broad lobes have a sediment veneer of about 40% on their gentler slopes, and there are pits, some little clusters of lemon drops, and a few little ponds of a brown or golden-brown sediment. There are many brittle stars. This lava is pretty shelly and still has a few scattered pits in it.
20:09:15			P	In fact, we're coming to a large, deep pit right now. Its floor is rubbly, with broken plates of lobate lava. Even though there is fairly extensive sediment cover (40-50% veneer), close-up you can see many specular reflections; the surface doesn't appear to be dulled much by hydration.
20:10:06	2225	1	E	Here's a sharp rim, probably of a lava-subsidence pit, or possibly the edge of the cleft. The subsidence fringing the cleft here seems narrow; this partially confirms the mapping done from previous camera runs, which suggested a broad subsided area east of the cleft but not west of it.

TIME	D	A	O	OBSERVATIONS
20:10:19	2221	1	E	The subsided floor is almost out of view. Bridge-like remnants of another shelly-lobate surface seem to occur beneath us, suggesting that a second subsided flow is within the subsided hollow of the main upper flow.
20:10:30			S	We've come to a rim. The floor, or first ledge down, is coming into view. It looks similar to the cleft floor at the previous site. Streaked sheetflows look smooth from high up, but as we drop down we see much relief on them, with large chunks a couple of m high. Most pieces are basically in place, but are folded and broken.
20:10:54			P	We've crossed into another large pit, and the floor of this one has much lobate lava with a billowy surface that is very irregular but not broken up very much. This must be a depression into (or through) which lava drained. Ahead to port are some large draped folds, possibly including some whorls.
20:11:27	2225	2	E	A generally flat surface appears to be composed of several overlapping broad lobes only a few cm thick--remarkably thin for submarine lobes. They are striated parallel to their elongations, with different directions on different lobes forming a sort of patchwork pattern.
20:11:44			P	We're crossing an extensive wrinkled surface. Then we go over the rim of another depression, and I see the rim of something even deeper ahead; we're getting back now into the axial cleft.
20:11:44			S	We're going over another larger drop-off; I can't see the floor. We've been coming down stepwise into the cleft and now are flying out into space and it's dropping abruptly beneath us. I can't see the bottom yet. We've come down a
	2225			few m from the rim. The floor is still out of view.
20:13	2230		S	We're over a steep slope; the depression is dropping off to our right. The slope beneath us is very rugged, and has lots of rubble. We pass a Tide detergent box!
20:13:05	2230		P	We seem to be back in the axial cleft. Surfaces are rugged and still going down in front of us. Oh, I see a box out there, somebody's Tide detergent box!
20:14:22			P	We're still crossing the floor of the cleft. It continues to go down ahead; it looks like a deeper part of the cleft.
20:14:30	2235		S	We're still going down, and now I begin to see the seafloor; it's beginning to look flat. We should be near the bottom of the depression; it's no longer sloping down.
20:15:03	2236	1	E	The surface seems to slope down to the right. It looks rubbly, a mixture of rubble and pimply-textured veneer.

TIME	D	A	O	OBSERVATIONS
20:15:07	2237		P	We're scraping the bottom. The lava is still rough, broken, and rubbly, with a hackly surface beneath the rubble. Small specular reflections occur; they don't show up readily except when you're close to the surface.
20:15:30	2237		S	We're scraping bottom on the port side but still up a m or so on the starboard side. We're in an area of finer-scale rubble. The bottom is fairly smooth, with rubble pieces fist-sized to a foot wide; some are angular, others are rounded. The surface has a mottled appearance (what I've called "flow breccia"?) and a light sediment dusting. I see lots of brittle stars and a large crab. There is an orange-red staining on broken pieces of basalt. We're at
	2239			the bottom of the depression. The terrain here is rugged, with larger blocks rising 1-2 m above loose smaller rubble. There is fresh glass on the surface, and some black coatings. There is a steep slope up to my right, with large blocks. The base of the slope shows some collapse and drainback. I see another crab. We seem to be
		2		in a narrow canyon now. We're over very rugged broken rubble. I see the beginnings of yellow sediment and small dead clams. I see many scattered clam shells. Yellow sediment forms a fairly light coating. We're bumping into a steep wall. The bottom drops down to my side.
20:15:43	2238	1	E	Pockets of yellowish sediment show up dimly far below.
20:15:46	2239		P	We're still going down. So far I've seen no signs of faults post-dating any lava. There is a definite depression running through here, but in all cases it looks like the lava has drained into it, and we see draped morphology and evidence of lava pulling away and subsiding. I see no sign of younger faults or fissures.
20:16:24	2242	1	E	The bottom here is rubbly and seems to have a relief of 1-2 m. But much of the coarser rubble is rounded and may be covered by a thin, pimply veneer. Many small lemon drops occur. Right here it looks like a crease in the seafloor extends, parallel to our axis (037°), between two convex slopes, almost as if lava drained into a narrow fissure and plugged it; but this may be an illusion. The left slope is rougher and more rubbly.
20:16:37	2238	1	E	Subangular pebbles and cobbles litter a pimply surface, with many small (1 cm) lemon drops. Our heading is 035°.
20:16:51- 20:17:04	2240	0	E	A large white crab is headed into a concave hollow paved by cobbly rubble, with interstices partly filled by yellow sand and lemon drops. The hollow may be a widening of the crease, with its bottom filled by rubble. The left side still looks more rubbly, like an aa front veneered by pimply veneer and younger rubble. Another slope may be ahead, facing us; if so, this may be a hummocky terrain instead of a linear trench. Our heading veers to 010° then 006°. The relief appears to be more than 2 m.

TIME	D	A	O	OBSERVATIONS
20:17:13			P	We're still flying across hackly, broken material on the floor of the cleft. When close to it, I see many brittle stars and some fecal tracks, but the surface has less than 10% sediment veneer in most places. We're crossing a low rim or ridge, and we start a little landslide as we bump it, going down into another depressions. Our depth right now is still (again?) 2239 m, and we're perhaps 1-2 m above the bottom of a local depression.
	2239	1		
20:17:18	2239	1	E	Here is a last view of an elongate (?) depression, with the slope to the left being more rugged and rubbly. Our heading is 007°. Then the hummocky rough terrain drops below us. An elongate depression may still be present but is not definitely definable.
20:17:58	2242	2	E	Except for the left-hand shadow, this frame is a very good view of a hackly surface that appears to be a rubble coated by a pimply veneer. Little younger rubble is visible here. Our heading is 357°.
20:18:25			P	We've just passed one of those long wedge-shaped worms with the big heads that leave long spiral fecal tracks, but this one looked pale, not violet in color.
20:18:45	2240		P	We're flying about 1/2 m above the bottom, which still has a rugged surface. There isn't much loose rubble here; it's a hackly surface. Then lots of boulder-sized chunks appear, littering the surface; it looks like many may be connected to each other. We're still at a depth of 2240 m, and another depression appears to go down ahead of us. Once again it doesn't appear to have a sharp edge like a fault; it's just an irregular, broad depression. Is this an optical effect that I've not allowed for enough, such that level slopes ahead look like they're going down?
20:20:00	2240	0	E	Except for the shadow, this photo is another good view of the rough, hummocky surface. A steep slope or small cliff to the left seems to lead into a narrow, symmetric depression more than 1 m deep. Our heading is 019°.
20:20:13	2241	2	E	Our heading has shifted to 011°, and the little scarp is facing away from us to the right. Above the scarp is a flatter area paved by veneered rubble. One globular mass on the rim looks like a pillow; it has small specular reflections. A fish and lemon drops are visible, but no heavy yellow sediment indicative of hydrothermal vents.
20:20:27	2244	1	E	Here is a unique view of a thin (10-20 cm) pad of lobate lava on pimply-veneered rubble, and above it a few stubby cylindrical lava toes apparently extruded from globular pillows. It looks like a small volume (less than 10 m^3) was extruded here, with the morphology grading to pillows as it waned. But it may not represent a true eruptive vent; it could be a small rootless flow. But why would it erupt here, through the thin dregs of the drained flow?

TIME	D	A	O	OBSERVATIONS
				Sediment cover is light (veneer about 20%, ponds less than 5%) on this smooth surface, and mostly colorless, though some small lemon drops occur. Our heading is 021o.
20:20:40	2241	0	E	At the right is a crab on another m-high mound of lava with bulbous toes; more pimply-veneered rubble is at the left. Our heading is 028o.
20:20:41	2241		P	We've crossed a single striated pillow about 1/2-1 m wide on this rubble. I don't know where it came from; it may have oozed up through the surface. We're going back over orange sediment now. Most of the surface is still a rubble of plates, folds, lobes, and other forms. We're rising up right now over extensive yellow sediment. [Pilot: Oh! Lots of broken shells over there!] I want to cross this deposit to determine its extent--but the pilot can already see beyond it. Now I see the broken clam shells, little ones, littering the surface, and many brittle stars too, even in the areas without much sediment.
20:20:54	2245	1	E	Here's the sharp edge of a thick sheet of golden-yellow sediment. This deposit is peculiar; it heavily coats low areas while small cobbles are completely clean, and it has a lineated, scoured appearance. There appear to be a few tube worms, recumbent and covered by sediment. More sediment is shown on the next two frames. It's only a small vent area, and maybe dead.
20:21:34	2238		E	These frames are nearly free of golden sediment, but many small white objects may be fragments of clam shells, with small brittle stars around them. A few seem to have the valves flared open but still together. They are small, smaller than the brittle stars. The vent may have died only recently because a crab is still crawling around it.
20:22:01	2240	2	E	The foreground surface consists of broken, draped folds, perhaps with a pimply veneer. Beyond it is the base of a mound consisting partly of platy rubble. A little gold sediment is present, and along the edges of plates are lttle yellow projections that resemble Jan's "iron filing" texture; but in this case they are yellow instead of black. The same material is shown on the next frame, and then the bottom goes out of view.
20:22:40			P	We've come over a little ridge that is draped on this side by a lot of sediment with a streamlined surface, as if currents swept over the ridge and eroded a previously more extensive deposit. The surface is mottled orange and black (or at least dark). There are not many clam shells anymore. The sediment is extensive now, with ponds a few to several cm thick covering about 60% of the surface. It looks barren of organisms from our height of about 1.5 m. A few broken clam shells are present. We pass an enormous crab to port, and many little dead (?) worms.

TIME	D	A	O	OBSERVATIONS
20:22:55			S	We're against a steep slope on the port side, and the bottom drops down on my side. We're into thicker patches of yellow sediment. I see small pieces of basalt rubble. There are white patches on the basalt, and brown staining on broken edges. The rocks are blue-black. This material is very rugged. Yellow sedment is thicker now, coating 70-80% of the area. We're on a sort of ridge; it drops to the right and looks somewhat like the last sampling site, a ridge near the center of the depression. I'm looking down a steep slope of broken, folded, rough basalt. We are now at about the limit of yellow sediment and now over folded sheetflows broken into blocks 1-3 ft wide. This ridge has a sharp rim. It drops off to our right several m down to a very rugged bottom, then rises again steeply.
20:23:22	2236	3	E	Yellow sediment ponds on a steep slope have a few small clam shells and at least one worm stalk.
20:23:36	2242	2	E	A fish is nosing around much yellow sediment at the base of a bulbous projection more than 1 m high and wide. It may be a fat sulfide chimney, but the view is dim.
20:24:03		2	E	Many recumbent worms are coated by sediment.
20:24:16-20:24:30	2238	3	E	Clean cobbles still project from golden-yellow sediment occupied by many brittle stars. Could the cobbles be uncoated and brittle stars be present at an active vent?
20:24:53			P	Many orange sediment ponds occur in rough rubble (large cobbles to boulders) dominated by broken folds. The ponds are restricted, and we soon pass beyond them.
			S	We've left the yellow sediment and are now over folded sheetflows, with some broken folds and less relief (1-2 ft). I see some lemon-drop clots and patches of gray sediment. Small slabs of basalt protrude a couple of ft. The bottom is more rugged now, still consisting of broken slabs but having greater relief.
20:25:51	2239	2	E	We've passed beyond the vent onto pimply-veneered rough lava, which is dim though a big white crab is visible.
20:26:00	2239		P	A depression falls off a couple of m below us. We're moving generally NE along a cleft, but slaloming back and forth from one side to another. We seem to find much of the sediment on the east side of the cleft and up its east wall. [Later note: This observation may be wrong. If the vents form mounds, the sediment would appear to become thinner away from each of the side ports. Robin may have inferred from his view that the sediment continued to thicken toward the starboard side. But we have no record of the reasoning behind this generalization. More accurate may be Jan's observation in some places of a mound in the center of the inner depression.] We're still not seeing the very steep wall with a sharp rim seen on

TIME	D	A	O	OBSERVATIONS
				ANGUS photos, but instead a pretty gentle slope into the cleft. [Later note: A narrow inner depression seems to occur on the floor of the main cleft, with sloping sides in some places and small cliffs in other places.] Now we're in another area of extensive sediment cover. The pilot recently saw a tube worm and a galathean crab . . [Pilot: I've got 3245 (?) m . . . having trouble now operating the slurp gun.] [This is the end of tape 1.]
20:27:39	2244		E	The veneered rubble is rugged over distances of several m, with scarps commonly having 1-2 m of relief.
20:28:53	2244		S	We're driving along the depression just above a floor of broken rubble. I see small dead clams. I see one large pillow (about 2 m wide) with breadcrust texture; otherwise the floor consists of broken sheetflows. I see worm tubes (dead?) 6-12 in long, a crab, garbage sacks(?), and broken clam shells. There are scattered thin patches of yellow sediment. We're over broken basalt rubble with reddish staining and manganese(?) coating.
20:29:27	2250	2	E	Another crab is visible.
20:31:55	2251	1	E	Scattered lemon drops occur, and little ponds of gravelly sediment consisting of canary-yellow to buff-colored pebbles that are probably lemon drops.
20:32	2247		S	The pilot sees galathean crabs and tube worms. To the right is broken basalt rubble and sparse patches of yellow sediment. Now I see many brittle stars and some small white tube worms. The worms are 6-10 in long, 1/4-1/3 in diameter, and look dead. We're over blocky basalt talus.
20:32:09	2254	2	E	Here are many recumbent worms that look something like the spaghetti in the Galapogos Rift except that the strands are thicker, shorter, and straighter.
20:32:22	2247	1	E	Many worms occur, and much gravelly sediment ranging in color from white to dark brownish-gray.
20:32:49		1	E	We pass rugged thick mounds, and the bottom drops away.
20:34:10	2247	3	E	Basalt rubble here is mostly coarse pebbles and small cobbles, mostly round to subround and maybe coated by pimply veneer. Many pebble-sized lemon drops occur.
20:35:55			S	We're still over mostly broken folds. We've passed a few pillows. I see a large black fish (rattail?).
	2248			We'll come up for a range to the Datasonics beacon.
20:36:12	2250	3	E	A flattish surface that is apparently coated by pimply veneer is broken by wide, shallow cracks that extend irregularly in several directions to form plates 5-10 cm thick that have pulled apart but still fit together like pieces of a jigsaw puzzle. This breakage seems to have

TIME	D	A	O	OBSERVATIONS
				arisen not from inflation but from subsidence of a flow surface onto underlying topography, much like the crust of fountain-fed lava in Hawaii that subsides onto tree-fern molds and is broken to form convex hillocks.
20:36:25		4	E	A sharp morphologic contact occurs between broken, smooth lava in the foreground and rubble in the background. The rubble appears to be younger.
20:38:31			P	[Beginning of tape 2.] We're on the floor of the cleft, awaiting a fix.
20:39:07	2252	2	E	A nearly featurless pimply surface is overlain by rubble. At least some blocks are not veneered; they have sharp edges, and some plates 5-10 cm thick have planar structure.
20:39:21	2243	0	E	A plate a few cm thick with planar structure projects vertically above rubble and pimply-coated material; the plate seems to lack a coating.
20:40			S	We're still coming up for a fix or range to the beacon.
20:40:15	2242	5	E	The seafloor fades; camera is turned off after 20:42:30.
20:45:43			P	We have a fix, and a range of about 2000 m to the beacon. Both place us near the north end of Vent 3, near the north end of the last large zone A target defined from ANGUS photos. A small zone A should occur about 50 m further north. We'll drop down here and take a water sample for Gary Massoth before we go on to take any other samples.
20:46			S	We're descending into the depression after getting a fix from the surface. Our range to the beacon is 2018 m, which puts us near the north end of Vent 3. We'll collect a water sample in the slurp gun for Massoth.
20:48:33			P	We're dropping onto a rubbly, rough floor having eqant broken plates underlain by the hackly veneer.
20:50	2243		S	We're beginning to take the water sample near the bottom in the Vent 3 region. We're using a 4-liter bucket, unfiltered. We're using bucket 4 and pump 12. The sample number is 3P4. We'll pump for about 5 minutes. We're directly below the last fix from the surface.
21:02			S	We've finished taking the water sample in the slurp gun after pumping 6 min. We'll now head north for another 50-100 m, which should bring us to the north edge of vent 3. We're looking for the northernmost discharge site of Vent 3, which should be near the east wall.
21:02:34			P	We're starting up again after slurping a sample for Gary Massoth. We'll go on up north to look for another little vent area about 50 m away along the east wall.

TIME	D	A	O	OBSERVATIONS
21:05			S	We're bumping into talus along the east wall of the depression. There are angular, broken blocks 0.5-2 ft wide, broken lobate forms, and broken platy sheetflows.
21:05:02			P	We're flying along the east wall. The lava has robust lobes and a few scattered pillows. We recently passed blocky accumulations that looked like talus. I've turned on the external camera again, with a repetition rate of 14 sec. Some striated pillows are below us now, among robust lobate forms. [Pilot: Orange sediment again, mixed in with . .] Sediment cover is variable; it appears to be more than 50% on central parts of lobes and falls away on steeper margins, so that the overall veneer is about 20%. We see a few little clots now of golden-yellow sediment, and little white puffballs and lemon drops. We're climbing up a wall to our left; it looks like a tilted block with many lava-subsidence selvages on it.
21:05:36	2248	1	E	Robust lobes are spread discontinuosly over coarse blocky rubble. Sediment veneer on broad lobes is 50-60% but the rougher surfaces have little sediment veneer. The sediment is mostly bright golden-yellow in one place but pale or dark in scattered sediment ponds.
21:06:03		1	E	Here is a good view of 20-30% sediment ponds among robust lobes, with the ponds fringed by bright yellow granular deposits of lemon-drop material.
21:06:24			S	The lava here generally consists of intact and broken lobate forms. We're beginning to see yellow sediment. We pass a few pillows, one with striations. There are some patches and streaks of yellow sediment. Photos (roll 2, frames 4-5): two pillows; I've seen few previously. We pass a fish about 1 ft long. Now I see more scattered patches of yellow sediment and larger angular basalt blocks. Robin sees pillows. There are white puff balls and clots in the yellow sediment. I see mostly angular pieces of broken basalt to the right, and thicker yellow sediment directly beneath us. Some basalt is covered with dark-colored "iron filing" projections.
21:06:56	2246	1	E	A few rude, globular pillows occur among the robust lobate forms, but they seem to lack striations.
21:07:23	2251	1	E	Sharped-edged rubble is to the left, lobes to the right, and gravelly sediment ponds between. A split pillow with concentric and radial structure may be in the foreground.
21:07:37	2246	0	E	Bright golden-yellow sediment ponds occur in blocky rubble.
21:07:39			P	There are some nice pillows here; some lack striations, apparently because their surfaces have spalled off. Are they older than much of the lava we have seen?

TIME	D	A	O	OBSERVATIONS
21:08:17	2247		E	Sediment is especially thick here, and some recumbent worms occur, but the next frames have little sediment.
21:08:22			P	I see little clumps of lemon drops, and ahead are ponds of golden sediment. I see a rattail fish, and then another; we may be near a vent. The lava here occurs mainly as lobate sheets, broken up a bit to form broken plates. We seem to be in a shallow depression. [Is this an illusion?]
21:08:44	2243	0	E	Robust lobes appear to the left, rubble to the right.
21:09			S	I see a rattail fish and large angular basalt blocks. There isn't much sediment--just scattered patches of yellow sediment and lemon drops. Basalt blocks are thick; they're not broken pieces of thin flows.
21:09:10	2243	1	E	Among the litter are large prismatic blocks of basalt having sharp edges and a lack of pimply veneer.
21:09:23	2240	1	E	Pimply-surfaced plates are broken but not disrupted.
21:09:36	2242	1	E	Here a few pieces of younger rubble seem to lie atop a pimply veneer on older rubble. An elongate rectangle may be a fragment of foundered crust veneered thinly by the dregs. Lemon drops are becoming more numerous.
21:10			S	Photos (roll 2, frames 6-7): small fish and black fish 1 m above rubble. Now we're above finer cobble-sized rubble. The base of a steep slope is to my right. I see small angular pieces of basalt with pebbly texture, and a few larger blocks about 1 ft wide. There is no
	2239			accumulation of larger pieces at the base of the slope.
21:10:03	2244	1	E	Small gravelly sedment ponds appear in the rubble.
21:10:30		0	E	Here is the last of the sediment ponds.
21:10:57	2240	1	E	Lemon drops again are few.
21:11			P	We're still flying over a coarse rubble of equant large cobbles and small boulders. Their origin is uncertain, though across this narrow depression are some tilted plates apparently derived from lobate sheetflows and
	2238			perhaps sheetflows of other kinds.
21:12			S	I occasionally see larger rubble pieces up to 2 m wide. Smaller pieces with striated surfaces seem to be thicker than those in collapse pits outside the cleft; these are more equant. We'll set a benchmark on the rim of the cleft and then go south to sample the yellow sediment.
21:12:29			P	I still see small rattail fish occasionally. There is some rubble; some pieces are platy, but most are equant, of various kinds. [Pilot: OK, we've come about 100 m.]

TIME	D	A	O	OBSERVATIONS
21:13:52			S	We're about 100 m north of the last fix and should be at north end of Vent 3. We're rising to set out a benchmark on the rim at the north end of our traverse; then we'll return to a vent to slurp yellow sediment.
21:14:05		4	E	After being out of view for a few frames, the seafloor now is a flat surface of lineated sheetflows.
21:14:18	2236	3	E	Lineations are oblique to our heading of 311°.
21:14:43	2235	2	E	The lineated surface is broken into thin plates, and some of these have been detached and rotated so that their lineations trend in various directions.
21:15	2231		S	We're going up. I see nicely striated flat sheetflows, with fractures perpendicular to the striations. Large slabs having continuous lineations are slightly broken and offset. We're coming up. This looks like the sheetflows we saw earlier at the edge of the depression from greater altitude, but we have a closer look this time.
21:15:00			P	We're rising out of the cleft on the east [west] side and now see broad plates of a lineated flat surface. The lineations seem to parallel the trend of the valley; at least they still parallel the contour. The surface is broken into large plates that have been dropped and draped onto an underlying topography. Rising through the plates are blocks with subsidence selvages. This seems to have been a subsiding lava lake or stream, with its upper crust draped onto the underlying surface. We're about 2100 m NNE of the beacon; we'll go up to the rim, set out our "Circle 3" marker, and then return to one of the bigger vent areas for more samples. [Later note: There was confusion about navigation. We had thought we were on the west side of the cleft but were told by the navigators that we were on the east side. Later correction of the navigaion data showed that we really were on the west side. During the dive we felt disoriented and uncertain about how to interpret what we saw here.]
21:15:10	2235	0	E	Lineations in this close-up view are oblique to each other.
21:15:24	2236	4	E	A gaping crack seems to break a lineated-sheetflow crust 5-10 cm thick. Thin shells beneath resemble shelly pahoehoe; could they be foundered crusts?
21:16:30	2220		S	We're further up the side of the cleft and have left the striated flows behind us. I see a steep slope ahead with bathtub rings, and some loose rubble on it. We're nearing the top now. I see tops of thin shelly lobes. They don't seem to be draped over the rim here. I'm looking down now over the east [west] rim. I see some collapse but mostly just lobate forms extending to the rim. We'll try to get another fix from the surface.

TIME	D	A	O	OBSERVATIONS
21:17:11	2221	5	E	The roll of film ends here, still in shelly sheetflows.
21:18:00			P	CTFM photos (roll 5, frames 14A-17A): two pairs of the CTFM and its time display, looking across the cleft from one rim to the other. The first pair was aimed improperly because the camera had been jostled. We're stopped on the east [west] rim of the cleft, at the north end of Vent 3. The lava here consists of lobate sheetflows and draped folds. I see no pits, but they may occur nearby.
	2222			
21:24:18			P	Photos (roll 3, frames 23-31): unsharp views of objects just beyond the port. A lemon drop as big as 5-6 cm wide wafted easily in the eddies around our hull.
21:25			S	We're awaiting a fix and preparing to deploy Circle 3. Photos (roll 2, frames 8-9): swirly surface on lobes.
21:29			P	We have a fix, and we seem to be on the west rim of the axial cleft, at the north end of Vent 3.
21:31			S	We've deployed benchmark Circle 3, which is white on top and yellow on sides and bottom. It's on the west (?) rim at the north end of our traverse, at what we think is north end of Vent 3. We'll now head south to a vent and try to collect samples, especially of yellow sediment. Photo (roll 2, frames 10-12): Circle 3.
21:33			P	We're underway again, heading SSW. I see my first little glass sponge of the day; it's only about 5-6 cm high. We're crossing very robust sheetflows giving the surface a billowy character. I don't see pits here. Sediment veneer is about 40%, and small sediment ponds contain both lemon drops and small black pebbles that appear to be glassy and may have spalled off the lava. The ponds probably cover less than 10% of the surface.
21:34			S	We're on the west (?) rim of the cleft, turning south. We're passing over flat lobate sheetflows; the lobate forms are a few m across and have a small amount of vertical relief. I see a crab. Photo (roll 2, frame 13, time of exposure not certain): crab.
21:36			P	Photos (roll 3, frames 35-36): big crab. I'm putting another roll into the camera.
21:38			S	A revised fix from the surface puts us on the east rim of the cleft, if navigation is correct. [It proved to be incorrect.] We'll head west to see if we come back to the cleft; then we'll go down into it and follow it south. We're still above lobate forms with swirly surfaces and subdued relief. A fairly thick sediment dusting covers about 60-70% of the surface. Sediment is ponding in low areas. Lobate flows are fractured, but there are no signs of collapse pits right here.

TIME	D	A	O	OBSERVATIONS
21:39		P		A revised fix put us on the east rim of the cleft. We're heading south over lobate sheetflows with heaving. Many thin plates are heaved on end and almost enclosed in the flow. Some form the steep sides of asymmetric pyramids. This heaving differs from what I've seen elsewhere on submarine flows; it involves thinner crust and perhaps was more rapid. It resembles the heaving on subaerial flows near their source as eruption wanes, not the heaving on tube-fed paheohoe. Here the sediment veneer appears to cover 40-50%, and small ponds 5-10%, of the surface; but sediment cover is hard to judge when looking obliquely over the steep sides of these robust lobes. Little patches or islands of broken plates and rougher, broken lava occur, and the lobate sheetflows seem to wrap around them. They may be kipukas of a rough flow beneath a discontinuous veneer of robust lobate sheetflows; if so, these robust lobes represent the last stage of spreading, and that is consistent with the heaving. This flow seems to have spread only a little beyond the rim of the cleft.
21:40:47		S		I see fractures, small collapsed areas, and signs of heaving. We've gone a little way west and have seen no sign of the central cleft, so we'll look for it to the east. We didn't drive very far when we came out of the depression, so we should have been very close to the rim. We're driving east now. Sediment veneer is about 50-60%, and some sediment ponds having scattered lemon drops.
21:41		P		I think we're west of the cleft now, so we'll turn and go east again across the rim. Many thin crusts here were detached from the melt beneath them and were shoved onto older crusts to give a shingled effect, like Wendell Duffield's pictures of the September 1971 flow between Cone Peak and the west rim of Kilauea caldera. I saw a small pit about 2 m wide a few seconds ago as I spoke.
21:43:06		S		Sediment is stirred up easily by our motion 1-2 m above bottom. Some of this lobate lava is marked with a cross-hatched pattern. Sediment collects in low points of cross-hatches, giving the surface a brecciated appearance that could be illusory. I see cracking of lobate flows, perhaps heaving of one part of the flow over another. Some small ledges jut up about 1 ft. I see some cracks with very small offsets. The cracks are very irregular--such as you might get from heaving?
21:43:25		P		We've just crossed a morphologic contact, from fairly robust lobate sheetflows to broken folds and broken plates. A fairly extensive broken terrane occurs to port, but very quickly we go back over robust sheetflows with signs of heaving. Sediment veneer is about 40-60%, and small sediment ponds between the lobes comprise perhaps 10% of the surface.

TIME	D	A	O	OBSERVATIONS
21:44:35			P	We've passed a hollow on the port side; it was apparently composed of just one big sheet-like lobe that subsided. Here we see several lobes several m wide; their surfaces are flat overall, but they generally have subdued wrinkles.
21:45:08	2222		P	The rim of the depression is coming up obliquely to port. We're crossing the rim. The bottom has dropped away beneath us suddenly. I can't see the floor. This is the sharpest, highest rim I've seen during the dive, but this is how the rim of the cleft appears on ANGUS photos in this vicinity.
21:45:15	2222		S	I only see the rim now. It dropped off abruptly; now I can't see the bottom at all. We left the rim behind and are over a void; it's a long way down. We'll go down now.
21:46			P	CTFM photo (roll 5, frame 18A, heading 065o): view of the upper east wall of the cleft ahead, in the upper right corner. What's the other thing? The west wall! The west wall is also shown, to the left.
21:47:15	2237	1	S	I see the seafloor; it's fairly smooth here, with small cracks in generally smooth sheetflows. It has a slightly knobby texture on a small scale--a few cm of relief--with a few small cobbles, fist-sized and slightly larger. Very thin sediment veneers about 40%, with a few sediment-filled striations. [Discussion: Do we have a fix from the last area of heavy yellow sediment, clam shells, and tube worms? No. Shall we go along the east or west wall?]
21:47:22			P	We've found the seafloor; it's flat and lineated. The lineations are shallow and look like wrinkly folds. Sediment veneer is 50-60% and forms a fine glass-shard mosaic. It looks like a lava pond. There is a rattail fish. This surface is billowy over a lateral scale of 10 m or so, and its total extent seems fairly small, less than 10 m wide, with lobate sheetflows beyond. Coming up to port, as we turn, is a step down and a depression.
21:49:56			S	We're over nicely striated sheetflows of low relief, with scattered lemon drops and flocculent yellow particles. To my right is rubble of both angular and rounded fragments. We're going over another rim with a fair drop-off. It looks like it drops down 4-5 m.
21:51:55			S	There are some striated rings on the sides of this drop-off. I see an area that looks heaved, with flat plates tilted at steep angles to one another. Larger plates have a striated surface. Above the plates is a rugged slope formed by a steep scarp having projections. Striations on the tilted plates are glassy. Photos (roll 2, frames 14-16): lineated and tilted plates.
21:54:43	2241		S	We're in the cleft, driving south along the east wall. I can't see the bottom through the starboard port.

TIME	D	A	O	OBSERVATIONS
21:57:30		S		We're over more rubble of broken folds and larger blocks. There's a craggy, steep scarp to the right, with tilted slabs along it. We pass a large crab. [Photo (roll 2, frame 17, time of exposure uncertain): small ledge with a drop of about 1 m.] I see scattered lemon drops, smaller fist-sized blocks of basalt, and sand-sized (?) pieces of glass. The basalt has brick-red and orange-brown staining; some of it has fresh glass on its surface. There seems to be a smoother sheetflow beneath, but it's almost entirely covered by rounded rubble fragments about 2-12 in wide. Larger fragments have a striated appearance. Jim sees a Tide box again; it looks like the same box as before. [Later note: It's probably not the same box according to the navigation. Several boxes may have been jettisoned at once and reached the seafloor at different places.] The depression is narrow here; the Pilot sees walls on both sides. I see a black fish (rattail?).
21:58:25		P		We're moving along a narrow depression. Many lemon drops are here, and apparently a lot of dark (black?) sand too. The sand may be glassy, and spalled from the lava. Much of the lava appears to be a punky, blocky rubble; it would generally be described as a rough surface.
22:00		P		We're still going over rubble. About 30 sec ago we passed a Tide detergent box again, and I saw a big rattail fish just afterward. Some very small patches of golden yellow sediment still occur; but the rubble continues to look fresh, as if it soaks up the sediment. It has a blocky, talus-like appearance, but it does not form talus cones; instead it just litters the surface of these hackly dregs.
22:00:35		S		We're close to a wall on the starboard side. I'm beginning to see larger patches of yellow sediment. I see a rattail fish. Now I see lots of yellow sediment and "iron filing" projections on the basalt. There is a white fluffy material on yellow sediment. This looks like a good site to get a slurp-gun sediment sample.
22:02:30		S		We'll try to slurp a sample of yellow sediment here.
22:04		S		[Start tape 2, side 1.] We're at an area with lots of fluffy yellow sediment, tube worms, and fish. We'll try to slurp a sample of the sediment.
22:05:09		P		The pilot is trying to slurp a sample in a fairly rugged area. I can't tell what our exact situation is, but we may be at the base of the inner cleft wall, among large blocks that appear to be as high as 3 m (overestimate?). Pale, greenish-yellow sediment ponds with little white pebbles in them are scattered around the periphery of this big patch, the center of which I cannot see out the port side. But out of the starboard port we can see thick golden-yellow sediment that we're trying to sample.

TIME	D	A	O	'	OBSERVATIONS
22:12:10			S		I've opened valve 3, which connects to a 4-liter bucket, and have turned on pump 12; I begin taking sample 4P3. There is confusion about the slurp gun. The pilot sees sediment being pumped out. I check the valves, and only valve 3 is open.
22:15:00			P		Slurping continues. I've taken a series of photos of small spider-like creatures on the rocks here. They're orange-brown and perhaps 1 cm wide. Photos (roll 4, frames 1-3): small spiders; frame 3 is the sharpest.
22:15:03			S		I've opened valve 1, have closed valve 3, and begin taking sample 5P1. I turn on pump 11 at the Pilot's suggestion. The Pilot doesn't think the slurp gun is working. Check: I have pump 11 and 12 on and valve 1 open. I try pump 13 on and off several times. The pilot says that nothing is happening. I turn all pumps off; then turn 12 on; nothing is happening. I try pumps 11 and 13.
22:17			S		We're not drawing current on any pump, according to Jim.
22:18:40			S		Pump 12 doesn't seem to work. Again I try pumps 11 and 13 into valve 1. Now I think pumps 11 and 13 are working, but maybe the nozzle is clogged. We were definitely pumping material at the beginning, but apparently not now.
22:20			P		Photos (roll 4, frames 4-25): several more views of the worms here; most with the 105 mm lens are unsharp, but frame 22 with the 24 mm lens is reasonably sharp.
22:21:38			S		I open valve 2, close 1, and begin taking sample 6P2. Jim still doesn't think it's working.
22:23:10	2243		S		I turn off pumps 11 and 13, and close valve 2.
22:23:55			S		We drop weights and leave the bottom. We're going straight up from the last sampling site and will try to get a fix from surface.
22:23:55			P		We've dropped our weights and started up. As we lift up, we get a range of 1958 m to the beacon and drop the Circle Plus marker.
22:25:55			S		We're ascending above the site of the slurp gun sediment samples. We'll deploy benchmark Circle Plus (+), which is white on top. The marker is away. Our range to the Datasonics beacon is 1958 m. [Later note: We did collect a 4-liter sediment sample in bucket 3, and two samples of the sediment on the large filters, numbers 1 and 2. Samples were numbered at the end of the dive according to this scheme: All samples numbered consecutively from the beginning of the dive, followed by a letter code (R = rock, P = Grassley pump) and for pump samples, a number on the end represents the valve number.