UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

Drilling report and core logs for the 1981 drilling of Kilauea Iki lava lake (Kilauea Volcano, Hawaii), with comparative notes on earlier (1967-1979) drilling experiences.

by

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Open-file Report 83-326

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INTRODUCTION

The purposes of this open-file report are: (1) to describe the 1981 drilling of Kilauea Iki lava lake, (2) to present the logs for the drill core recovered during the 1981 drilling, and (3) to present a summary of some of the field observations made during the 1967, 1975, 1976 and 1979 drillings that are relevant to the crystallization history of Kilauea Iki lava lake. This report supplements logs for the 1967-79 core presented in Helz et al. (1980). Levelling data and down-hole temperature data will be summarized in separate open-file reports to be issued later.

Kilauea Iki lava lake, formed during the 1959 summit eruption of Kilauea volcano, lies at the extreme upper end of Kilauea's east rift zone (Fig. 1). The 1959 eruption itself was extensively studied: Murata and Richter (1966) and Richter and Murata (1966) described the chemistry and petrography of the lavas, respectively, while Richter et al. (1970) described the complex history of the eruption, with its 17 phases of high fountaining activity. Wright (1973) included additional chemical analyses of eruption pumices and presented quantitative proof that this eruption involved mixing of two distinct magmas.

Studies of the lava lake began in early 1960 with the establishment of two perpendicular lines of levelling nails on the lake surface. In addition, four holes were drilled through the upper crust in the center of the lake during the period 1960-62, at which time the crust was only 22-44 feet (6.7-13.4 m) thick. Richter and Moore (1966) provide a thorough description of this early core, including descriptive logs of all the core plus petrographic, modal and bulk compositional data for selected samples.

Studies of the later core, from the 1967, 1975, 1976, 1979 and 1981 drillings, have not yet been completed. References available to date (10/82) which include some petrologic description or chemical data on these later cores include: Helz (1979, 1980), Helz et al. (1980), Luth and Gerlach (1980, 1981), and Helz and Thornber (1981).

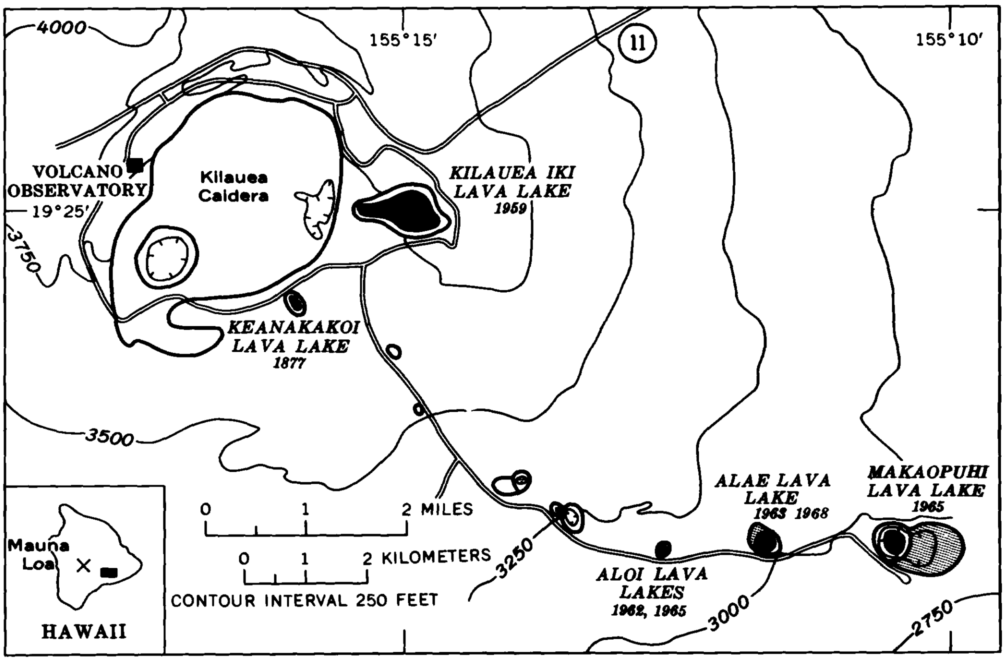

Figure 1. Index map of the summit area of Kilauea Volcano. All historic lava lakes formed prior to 1968, with their dates of filling, are shown. Of these, only the 1959 Kilauea Iki lava lake is both still in a partly molten state and still available for study. The lava lakes farther down on the east rift (Aloi, Alae, Makaopuhi) are now covered by lavas from Mauna Ulu. (This figure is reproduced from Wright et al., 1976.)

HISTORY OF DRILLING IN KILAUEA IKI LAVA LAKE, 1967-1981

After the 1960-62 drilling, described by Richter and Moore (1966), Kilauea Iki lava lake was not drilled again until 1967, by which time the upper crust was 90-100 feet (27-30 m) thick. The three 1967 locations were redrilled in 1975, again by the staff of the Hawaiian Volcano Observatory and other U.S. Geological Survey workers. Subsequent drilling (in 1976, 1978-79 and 1981) has been conducted by Sandia National Laboratories, in cooperation with the U.S. Geological Survey. The latest (1981) drilling produced seven new holes, mostly near the middle of the lava lake. These, with the 14 holes drilled in 1967-1979, bring the number of deep holes in Kilauea Iki to 21. The 3764 feet (1147 m) of core recovered to date is the most complete sampling available for a deep Hawaiian lava lake.

Figure 2a shows the approximate location, in plan view, of these drill holes, relative to the network of levelling nails which HVO workers have installed on the surface of Kilauea Iki. Figure 2b shows the clusters of drill holes in the center of the lake in greater detail. Only one of the 1981 holes (KI81-3) lies outside the area shown in Fig. 2b.

Figure 3 shows the location of most of the drill holes in cross-section, to give some idea of how deeply they penetrate the lake. The exact depth of the lake near its center is not known, as it has not yet been possible to drill completely through the extensive partially molten zone still present there. One hole did pass completely through the lake (KI79-5, commissioned by the U.S.G.S.); at that location, the lake was 80 feet (25 m) deeper than expected (see Fig. 3). The position of the maximum glass content in the core from KI81-1 (217-227 feet or 68.3-71.4 m), if it coincides with the temperature maximum, implies that the thickness of the lake in that location is 395-410 feet (124.3-129.0 m), or about the same as the deeper (1955) topographic profile. [This assumes that the thermal maximum in Kilauea Iki occurs at a depth equal to ~ 55% of the lake's thickness, as was true for the prehistoric Makaopuhi lava lake (Moore and Evans, 1967), and also in hole KI 79-5.] This is considerably deeper than the 360 foot depth given by Richter and Moore (1966), based on the published topographic map (Kilauea Crater, 1:24000 series).

Details of the 1981 Drilling

In April and May 1981, seven new holes were drilled in Kilauea Iki lava lake, the drilling being done by Sandia Laboratories, in cooperation with the U.S. Geological Survey, as mentioned above. As in 1976 and 1979, this coring was done using diamond drill bits. Accordingly, drilling rates were high; typically the bit advanced 1 foot per minute when drilling in the partially molten zone (at depths below 185 feet). Cooling water consumption was also high, running about 40 gal/foot or 40

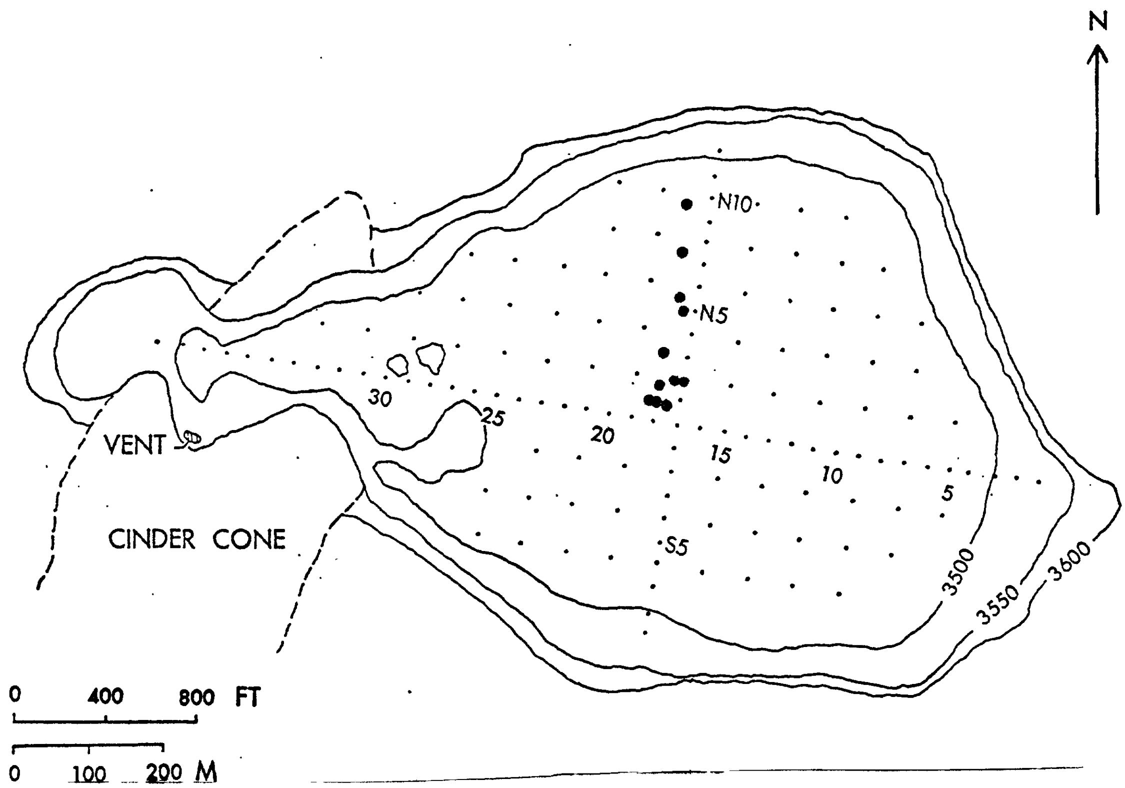

Figure 2a. Plan view of the post-1959 surface of Kilauea Iki. The network of levelling stations is shown by the small dots. Their labelling is read as follows: the point labelled "N5" is levelling station 17N5, that is, it is 1700 feet west of the easternmost station on the principal east-west line, and 500 feet north of that line. The locations of drill holes are given in Table 1 in terms of this network of levelling nails. The large filled circles indicate the location of drilling sites occupied from 1967 to 1981.

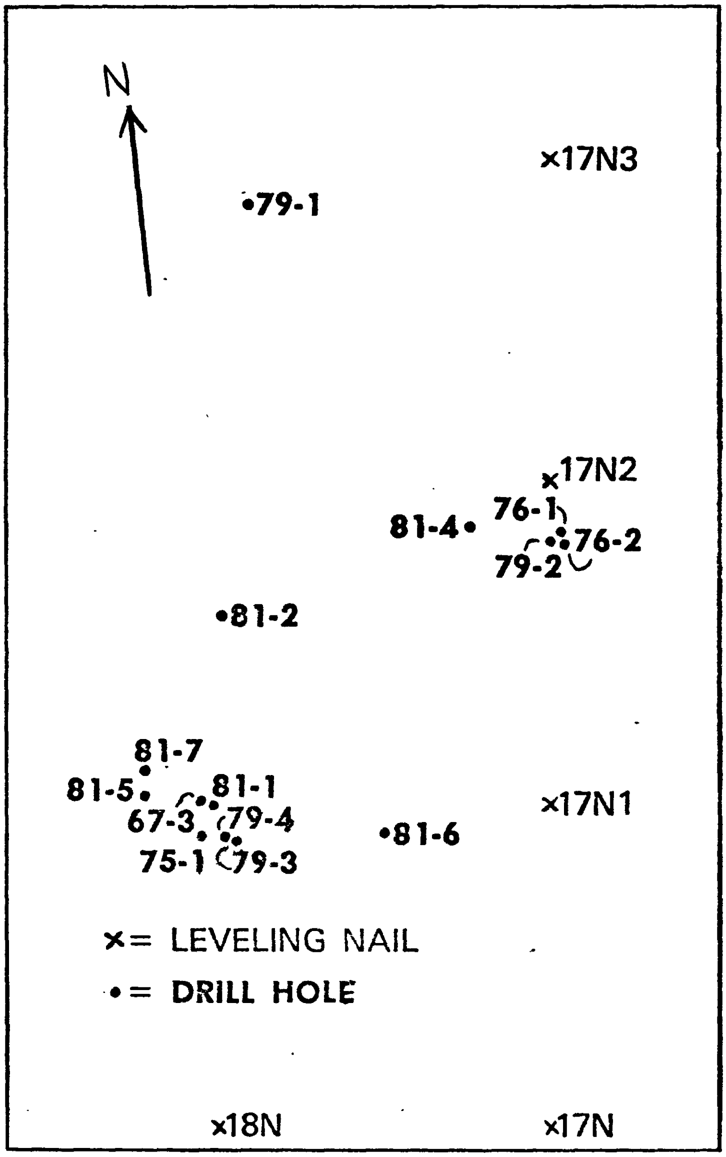

Figure 2b. Detail of the central part of the lake, showing the relative positions of individual drill holes too close to be plotted separately in Fig. 2a. Nearby levelling nails are shown for reference. The scale is given by the levelling nails, which are 100 feet apart.

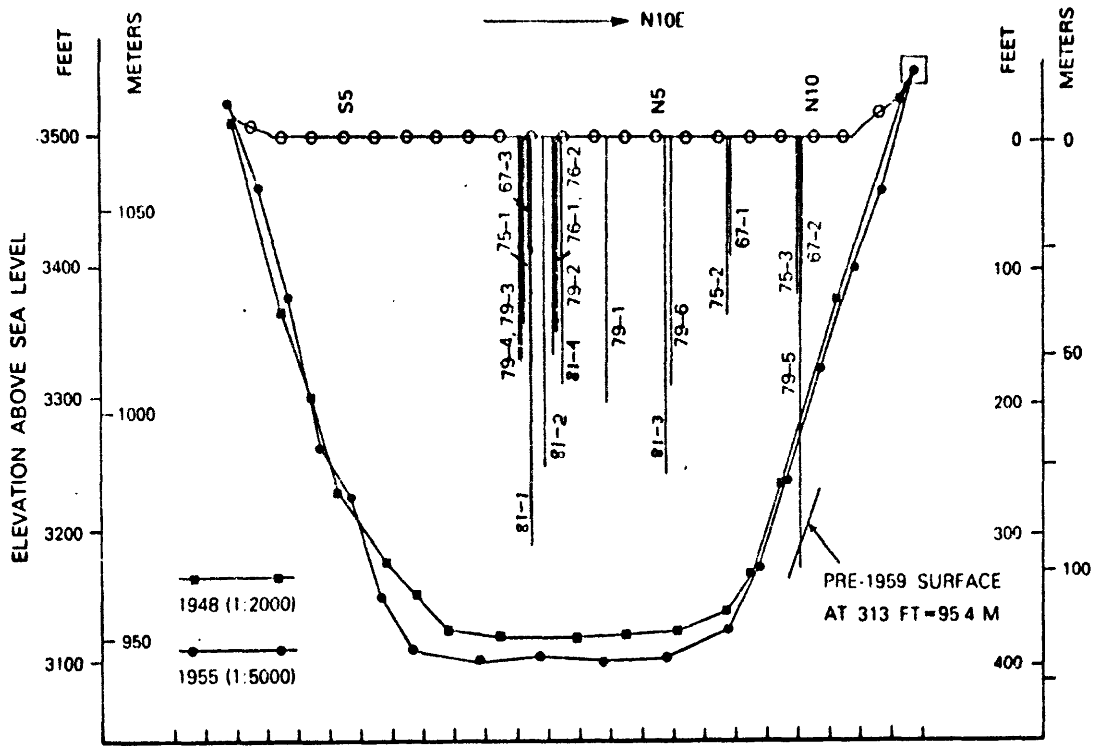

Figure 3. Cross-section of Kilauea Iki lava lake, taken along the N-S line of closely-spaced levelling stations shown in Fig. 2a. The present surface of the lava lake and two pre-eruption profiles are shown. The pre-eruption profiles are taken from two different topographic maps: one (at 1:2000) is based on air photos taken in 1948; the other (at 1:5000) is based on air photos taken in 1955 (both prepared by R. Jordan, U.S.G.S., Flagstaff). The actual location of the lake bottom below hole KI79-5 is significantly different from either, as indicated. Vertical exaggeration is 4:1.

The drill holes, which mostly lie along a parallel line 100 feet to the west of this section, are shown projected onto this cross section. Several of the drill hole locations, indicated approximately in Fig. 2, have been occupied more than once, in order to sample the same section of crust in several stages of development. These clusters of closely spaced drill holes are shown schematically this figure; the spacing between holes within clusters is not to scale. Holes KI81-5,6 and 7 have been omitted for clarity.

gal/minute in the partially molten zone. (Cooling water data are from J.C. Dunn, Sandia Labs., oral comm., 1981).

Basic data on the 1981 drill holes are summarized in Table 1. The holes are listed in chronological sequence. (It should be noted that, in contrast to all other drillings, the hole numbers do not reflect the sequence in which the 1981 holes were drilled.) Several of the 1981 holes were to be used for engineering experiments: these holes (KI81-2, KI81-4 and KI81-6) were therefore terminated at the depths appropriate for the intended experiments. Most of the other holes were lost by drilling accidents, as noted in Table 1.

The results of the 1981 drilling were in some respects quite unlike those of most earlier drilling episodes in Kilauea Iki. In earlier drilling episodes, both in Kilauea Iki and in the Alae and 1965 Makaopuhi lava lakes, drill holes normally terminated in "melt". The drilling definition of "melt" is that it consists of any combination of silicate liquid plus crystals that behaves as a fluid rather than as a solid, when one tries to drill into it. Specifically, when the drillbit reaches "melt", or the "crust/melt interface", the drill string begins to fall freely under its own weight (see discussion in Wright et al., 1976). Material recovered from below the lowest piece of rigid crust is mostly black glass with scattered crystals, or clumps of crystals, of olivine, augite and plagioclase. When the drill string was withdrawn after hitting "melt", the drill holes did not remain open to the base of the crust. Instead, a liquid-rich fraction of the material from below the crust/melt interface moved up into the empty holes. This material, when recovered, usually in devitrified form, is referred to in this report, and elsewhere in the literature on Kilauean lava lakes, as "ooze".

In contrast to most earlier experience, the 1981 holes did not hit "melt", using the traditional criteria to define "melt". Also, the 1981 holes were not backfilled with ooze, the mobile, filterpressed liquid which blocked the lower parts of most of the 1967-1979 drill holes, as discussed below. Lastly, in 1981, no significant new segregation veins were encountered deeper than the deepest segregations seen in 1979.

These three observations are related in that the "melt" hit in many drill holes, including all of those that terminated in "melt" in 1976 and 1979, was a very glassy segregation vein. The veins, which were the main source of the ooze that moved into open holes, were too fluid to be drilled through, so they marked the effective base of the crust at the time and place. The absence of any significant volume of very fluid material in the lake in 1981 suggests that the crystallization history of Kilauea Iki lava lake has entered its final stage, where large-scale fractionation of the lake is no longer possible, and in-situ crystallization is the dominant process.

Even in the absence of an abrupt transition from crust to melt, however, it was still possible in 1981 to recognize an approximate boundary between rigid crust and more plastic material below. Holes left overnight would tend to close up below a certain depth, as follows:

Table 1. Data on holes drilled in 1981 in Kilauea Iki lava lake.

Hole #	Location	Date Collared	Date Finished	Maximum depth of hole (feet)	Core diameter (cm)	Nature & depth of lowest piece of coherent core	Comments
KI81-1	1801N101	4/07/81	4/14/81	307.0	3	Partially molten core from 307.0 ft.	Hole terminated at 307 ft. for use in seismic experiments. SS. tube now blocked at 194 feet by melt.
KI81-3	1722N501	4/08/81	4/17/81	258.8	3	Partially molten core from 254.1 ft.	Hole terminated at 257 feet when bit disintegrated as driller tried to drill through some dropped core. SS. tube now blocked at 197 ft.
KI81-2	1798N158	4/16/81	4/21/81	221	5		Hole cased to 221 ft., for use in heat extraction experiment. Deepest NX core recovered from 214.9 ft.
			4/22/81	236.0	3	Partially molten core from 236.0 ft.	Hole extended to 236 ft. by drilling inside the casing. BQ core recovered from 215-236 ft., by drilling through the NX core at 215-221 ft. which was dropped 4/21. Hole now blocked at 202 ft.
KI81-6	1749N92	4/20/81	4/23/81	205.1	3	Partially molten core from 205.1 ft.	Hole terminated at 205.1 ft. for use in heating/convection experiment. Hole now blocked at 175 ft.
KI81-7	1821N111	4/23/81	4/27/81	167.2	3	Crust, probably subsolidus, from 167.2 ft.	Hole lost because the crown of the bit broke off when the core barrel was dropped down the hole too fast.
KI81-4	1723N187	4/28/81	4/30/81	181.7	3	Crust with interstitial melt from 181.7.	Hole terminated at 181.7 ft. for use in heat extraction experiment.
KI81-5	1822N103	4/28/81	5/04/81	288.3	3	Partially molten rock from 288.3 ft.	Hole lost when the crown of the bit disintegrated in the bottom of the hole, after an extended series of mishaps on 5/1/81.

(1) Hole KI81-1 was drilled to a depth of 237 feet on 4/13/81. To keep the hole open overnight, water was run down it all night long at the rate of 5 gal/minute. When KI81-1 was reentered on 4/14/81, the driller had to ream out the hole from 197 feet to 237 feet, as it had necked down overnight.

(2) Similarly, hole KI81-6 had to be reamed out from 198 feet to 205 feet on 4/24/81 to bring it back up to size. In this case, no water was run down the hole overnight.

(3) Hole KI81-3 had to be reamed out from 210 feet to 242 feet on 4/17/81, even though 5 gallons/minute of water were run down it the preceding night, to keep it open.

Thus, one can place the base of the crust in 1981 at the rheological transition seen at 197-198 feet in the middle of the lake and at 210 feet farther north.

Even though the 1981 drilling did not penetrate "melt", in the usual sense, the 1981 holes extended into very plastic material. Certainly the hottest core recovered was quenched from higher temperatures [1140°-1150°C, using the calibration of Helz and Thornber (1981)] than any core recovered earlier. Factors contributing to the greater stability of the 1981 drill holes include:

(1) More cooling water was used, per foot of hole, than in earlier drillings.

(2) Hole diameter was considerably smaller than in 1976 and 1979. Hence the number of gallons of cooling water per unit area of wall was much greater than in 1976 and 1979, and quenching of the walls more effective.

(3) The average olivine content of the core and wallrock was very high (20-40%) so that the material was very viscous even at high (>1100°C) temperatures.

Lastly, the reason why it was possible to drill much deeper at the KI81-1, and KI81-5 sites than at KI81-3 may have been because the more southerly holes encountered a large block of foundered crust and its associated chilled rind from 260 feet on down. In any case, petrography of the core suggests that the peak temperatures in KI81-1 were lower than those in KI81-3, even though the crust was thicker at the KI81-3 locality.

The current condition of the 1981 holes is quite variable. Many are blocked at depths shallower than their original maximum depth, as noted in Table 1. The depths of blockage given in the table are as of April or May 1981; the present condition of the holes is unknown.

In addition, several of the holes contain a variety of foreign objects. For example, holes KI81-1 and KI81-3 contain narrow (1" o.d.) stainless steel tubing, which extends to depths of 295 feet in KI81-1 and ~250 feet in KI81-3. This tubing, inserted by Sandia personnel, is in 10-foot lengths, joined by a stainless steel sleeve at each joint, and blocked at the bottom. After this tubing was inserted, the part of these holes outside the tubing was packed with sand. The sand used was olivine-poor Mauna Loa tholeiite from a quarry near Hilo. It was hoped that these small, sealed tubes would allow thermocouple access to the bottom of the tubes for longer than the holes themselves would stay open. Unfortunately, as noted in Table 1, these tubes were found to be blocked by melt at 194 ft. and 197 ft., respectively, on April 27, 1981. (The melt is probably largely derived from the sand used to pack the holes.) On 4/28/82, Sandia personnel attempted unsuccessfully to recover the tubing from KI81-3; in the process, the tubing broke, at an unknown depth.

KI81-2 was originally cased to 221 feet; the heat exchanger used during the heat extraction experiment (Hardee et al., 1981) was lowered through the casing and installed at a depth of 230-236 ft. The casing was removed from the hole at the end of the experiment, but the heat exchanger was imbedded firmly in the lake and is still there. The blockage at 202 feet mentioned in Table 1 is not the heat exchanger: this represents the depth at which the hole was blocked (by wall collapse?) on 5/1/82 when a temperature profile was taken in KI81-2.

KI81-6 has a 30-foot furnace left from the heating/convection experiment, extending from 175-205 feet. KI81-5 and KI81-7 each have the crown of a diamond bit in them, at depths of 288.3 and 167.2 feet respectively. Hole KI81-4 is thus the only one of the 1981 holes which could be reentered and drilled deeper. Obviously, none of the 1981 holes has remained open to sufficient depth for temperature or other measurements to be made deeper than the very top of the partially molten zone. The only possible hole would have been KI81-5, but it seems likely from the blockage of KI81-1, 2 and 3 at 194 feet, 202 feet, and 197 feet, that KI81-5 would have closed shut below 195-200 feet by mid-May 1981. As of this writing (12/82) no temperature profiles have been made in any of the 1981 holes since two were taken on May 1, 1981, in holes KI81-1 and KI81-2, by R. Hills (Sandia) and M.P. Ryan (U.S.G.S. Reston).

Chronology of Entry of Filterpressed Melt (Ooze) into Kilauea Iki Drill Holes, 1967-79

Deep drill holes in Kilauea Iki drilled prior to 1981 usually terminated in "melt," as mentioned above. The only exceptions were KI75-3 (stopped arbitrarily at 145.7 feet), KI79-1 (stopped at 204 feet), and KI79-5, which passed all the way through the lake. The other holes, which approached and subsequently hit "melt," were not stable: they filled in from the bottom and/or sides with a crystal-poor liquid, referred to in this report and elsewhere as "ooze." Backfilling of drillholes by such ooze has been observed in all the historic lava lakes which have been drilled (Alae, Makaopuhi, Kilauea Iki; see Wright et al., 1976; Wright and Okamura, 1977; Wright and Peck, 1978).

The chronology of filling of Kilauea Iki drill holes by ooze is summarized in Figs. 4a-c. The sources of the information on hole re-entry and ooze recovery are indicated in the figure captions. The photographs of core boxes taken routinely by USGS/HVO personnel were particularly useful in verifying recovery of ooze.

As can be seen in these figures, the re-entry history of the holes is quite variable. We usually know how high the ooze stood when it finally stabilized, but the rate of rise is often unknown, and where known, varied greatly from one hole to the next, and even from one re-entry of a given hole to the next.

In 1967, drilling was intermittent, with periods of 3-6 weeks elapsed between re-entry of the holes, so the rate of rise of ooze in these holes is mostly not well-defined. Nevertheless, several things are clear from Fig. 4a:

1. Two of these holes were significantly infilled by ooze before the crust/melt interface was reached. Five feet of ooze moved into KI67-1 when the crust/melt interface was still 5 feet deeper. KI67-2 was filled in twice: with 7 feet of ooze and again with 11 feet of ooze when the base of the crust (at 98 feet) was 11 feet and 4 feet deeper, respectively.

2. Backfilling of these holes by ooze was much more extensive once the "melt" was reached, with 13 feet and 33 feet of ooze in KI67-1 and 2 respectively.

The history of KI67-2 was particularly complex. The first hole drilled at this site was very extensively backfilled with ooze on three different occasions. During the last, ooze rose to 65 feet, or 33 feet above the crust/melt interface at 98 feet. When KI67-2 was re-entered, for the fourth time (7/29/67), the drill veered off the original hole at 80-83 feet, and cored new rock from 83 to 97 feet. This second hole was then cased, and the casing blocked at the bottom. Nevertheless, the hole backfilled with ooze to 87 feet. Evidently casing the hole inhibited oozing somewhat, but it did not prevent it completely.

The only information we have on the rate of ooze-back in 1967 comes from the drilling of KI67-3. On the morning of 10/27/67 this hole was extended from 79 to 87 feet, at which depth the drill hit "melt". A thermocouple was then lowered to the bottom of the hole, with the idea of monitoring the thermal recovery of the hole while the drill crew ate lunch. During 1 minute, 45 sec., the temperature rose from 725 to 800°C. After eight more minutes, and some lunch, the temperature was rechecked. The thermocouple read 1030°C and was found to be stuck in melt in the hole. The melt had reheated, softened and moved back up the hole within 10 minutes. The height of ooze-back could not be determined, as the 57 feet of thermocouple sheathing stuck in the hole blocked all further re-entry. This accident was the first indication that at least the onset of ooze-back could be quite rapid.

The ooze-back history of the 1975-76 holes is given in Fig. 4b. In 1975, there was very little redrilling of holes: the height to which ooze rose in these holes was determined principally by locating the bottom of the hole with a weighted thermocouple. KI75-1, like KI67-1 and KI67-2, experienced significant infilling with ooze (2.8 feet) at 140.8 ft, before the final crust/melt interface was penetrated at 145.1 feet. After the interface was breached, ooze-back was rapid at first, with 10.4 feet of ooze moving up into the hole overnight (17 hours). The ooze crept up over the next 6 weeks, stabilizing at a hole depth of 132 feet, or 13.0 feet of ooze. The pattern in KI75-2 was probably the

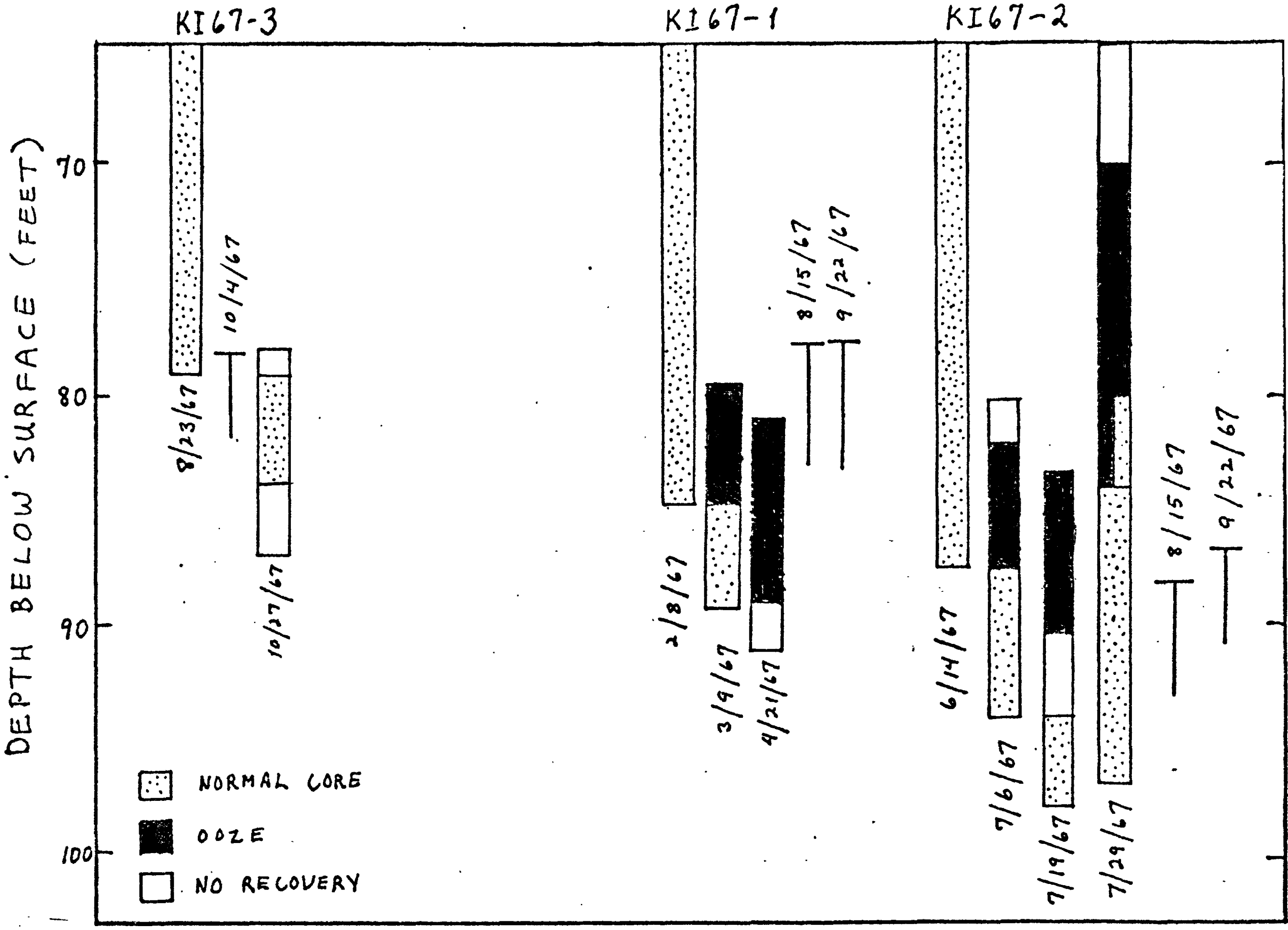

Figure 4a. Caption on next page.

Figure 4a. Drilling and re-entry history of the 1967 Kilauea Iki holes. The vertical axis is depth in feet. The horizontal axis, which is not to scale, shows the approximate location of the three holes relative to each other. The orientation of the section is the same as in Fig. 3. Thus KI67-3 is the southernmost hole, KI67-2 the northernmost. Successive re-entries for each hole are displaced to the right, for clarity's sake.

Solid or patterned bars indicate drilling. The top of the bar indicates where drilling began, the bottom where drilling stopped. The nature of the core recovered is indicated in the key. The dates below the bars give the day the bottom of the drilling interval was reached.

The vertical lines with a short horizontal cross indicate occasions when the bottom of the hole was sounded, but no drilling occurred. Most of these depth soundings were made with a weighted thermocouple, during downhole temperature measurements. In each case, the horizontal line indicates where the hole bottomed, and the date above the line is the day on which the sounding was made.

The information summarized in Fig. 4a was assembled from the following sources:

1. the field notebook kept by R.S. Fiske during the drilling

2. recovery logs and photographs of the core boxes, both made by R.S. Fiske. These logs were included in Helz et al. (1980)

3. field notebooks recording downhole temperature data. These data were collected by R.S. Fiske, R. Okamura, T.L. Wright, K. Yamashita, A. Yamamoto and M. Sako, all staff members of the Hawaiian Volcano Observatory.

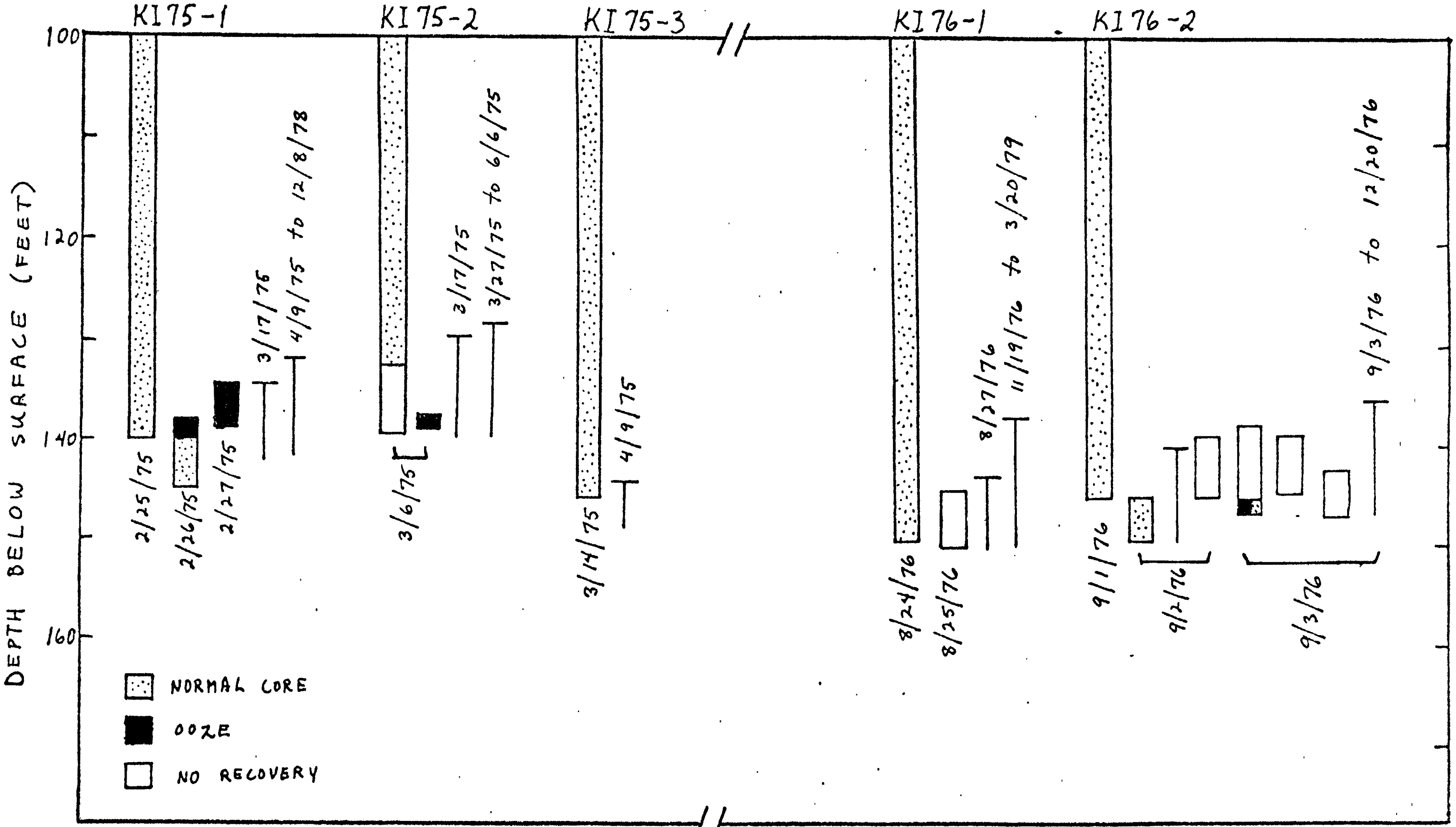

Figure 4b, Caption on next page.

Figure 4b. Drilling and re-entry history of the 1975 and 1976 Kilauea Iki drill holes. The vertical axis is depth below the surface of the lake, in feet. The horizontal axis is not to scale. The 1975 holes, on the left, are shown in sequence from south to north, as were the 1967 holes in Fig. 4a. The 1976 holes are shown separately to the right, and are not in spatial sequence relative to the 1975 holes. As in Fig. 4a, successive re-entries are displaced to the right. Other symbols and conventions as in Fig. 4a.

The information summarized in Fig. 4b was compiled from the following original sources:

For 1975:

1. The field notebook kept by R.T. Helz during the drilling (equivalent to the recovery logs in Helz _et al_., 1980).

2. Photographs of the core drawers made by R.T. Helz and John Forbes (HVO).

3. Field notes recording temperature data collected by R.I. Tilling, C. Zablocki, M. Sato, and other staff members of the Hawaiian Volcano Observatory.

For 1976:

1. The field notebook kept by R.T. Helz during the drilling (equivalent to recovery logs in Helz _et al_., 1980).

2. Photographs of core boxes made by R.T. Helz and John Forbes (HVO).

3. Radio conversations with John Colp on 9/3/76, during the final day of drilling, as recorded in the field notebook and in a summary report of the drilling sent from R.T. Helz to H.R. Shaw on 1/5/77. The re-entry history of KI76-2 as shown here differs in several details from that given in Colp (1979).

4. Field notebooks recording temperature profiles made by HVO staff members.

same, though only the period of slow rise (from 3/17/75 to 3/27/75) was monitored. Hole KI75-3 behaved as KI75-1 did before it reached the melt: that is, a small amount of ooze (1.5 feet) moved into the hole, between 3/14/75 and 4/9/75. Ooze-back in KI76-1 was somewhat like that in KI75-1: there was a rapid overnight rise of 5 feet of ooze, followed by a gradual rise to 138 feet, or 12.0 feet of ooze.

In KI76-2, repeated re-entry of the hole on 9/2/76 and 9/3/76 allowed more precise timing of the rise of ooze. After first hitting melt, at 150 feet, the string was pulled back 10 feet and cooling water run down the hole for 10-15 minutes. Upon relowering the string from 140 feet, the hole was found to be blocked at 141 feet. This first surge of ooze, from 150 to 141 feet, thus took place in <15 minutes. The entire string was then withdrawn from the hole, the bit examined, and the string re-lowered. During this elapsed half hour, the ooze was found to have risen another 2 feet, to 139 feet, or 11 feet above the crust/melt interface. The hole was cleared out to 147.5 feet and left overnight. Next morning, bottom was at 138.5 ft. The hole was drilled out from 138.5 to 147.1 feet, and the string pulled. Less than one foot of ooze was recovered. The string, when relowered, hit bottom at 139.2 feet. The ooze in hole was again drilled out, from 139.2 to 145.4 feet. The string was then raised slightly during wirelining, and lowered again 10-15 minutes later, to find the hole bottom at 143 feet. The hole was cleared out from 143 to 147.8 feet and the string pulled. When the string was lowered for a fourth time, 30-45 minutes later, and hit bottom at 136.3 feet, the hole was abandoned. These unsuccessful attempts to drill through ooze provided the first real insight into how fast ooze-back could be.

The oozing history of the 1979 drill holes is summarized in Fig. 4c. This was the first drilling since 1967 in which significant amounts of ooze were actually recovered by coring. (In 1976, the material drilled was apparently too fragmental to be caught by the core catcher.)

Several of these holes were re-drilled only once. KI75-1R backfilled overnight with 8 feet of ooze derived from a segregation vein. KI79-3, 5 feet away, backfilled overnight with 18 feet of ooze, from the same segregation. In both cases the ooze was partly cored out, with some left to block the bottom of the hole. This arrangement was not stable, however: the ooze in KI79-3 rose again, to 157 feet, 16 feet above the bottom of the hole. Ooze in KI75-1R again moved to 165 feet, or 8 feet above the base of the crust.

KI79-2 hit "melt" at 165.6 ft, and was backfilled with ooze to 155 feet almost immediately. The hole was redrilled to 165 feet that same day (1/5/79) and the hole left. The next sounding of the hole, on 3/20/79, found bottom at 136 feet. This was probably ooze, and it probably rose to this level on 1/5/79, by analogy with the oozing behavior observed for KI79-6.

KI79-6 was drilled to 190.3 ft on 2/14/79, and backfilled with ooze overnight to 168.4 feet (22 feet of ooze). The hole was re-entered twice the next day. The first time it was drilled to 184.5 feet, then to 187.5 feet, with ooze rebounding as shown in Fig. 4c. The third surge of ooze, from 187.5 to 141.7 feet (45.8 ft of ooze) took place in <10 minutes, according to field notes made by R. B. Moore (HVO). At 4.6 feet per minute, this is the fastest documented rise of ooze in Kilauea Iki.

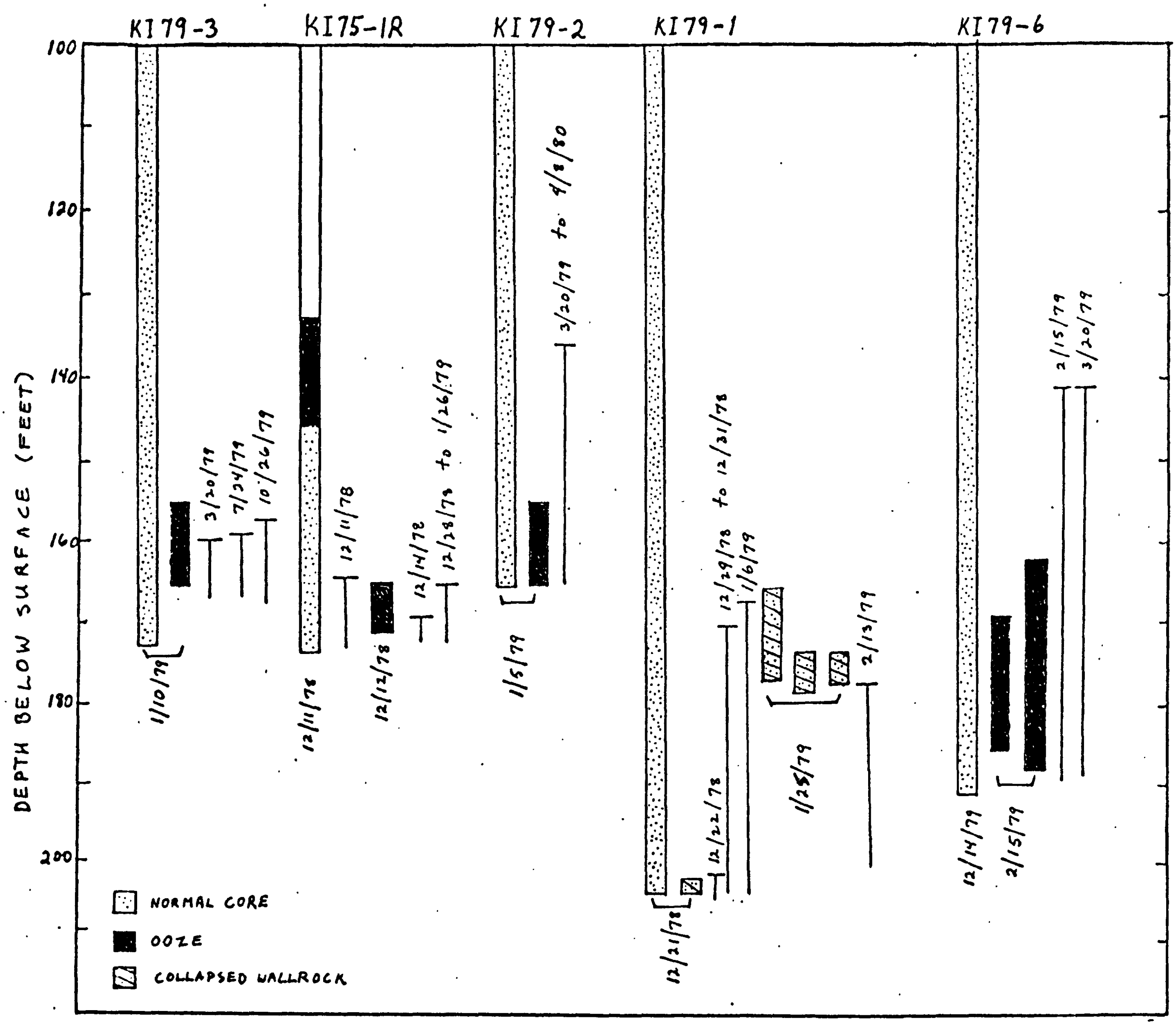

Figure 4c. Caption on next page

Figure 4c. Drilling and re-entry history of the 1979 Kilauea Iki drill holes. The vertical axis is depth in feet. The horizontal axis is not to scale. The holes are shown in sequence from south (left) to north (right) as in Fig. 4a. Successive re-entries are displaced to the right, as in Figs. 4a and b. Other symbols and conventions as in Fig. 4a.

Hole KI75-1R is hole KI75-1, re-drilled and extended in late 1978. The hole was open to 132 feet, as shown in Fig. 4b: hence no core was recovered above that depth.

The information summarized in Fig. 4c was compiled from the following sources:

1. Field notebooks kept by N.G. Banks (HVO) for holes KI75-1R, KI79-1, KI79-2 and KI79-6; Kurt Servos (Menlo College, CA) for holes KI79-2, KI79-3; and R.B. Moore (HVO) for holes KI75-1R and KI79-6.

2. Photographs of core drawers made by J. Griggs (HVO).

3. Recovery logs (Helz et al., 1980) based on the location of driller's blocks and HVO monthly reports of the drilling, in addition to the field notes mentioned above.

4. Some temperature profiles and other re-entry information from Colp (1979).

5. Field notes for various temperature profiles, as follows:

   J. Colp (Sandia), the 2/15/79 and 7/24/79 data

   T.J. Casadevall (HVO) and M.P. Ryan (U. of Hawaii) the 3/20/79, 10/26/79 and 4/4/80 data.

The drilling history of KI79-1 reflects quite a different phenomenon: in this hole, drilling was blocked by collapse of the wallrock, rather than movement of filterpressed liquid into the hole. Core recovered during redrilling is petrographically indistinguishable from the initial core recovered. This process apparently began 12/21/78, as soon as the hole reached its final depth. The hole was first drilled to 204 feet, according to field notes made by N. G. Banks (HVO). Then the string was pulled, to examine the bit (J. Colp, oral communication, 9/19/76). When the string was relowered, it hit bottom at 203.2 feet. The hole was redrilled to 204 feet and drilling stopped for several weeks. The core recovered from the 203.2-204.0 interval in the second pass is undersized, and the glass in it completely devitrified, in contrast to core from the same interval recovered during the first pass. It is clear from examination of the 1979 core that the cooling effect of the drilling water did not extend deeper than the drill bit itself; in fact, the heavily corrugated surfaces of the deepest KI79-1 core suggest that the melt in the core was still plastic while passing through the core catcher. Hence the devitrified 0.8 feet of core recovered in the second pass between 203.2 and 204.0 feet is more likely to be wall material that moved laterally into the hole, than it is to be material that moved up from below.

KI79-1 closed up fairly quickly over the next 7 days, to a depth of 170 feet by 12/29/78. By 1/25/79, when redrilling was begun, the hole bottom was at 166.8 feet. It was redrilled from 166.8 to 176.8 feet, from 172.9 to 178.0 feet and from 172.9 to 177.9 feet, in rapid succession, very similar to the re-entry pattern for KI76-2. In the last two passes, the core barrel contained more core (6.4 and 6.7 feet respectively), than would be expected from a 5-foot advance of the drill bit (see Helz _et al._, 1980, p. 47). It was the impression of the driller (recorded by N. G. Banks of H.V.O. in the field notes) that material was flowing up into the core barrel, presumably against the pressure of the drilling water, after drilling stopped and before the string was raised.

All of the material recovered in the various re-entries of KI79-1 is very olivine-rich, resembling core recovered in the same interval except perhaps for having less fresh glass. It is _not_ the filterpressed liquid which oozed into all other holes.

Discussion of Oozing Behavior

Some questions about the movement of ooze into Kilauea Iki drill holes have not yet been discussed. These include (1) the nature of the source of the ooze, (2) the depth of origin of ooze, and (3) the physical factors causing or controlling oozing.

We usually know, in a general way, the nature of the source of the ooze in each hole. This can be determined by inspection of the core from the drill hole itself or by inspection of drill core from the appropriate depth in an adjacent hole. Petrographic examination can be supplemented by chemical analysis. For example, it is clear from the extremely differentiated composition of the ooze that moved into KI67-2 between 6/14 and 7/6/67, that it was derived from a partially crystallized segregation vein (see analysis in Table 2, Col. 5, Helz, 1980).

All other oozes that moved into drill holes before the crust/melt interface was breached (as in KI67-1, KI75-1, and KI75-3) appear to have resulted from lateral drainage of interstitial liquid from the partially molten but rigid wall rock. Certainly the nature of the core from 145-146 feet in KI79-5, with its open, interconnecting voids in the groundmass, which are coarser and more extensive than those seen in other parts of the core, suggests that the 1.2 feet of ooze observed in KI75-3 was produced by lateral drainage of melt from within a rigid crystal framework. (KI79-5 and KI75-3 are about 6 feet apart.)

Most oozes come from below the "crust/melt interface", whatever this interface may have been in any given hole, and here there are several distinct sources. The nature of these sources is given, where known, in Table 2, along with data on the quenching temperature of the deepest glass recovered from each hole. The temperatures are based on the CaO and MgO contents of the glass, using the calibration of Helz and Thornber (1981). The ooze is presumably either equivalent to the deepest glass recovered or slightly hotter (if it comes from deeper in the lake), so these quenching temperatures are minima for the ooze at its source.

The coolest oozes are those derived from segregations that have crystallized enough so that they can be identified as such by inspection of the core, as was the case in KI75-2, KI76-1 and 2, KI79-3, and KI79-2. Other known sources are distinctly hotter. The source in KI67-1 and 2 was apparently interstitial liquid from the upper margin of the main body of melt, rather than a pre-existing segregation vein. The temperatures are low because the base of the crust was at that time just moving into the most olivine-depleted part of the lake (see Helz (1980) for a discussion of the olivine distribution in the lake), and hence lost its rigidity at a relatively low temperature. The source of ooze in KI67-3 is ambiguous: there is no evidence of a segregation in KI67-3 or in KI75-1 at 87.0 feet, but there is a segregation vein in KI81-1 at the appropriate depth. Possibilities for the source of ooze in KI67-3 include (1) that the ooze came directly from the interstitial melt at the top of the main lens of melt, as in KI67-1 and KI67-2 or (2) that it came from a segregation vein which had not begun to crystallize at all when KI67-3 was drilled. The temperature of the melt from the bottom of KI67-3 is compatible with both. If the former is the case, then the segregation seen in KI81-1 (absent from KI75-1, which is farther away from KI67-3 than KI81-1 is) might be interpreted as a local pocket of melt formed near KI67-3 _as a result_ of the drilling, a possibility raised in Helz (1979). In each case, however, the glass recovered from below the crust/melt interface is the _liquid fraction only_, of the underlying crystal/liquid mush. Removal of crystals from liquid, whether by flow differentiation or some other process, was very efficient as the liquid flowed up the hole.

The hottest ooze of known origin is that in KI75-1, which was derived from one of the _vertical olivine-rich bodies_ (vorbs for short), interpreted in Helz (1980) as tracks of finger diapirs. Glass of comparable quenching temperature was recovered from KI79-6, the only hole for which the source of the ooze is not obvious. The highest-temperature glass in Table 2 is that from hole KI79-1, in which the hole was closed by collapse of the wallrock (see previous section) rather than by movement of ooze into the

Table 2. Sources of ooze from below the crust/melt interface and quenching temperature of the glass which best represents the ooze.

Hole	Quenching temperatures of deepest glass (°C)			Source of ooze?	How source determined?
	T_{MgO}	T_{CaO}	Average		
KI67-1	1114	1120	1117	Main body of melt	Petrography of KI67-1, KI75-2
KI67-2	1124	1122	1123	Main body of melt	Petrography of KI67-2, KI75-3, and KI79-5; bulk composition of oozes = that of glass in bit.
KI67-3	1125	1123	1124	As above, or very new segregation	Petrography of KI67-3, KI75-1, KI79-3, KI79-4, and KI81-1
KI75-1	1131	1131	1131	Active "vorb"	Petrography of KI75-1, KI75-1R
KI75-2	1110	1114	1112	Segregation	Petrography of KI75-2
KI75-3	1108	1107	1108	Lateral drainage of interstitial liquid	Petrography of KI75-3, KI79-5
KI76-1	1116	1120	1118	Segregation	Petrography of KI76-1, KI79-2
KI76-2	1113	1115	1114	Segregation	Petrography of KI76-1, KI76-2, KI79-2
KI79-1	1140	1138	1139	No ooze	
KI79-2	1105	1107	1106	Segregation	Petrography of KI79-2
KI79-3	1112	1115	1114	Segregation	Petrography of KI79-3, KI81-1
KI79-6	1135	1130	1133	Unknown	

hole. The evidence for very high-temperature liquid in the wallrock of KI79-1, plus the absence of oozing in hole KI79-1 emphasizes that in 1979, oozing occurred only when there was a local melt-rich source. In other words, there must have been some local source generating the abundant ooze in KI79-6, even though the nature of it is not at all clear from looking at the core from KI79-6 itself.

Table 3 summarizes information on melt-rich regions of the lake found within the olivine cumulate zone, in the deepest cores. The deepest segregations are not deep enough to have been the source of the KI79-6 ooze. The diapir tracks, or vorbs, do not usually extend deep enough either. The only melt-rich regions consistently available below 190 feet are the shallow-dipping glass-rich areas seen in most holes between 190 and 240 feet. Even these were not obviously present in KI79-6; nevertheless one of these is the likeliest source for the ooze in KI79-6.

The depth at which ooze (and collapsed wallrock) originated is not yet known except for the ooze in KI67-2, and that in KI75-3, though this information is recoverable in principal. When characterization of the core is complete, and the ooze (or collapsed wallrock) adequately sampled, it will probably be possible to determine quite closely whether ooze came only from below, or was fed partly from the sides, etc. At present, however, the ooze has not yet been logged in any detail and has not been completely sampled. Oozes recovered in 1967 and 1975 are at the National Museum, with the appropriate cores. That from KI76-2 and all of the 1979 ooze and collapsed wallrock is in storage at HVO.

Although the source of the various oozes is generally known and the exact depth of origin probably knowable (with more work), the physical parameters causing or controlling oozing are more elusive. For the middle of the lake it appears that the most important factor governing the onset of oozing, and its manageability as an obstacle to drilling, was the difference between lithostatic pressure (in the wallrock) and atmospheric pressure (in the newly opened hole). This difference ranged from about 7 bars in 1967 to 18 bars in 1979.

When the crust was relatively thin (90 feet or so in 1967), oozing began before the crust/melt interface was reached. That is, it was possible to drill into crust with such a high melt content that it itself could be a source of significant ooze (5 feet in KI67-1). By 1975, the crust could produce only 1-2 feet of ooze, at comparable distances (4 feet) above the crust/melt interface, presumably because it did not contain as much interstitial liquid.(1) By 1976, a glassy segregation 1.5 feet thick was an impassable barrier, even though there was probably 3-5 feet of rigid crust

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(1)It is assumed here that all significant movement of ooze into open holes took place within a few hours after drilling ceased, i.e. that the more extensive 1967 oozing was not simply an effect of the longer elapsed times between reentry of drill holes.

Table 3. Possible sources of ooze in the olivine cumulate zone (below 130 feet) in Kilauea Iki.

Hole (depth, feet)	Deepest segregation vein Depth (feet)	Deepest segregation vein Thickness (cm)	Vorbs, depth range (feet)	Shallow-dipping glass ± olivine-rich layers depth range (feet)
KI81-1 (307)	178.5-178.9	5 cm	134-181	196-242
KI81-5 (288)	181.9	1 cm	138-181	196-243
KI81-6 (205)	183.9-184.2	10 cm	140-192	195-205
KI81-2 (236)	174.9	1 cm	136-185(?)	191-236
KI81-4 (182)	179.3	1-2 cm	137-182	---
KI79-1 (204)	173.7	2 cm	141-177	195-202
KI81-3 (254)	185.4	3 cm	140-162	192-212
KI79-6 (190)	175.7	4 cm	142-177	---

Table 4. Data on height of ooze and temperature of adjacent wallrock in Kilauea Iki drill holes

Hole	Stable top of ooze column (feet)	Hottest temperature at that depth (°C)	Date recorded
KI67-1	77.6	971	8/15/67
KI67-2	86.5	1035	9/22/67
KI75-1	132.1	990	4/ 9/75
KI75-2	128.6	950	3/27/75
KI75-3	144.2	1075	4/ 9/75
KI76-1	137.5	916	11/19/76
KI76-2	136.0	887	10/14/76
KI75-1R	164 ±	1010	12/28/78
KI79-1	172.0 (collapsed wallrock)	938	7/24/79
KI79-2	136.0	272	3/20/79
KI79-3	157.4	809	10/26/79
KI79-6	141.7	93	3/20/79

below it. By 1979 drilling could be blocked completely by a segregation only 0.1-0.2 ft thick, as in KI79-3, KI75-1R or KI79-2.

The onset of oozing, and its severity, thus correlates roughly with thickness of crust. The height attained by the column of ooze in a particular hole might also be thought to depend on crustal thickness, but the correlation is in fact quite poor, as other factors, notably the size and nature of the source of the ooze, and frequency of re-entry of the hole, are also involved. At first it was thought that the ultimate height to which ooze would creep up a hole might be controlled by the temperature of the wallrock, but this appears, from the data of Table 4, not to be true. Even when one discards the heights reached by the rapid surges in KI79-2 and KI79-6, one is left with a temperature range of 809 to 1075°C. The solidus of the basalt is at about 970°C. In two holes, the ooze did stabilize at depths near the solidus temperature. In three holes it stabilized at temperatures >1000°C, however, and in others continued creeping past wallrock 30-150°C below the solidus temperature. Clearly the impetus of ooze to move, even by slow creep, was governed by conditions at the base of the column, more than by heat loss to the wallrock further up the hole.

There is also no good correlation between the temperature of the source and final height of ooze. The three highest columns of ooze come from the coolest source (KI79-2 at 1106°C), an intermediate source (KI67-2 at 1123°C), and the hottest source (KI79-6 at 1133°C). What does control the height of ooze, in these cases at least, is frequency of retapping the source of the ooze.

One of the most interesting pieces of information that emerges from the oozing/redrilling history is that the rheological properties of partially molten lake materials changed with time under continued stress. That is, after the material flowed once, into an open hole, it was much more mobile the second or third time. The most striking instance of this is not any of the ooze surges but the notable mobility of the collapsing wallrock in KI79-1 on 1/25/79. This material, which was easily drilled through five weeks earlier, and generated no ooze, was too fluid to support a hole for even a few minutes after repeated redrilling. This collapse does not involve the same extreme fluidity as the ooze surges, of course. It is possible that the collapsed wallrock material moved slightly upward as well as inward, but there is nothing in its appearance to suggest that it rose 30-40 feet up a narrow drillhole, as the ooze did on several occasions. The precise rheological properties of this olivine-rich material, and of the ooze, are unknown, however; detailed study of this core might provide useful constraints on the rheology of these materials as well as on their depth of origin.

Sulfur Emission from Kilauea Iki Drill Holes

Kilauean lavas degas extensively during fountaining and rapid flow, such as occur during or and/or immediately after eruption. Swanson and Fabbi (1973) provide quantitative evidence for this process occurring in the 1969-71 Mauna Ulu lavas, but the process is general for all Kilauean lavas. Volatiles lost include H_2O, sulfur, and chlorine compounds, monitored by Swanson and Fabbi (1973), as well as H_2 and carbon compounds (studied by e.g., Heald et al., 1963).

The fountains of the 1959 eruption, which fed Kilauea Iki lava lake, emitted great quantities of sulfurous fume, as did the newly-formed lake (Richter et al., 1970). Several studies of gases evolved from Kilauea Iki eruption products have been made. Heald et al. (1963) report analyses of gases from Puu Puai, the main vent which fed Kilauea Iki. These show the gases becoming richer in H_2O and poorer in other primary magmatic components (CO_2, H_2, SO_2, H_2S) with time. The period of collection ranged from 11/30/59 to 7/28/60. Murata (1966) presents a single analysis of an unusual HCl-rich gas from a cinder cone on the rim of Kilauea Iki pit crater. It is unlike any of the samples of Heald et al. and its significance difficult to assess.

In his description of the first drilling of Kilauea Iki lava lake to encounter melt, Rawson (1960) mentions that outgassing of the melt (encountered 7/25/60 at 19 feet) was significant and that "sulphur from the outgassing melt was deposited on the (drill) bit" (op. cit., p. 931). This hole produced gas at a sufficient rate for it to be attractive for gas sampling. The three samples collected are included in Heald et al. (1963). The samples have concentrations of CO_2, H_2, SO_2, and H_2S intermediate between the early (11/30/59-4/11/60) Puu Puai samples and the latest Puu Puai samples (collected 7/28/60). Evidently the lake, though much degassed relative to the original eruption pumices, still contained an appreciable amount of dissolved volatiles in mid-1960.

Information on the degassing of Kilauea Iki lava lake from later drill holes is sparse, and no gas samples have been taken in these subsequent drill holes. There are two reasons for this. First, all other holes, including those described by Richter and Moore (1966) were drilled using water as a coolant, instead of compressed air, so the possibility of contamination was much greater. Second, gas production rate was apparently too low for sampling to be feasible. Nevertheless, the longer-term outgassing behavior of the lava lake may be of some interest, so we include here a summary of all of the available observations relevant to this subject:

(1) In KI67-3 there was "a tremendous bloom (sic) of sulphur-bearing gases released" when the drill string was pulled after reaching 79.0 feet. One of us (T.L. Wright) recalls that all the 1967 holes emitted noticeable sulfurous fume.

(2) In two of the 1975 holes, the steel rods of the drill string came up heavily blackened and tarnished, when brought up from depths of 130-139.5 feet (KI75-2), and from 110-116 and 129-134 feet (KI75-3). In these cases there was very strong emission of gas after the string was removed from the hole, and the gas had a very strong sulfurous smell.

(3) In hole KI75-1, the drill steel never developed the conspicuous powdery black tarnish seen in drilling KI75-2 and KI75-3. Steam from the hole did have a sulfurous smell, however, and a Cr-Al thermocouple lowered to the bottom of the hole on 3/6/75 came up encrusted with crystals of pentlandite (NiS), formed by reaction between the nickel-alloy wires and the gases being emitted by the lake.

(4) In 1976, two holes were drilled, only 15 inches apart. To drill the second of these, the drill rig was pulled 15 inches forward, so that the anchor bolts could be reused. Thus KI76-1 was directly under the drill rig during the drilling of KI76-2. During the first few days, drilling of KI76-2 was enlivened by periodic geysering from KI76-1, produced as water from drilling KI76-2 ran sideways 15 inches and down to the bottom of KI76-1. After a period of an hour to several hours, the resulting column of water was blasted out of the hole by the underlying steam bubble, produced by heating the water. Fortunately, the driller was agile enough to escape being scalded, always leaping clear of the rig at the first gurgle from KI76-1. The geysering tapered off gradually, from 8/30 to the morning of 9/1/76. After geysering ceased, gas emission from KI76-1 continued, and by the afternoon of 9/1/76, the underside of the drilling was coated with pale yellow native sulfur, and remained so throughout the rest of the 1976 drilling.

Thus from 1967 to 1976, all of the holes emitted noticeable amounts of sulfur. It is possible that carbon, chlorine, and fluorine compounds were also being emitted, but no attempt was made to test for their presence.

The 1979 drilling was quite different from the earlier episodes with respect to magmatic outgassing. The log for KI75-1R notes that there was "no sulfur smell" from that hole. Later conversation with N.G. Banks (7/15/82) confirmed that there was no smell of sulfur from any of the 1979 holes during drilling, nor was there any deposit of sulfur near the hole, on the drill rig, etc. T.J. Casadevall and F. LeGuern attempted, using a field gas chromatograph, to measure sulfur in the steam emitted from KI79-5 after drilling was complete, but found sulfur to be below the limit of detection. Also, notes of the many temperature profiles made in the 1979 holes make no mention of sulfur smell or of tarnish or sulfide crystals on any of the various thermocouples used.

In 1981, again, there was no detectable sulfur emitted from any of the new drill holes. At one point during the drilling one of us (R.T. Helz) made a tour of all of the older holes, to see if sulfur emission had ceased from all of them. The only site at which sulfur was still detectable to the nose was the KI67-1/KI75-2 location. All other drilling locations were emitting odorless steam or nothing at all.

The observations summarized above suggest the molten core of the lake was more volatile-rich in 1967-1976, and appreciably more degassed in 1979-1981, a progression which implies the lake is degassing faster than it is crystallizing. Where it was observed, heavy sulfur emission usually began when the hole first reached partially molten crust, suggesting that SO_2 was exsolving directly from the interstitial melt into the open drill hole.

Summary

The drilling of Kilauea Iki has spanned twenty-one years and a great fraction of the lake's crystallization history. Much of the resulting body of information on the physical behavior of the lake during the later (1967-1981) drilling has been presented either in Helz (1980) or in this report.

The most obvious change in the lava lake in this time period has been the gradual thickening of the upper crust. The thickness of the rigid upper crust was 87 feet in 1967, 145 feet in 1975, 173 feet in 1979, and 198 feet in 1981, in the middle of the lake. The average growth rate in the intervals between drilling was:

1967-75	7.7	ft/year
1975-79	7.0	ft/year
1979-81	10.4	ft/year.

The nature of the "crust/melt interface" has changed from 1967 to 1979. In 1967, the "melt" encountered may actually have been the top of the main lens of melt, as it presumably was in the 1965 Makaopuhi lava lake (Wright and Okamura, 1977). In all but one hole drilled in 1975, 1976, and 1979, however, "melt" was an isolated melt-rich source such as a segregation vein or an active finger diapir. In KI79-1, no melt-rich region was encountered. Likewise, in 1981, no sharp crust/melt interface existed in any of the drill holes.

Because of the absence of local melt-rich regions in KI79-1 and in the 1981 holes, it was possible to extend these holes deeper into the lake, technically speaking beyond the base of the rigid upper crust, and to recover core from the plastic crystal/liquid mush forming the interior of the lake. By contrast, in earlier drillings, and in most of the 1979 holes, drilling terminated quite abruptly, at the crust/melt interface, because it was not possible to drill past the filterpressed liquid, or ooze, which moved up all of the 1967-79 holes that hit "melt".

The oozing history of the various drill holes has been discussed in detail. Its most important features may be summarized as follows:

1. In 1967 and 1975, oozing occurred in several holes at depths well above the crust/melt interface. These holes include KI67-1, KI67-2, KI75-1, and KI75-3.

2. In later drillings (1976 and 1979), oozing occurred only after the hole had reached the effective crust/melt interface.

3. The first rise of ooze into a hole after the crust/melt interface was breached was rapid (6-18 feet, within 10 minutes to 18 hours).

4. If left alone, the column of ooze would continue to creep up another 1-3 feet over the next few weeks, before stabilizing.

5. If partly reamed out, the ooze column would rise again to its initial height (±2 feet).

6. If completely reamed out, so that the melt was re-entered a second (or third) time, the ooze column would rise faster and/or farther than it did the first time. The most spectacular, well-documented oozeback was the last surge in KI79-6 on 2/15/79, in which ooze rose 45.8 feet in <10 minutes, after the melt was penetrated for a third time.

7. In cases where closely spaced drill holes tapped the same segregation vein source, ooze moved faster and/or farther in the later hole (compare KI76-1 and KI76-2; KI75-1R and KI79-3).

Kilauea Iki lava lake has continued to lose volatiles throughout much of this period. This is not surprising: Because the volume of melt has decreased steadily with time, the lake must progressively lose all volatiles not fixed in crystalline phases, as F is in apatite. The available observations on emission of sulfur from drill holes suggest, however, that loss of dissolved gases is proceeding faster than crystallization. In 1967-76, drill holes emitted conspicuous amounts of sulfur when the hole first reached partially molten core. Holes in 1979-81 produced no detectable sulfur, even though all of them extended into partially molten rock and some of them (KI81-1, 81-3) extended through the hottest part of the lake.

In conclusion, all lines of observation suggest that Kilauea Iki today is in the last stages of its crystallization. Its partially molten core, though very hot, and still quite thick, is a plastic, of complex rheology, rather than a liquid. The remaining melt is very thoroughly degassed. Although it will be many years before the lake is completely solid, its history as a differentiating self-roofed magma chamber is over.

DESCRIPTION OF THE 1981 CORE LOGS

The logs for the 1981 holes are arranged in numerical, not chronological order. Logging for most holes was done by R.T. Helz. The petrographic log for KI81-5 was made by T.L. Wright.

For each hole there are two logs. The first is a recovery log which gives the dates on which particular depth intervals were drilled and the amount of core recovered. Core recovery was 100% in most cases. Where missing core can be assigned to specific intervals, these gaps are specified.

The second table for each hole is a brief petrographic log of the core. The lake consists mostly of olivine basalt, with 5-10% coarser grained, diabasic segregation veins (Helz, 1980), so the logs describe variations within a fairly narrow range of rock types. Features noted include:

(1) Freshness. Presence and extent of oxidation or other alteration.

(2) Vesicularity. Shape of vesicles. (Foundered crust frequently has vesicles preserved but distorted or partly filled with segregation-vein type material.) Presence of denser layers, even if very thin. (Those in the uppermost part of the lake may mark contacts between slabs of very shallow foundered crust.)

(3) Presence and relative abundance of olivine phenocrysts. The quantity terms used carry the following approximate significance:

olivine-rich	>25%	olivine	by	volume
olivine common	10-25%	"	"	"
olivine present	5-10%	"	"	"
olivine sparse	<5%	"	"	"

Note that these limits have been modified from those given in Helz et al. (1980). New chemical data on the core suggests that these lower limits are applicable to the 1967-1979 core, as well as the 1981 core.

(4) Presence of glass. Glass first appears in the core as black, vitreous specks. The matrix of the rock darkens through dark gray to black as the percentage of glass increases.

(5) Presence of vesicle fillings (anhydrite/gypsum; cristobalite). Presence of whitish bloom on core collected just above steam-water interface. (This is Na_2SO_4, thenardite.)

(6) Presence, thickness, and orientation of diabasic segregation veins.

(7) Presence, orientation of "vertical olivine-rich bodies," and their relation to segregation-vein material, if any.

(8) Presence and character of fractures in the core.

The core was logged from top to bottom, so comparative terms (e.g., "less oxidized," "more olivine-rich," etc.) refer to the immediately preceding interval of core unless otherwise specified. As hole KI81-5 was logged by T.L. Wright rather than R.T. Helz, the style of that log is somewhat different. The core from KI81-5 is very similar to that from KI81-1, 20 feet to the southeast. Differences between these two descriptive logs mostly reflect differences in personal style of logging of the observer, rather than differences in the core.

Most petrographic terminology is standard. A few peculiar field terms occur in these logs, however. "Spotted rock" refers to core that consists of foundered crust, the vesicles of which have been completely filled by segregation material. "Spotted rock" grades up (or down) into rock with partly filled vesicles, to rock with completely open vesicles. "Leopard rock," as in holes KI81-1 and KI81-5, is the same, except that it was cored while partly molten, whereas the "spotted rock" was cored at subsolidus temperatures. The "vertical olivine-rich bodies" (vorbs) referred to are regions with higher concentrations of coarser olivines than the surrounding matrix rock. They usually run up the side of the core, with dips of 70-90°, or occur in patches on one side of the core. They were observed in the 1975, 1976, and 1979 core as well, but are not as explicitly described in the earlier logs. Their petrography and possible origin are discussed in Helz (1980). These vorbs are often described as "vuggy." In this context, "vuggy" means that the rock is quite porous, or coarsely diktytaxitic. The intent is to distinguish the angular or irregular voids in these "vuggy" rocks from vesicles observed in other parts of the core.

In the KI81-1 log there are several references to "white blocky" crystals or oikocrysts. Subsequent examination has confirmed that these are all olivine. It is not yet clear why some olivine is white and some is green.

The "blue zones" referred to in the KI81-5 log are places where the partially molten core devitrified just prior to being drilled. This occurred because drilling was stopped (but the cooling water left running) either (1) because the core barrel was being hauled up or (2) to accommodate the various seismic experiments being conducted during the drilling. In the other 1981 descriptive logs the "blue zones" are referred to as "devitrified zones." The fact that these zones occur 1-2" below the position where drilling was stopped implies that, during drilling, the rock was actually being quenched to temperatures below those at which devitrification takes place 1-2" ahead of the bit, prior to being drilled. This phenomenon has not been observed in earlier core and presumably is the result of a new bit design used in 1981, as described in Hardee *et al*. (1981).

In addition, logs contain a variety of terms used to describe the fractures which form when hot core is quenched by the water used to cool the bit during drilling. These include a set of radial fractures with occasional hackly horizontal breaks in core collected at high subsolidus temperatures (hackly fractures), and closely spaced concentric ("onionskin") fractures in core that was partly molten just prior to being quenched by the drilling water.

Three core boxes from KI81-5 (boxes 13, 14, and 15, containing core recovered between 214.7 and 278.6 feet) fell out of the basket on the tram as they were being lifted over the top of the cliff that surrounds Kilauea Iki crater. The lids of the boxes came part way off, so some core was lost, and the rest broken and scrambled. The boxes were recovered by Jack Harris (HVO), who climbed down the cliff to get them. Individual pieces of core that fell out were not recovered, however, as the cliff was quite steep and it was raining very heavily at the time of the accident.

The core remaining in the boxes was sorted by R.T. Helz, putting like pieces with like as much as possible. However, the location of individual pieces of core from these boxes is a little uncertain, especially from box 15, from which almost 30% of the core was lost. Anyone contemplating using this core for detailed scientific investigation should probably use core from KI81-1 instead.

LOCATION, AVAILABILITY, LABELLING OF CORE

The 1981 core is currently (12/82) being stored at the Hawaiian Volcano Observatory. Requests for this core should be routed through R.T. Helz (U.S.G.S., Reston), to facilitate coordination with other ongoing studies of Kilauea Iki lava lake.

The core boxes were labelled in feet, rather than meters. All depth and most length measurements in the logs are in feet, to make it easier to work with the core as labelled.

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Core Recovery Log for KI81-1

Date	Interval drilled (in feet)	Core recovered (in feet)	Percent Recovery
4/7/81	0.0- 1.1	1.1	100
	1.1- 2.1	1.0	100
	2.1- 3.0	0.9	100
	3.0- 4.1	1.1	100
	4.1- 9.0	4.9	100
	9.0- 11.5	2.5	100
4/8/81	11.5- 21.5	10.0	100
	21.5- 31.5	10.1	100+
	31.5- 41.5	10.0	100
	41.5- 51.5	10.0	100
	51.5- 61.5	10.0	100
	61.5- 71.7	10.2	100
	71.7- 81.7	10.0	100
	81.7- 91.8	10.1	100
4/9/81	91.8-101.9	10.1	100
	101.9-111.9	10.0	100
	111.9-121.9	10.0	100
	121.9-131.9	10.0	100
	131.9-141.9	10.0	100
	141.9-151.9	9.9	99
4/10/81	151.9-161.9	10.0	100
	161.9-171.9	10.0	100
	171.9-181.9	10.0	100
4/13/81	181.9-186.9	4.8	96
	186.9-196.9	9.9	99
	196.9-207.0	10.1	100
	207.0-217.0	10.0	100
	217.0-227.0	10.0	100
	227.0-237.0	10.0	100
4/14/81	237.0-247.0	9.8	98
	247.0-257.0	10.1	100+
	257.0-267.0	10.0	100
	267.0-277.0	10.0	100
	277.0-287.0	10.0	100
	287.0-297.0	10.0	100
	297.0-307.0	10.0	100

Petrographic Log for KI81-1

Depth (in feet)	Description of Core
0.0- 4.1	Highly vesicular core, with moderate to high olivine content. Mostly slightly oxidized. Anhydrite/gypsum present as vesicle linings from 0.4-3.2 ft.
4.1- 9.0	Somewhat less vesicular, more olivine-rich than in above interval. Core at 4.2 relatively fresh, becoming more oxidized with depth. Small segregation at 8.8 ft.
9.0-11.5	Dense layer at 9.0-9.2, underlain by highly vesicular, olivine-rich, oxidized rock, with slightly denser rock from 11.3-11.5.
11.5-21.5	Core from 11.5-11.7 as in the slightly denser layer seen above. It is underlain by coarsely vesicular, slightly oxidized, olivine-rich core from 11.7 to 16.8 ft. Individual olivines in this interval may be as long as one inch. From 16.8 to 17.7 the core is fresh and fairly dense, with moderate olivine content. This dense layer is underlain by vesicular olivine-rich crust (17.7-18.1) followed by a thinner denser layer (18.1-18.3) followed by more highly vesicular, olivine-rich oxidized crust to 21.5 ft.
21.5-31.5	Vesicular crust, olivine content moderate. Upper half of interval somewhat oxidized. Lower half is fresher and the vesicles are consistently smaller than in the overlying crust, though still numerous.
31.5-41.5	Olivine content moderate. Vesicles mostly small, decreasing in abundance downward. Between 32 ft and 38 ft are many flattened, sheetlike vesicles, some containing minor segregation material, and mostly dipping 10°-30°. Top of this interval is slightly oxidized but below 33 ft the rock is quite fresh.
41.5-51.5	From 41.5 to 46.5 the core is somewhat more vesicular than that above. Olivine content moderate to high. Stretched vesicles, lined with segregation material still present, dipping from 0° to 60°. From 46.5 to 51.5 the rock is denser than above except for a very spongy olivine-rich area at 49.7-50.1 ft. Thin segregation at 44.9 ft.

Depth (feet)	Description of Core (KI81-1)
51.5-61.5	Gray core, quite fresh, olivine content moderate, throughout the interval. Steeply dipping vesicle streams present from 52.0 to 58.0 ft. Segregations at: 54.2-54.4 and 61.3-61.5, both dipping 30°.
61.5-71.7	Fresh gray finely vesicular core. Olivine content moderate. Some coarse olivines present. Segregation at: 69.4-69.5. Single very large vesicle (3/4 inches long) at 69.1, partly filled with segregation material.
71.7-81.7	Fresh gray finely vesicular to diktytaxitic rock. Olivine content decreases with depth from moderate to rather sparse. Most olivine quite small. Segregations at 71.9, 75.9-76.6, and 77.2-77.3.
81.7-91.8	Fresh core, finely vesicular to diktytaxitic. Small olivines present. Segregations at: 86.2-88.4 and 91.1-91.8. The upper vein was "melt" in 1967.
91.8-101.9	Fresh gray core, finely vesicular to diktytaxitic. Small olivine present throughout, but somewhat more abundant between 100-101.9 ft. Segregations at: 91.8-92.0 (continuous from above interval) 96.7-96.8, 100.1-100.2, plus minor patches at 92-93 ft.
101.9-111.9	Fresh gray diktytaxitic rock; olivine content decreases downward. Segregations at: 102.7-102.8, 103.1-103.5 (dipping 60°) 109.1-109.2.
111.9-121.9	Gray diktytaxitic core. Olivine sparse. Core shattered during drilling, with fractures running at high angles to the core. Segregations at 112.1-113.1 and 114.5-117.8. Upper vein contains olivine.
121.9-131.9	Gray diktytaxitic core. Olivine content increases from top to bottom. Small olivines common by 131.9 ft. High-angle fractures continue to 130 ft. Segregations at: 122.0, 124.1-126.1. Lower one contains olivine.

Depth (feet)	Description of Core (KI81-1)
131.9-141.9	Fresh gray core, diktytaxitic. Large olivines present. Olivine common to abundant. Vertical olivine-rich bodies present from 134 ft on down.
	Na_2SO_4 bloom present from 134.7-137.6. Heaviest at 135.5$\pm$0.3 ft.
	Segregations at: 138.7-138.8 (olivine bearing), 140.2-140.3, and 140.8-140.9.
141.9-151.9	Dense gray core, sparsely diktytaxitic except in olivine-rich bodies, which occur throughout the interval. Olivine common to abundant, fresh except at 145.6-146.0, where it is slightly oxidized.
	Segregation at: 146.2-147.0.
151.9-161.9	Core as in above interval. Small segregation, at 157.3-157.4, contains olivine, is associated with vertical olivine-rich body.
161.9-171.9	Dense gray sparsely diktytaxitic matrix. Olivine common to abundant. Vertical olivine-rich bodies present throughout. Radial hackly fractures first appear in core at 167.2 ft; they are present below that depth through the rest of this interval.
171.9-181.9	Fresh core with well-developed hackly fracture. Olivine common to abundant. Vertical olivine-rich bodies present from 171.9-179.0 ft.
	Matrix changes from light gray (where rock is holo-crystalline) at 172-174 ft through greenish gray (177 ft) to dark gray (179-182 ft).
	Unusual clot of fine-grained olivine present at 181.4 ft.
	Segregations at 173.1-173.3 (this was "melt" in 1979) and 178.5-178.7. The lower vein is partly glassy.
181.9-186.9	Olivine-rich core, olivines distributed uniformly throughout. Matrix ranges from dark gray at 182 ft to black at 186.9. Core first develops concentric fractures at about 183 ft.
186.9-196.9	Black, olivine-rich core with concentric fracture. Special textures: at 187.5-188.0, the matrix is coarser, vuggier as in an olivine-rich body, but the concentration of olivine is not anomalous. At 189.5 there is a small segregation, half crystallized, half glassy, as though chilled from one side.

Depth (feet)	Description of Core (KI81-1)
186.9-196.9 (cont.)	At 193.0, and 195.2-196.9 are some olivine-rich bodies, with very abundant coarse olivine. Sporadically developed though this interval are lighter, almost white, blocky crystals, which contrast in color with olivines of the same size. They appear to be oikocrystic, as they usually appear to be full of inclusions.
196.9-207.0	Black, glassy olivine-rich rock. Vertical olivine-glass bodies present from 197-201 ft. Very glassy pocket, present in core from 205.5-206.2 ft, is crystallized around edges but appears to be 100 percent glass in middle. Core plastic, corrugated in this and some other places. The top 3-4 inches of the core in this interval are devitrified because they were exposed to extra cooling water during wire-lining the core barrel. There are similar small bluish devitrified zones present in several places within this interval. These mark depths where the drill was turned off during seismic experiments.
207.0-217.0	Black, glassy friable core. Olivine very abundant. Higher concentrations of very coarse olivine + glass present at 210.4-211.0 and 214.3-215.3. Plagioclase sparse in these areas. Upper 3-4 inches of core devitrified as in preceding interval.
217.0-227.0	Black, very glassy, friable cores. Olivine very abundant. Concentration of coarse olivine + glass present at 218.8, 220.8-221.3, 222.7, and from 224.3-225.2. Some of these quite open, vesicular. This and the preceding interval are the blackest, probably the most glass-rich core, and may be the zone of maximum temperature.
227.0-237.0	Black, very glassy core. Olivine abundant, mostly uniformly distributed. In this interval, it is more obvious than usual that the zone of maximum devitrification is 1-2 inches below the very top of the interval. Exterior surface of core finely corrugated throughout this interval.

Depth (feet)	Description of Core (KI81-1
237.0-247.0	Black, glassy friable core. Concentric fractures. Olivine coarse, abundant. Vuggy olivine-glass concentrations at 242.0-243.0, 245.5 and 246.5.
247.0-257.0	Black, glassy friable core, with concentric fractures. Olivine abundant, uniformly distributed. Somewhat glassier sections at 250.8-251.1. Unusual area at 254.0 looks like "leopard rock."
257.0-267.0	Glassy olivine-rich core from 257-261 ft. Olivine, glass contents decrease downward through this interval. The whitish, blocky oikocrysts, present at 187-197 ft, reappear in this interval.
267.0-277.0	Black friable core. Coarse green olivine phenocrysts decrease from moderate to scarce downward, except for a thin layer of olivine-rich rock at 271.1-271.2 ft. Whitish blocky oikocrysts (?) of olivine prominent throughout except in two intervals (272.3-273.3 and 274.5-275.0). These intervals seem to be glassier, are more strongly corrugated, but contain olivine phenocrysts and show no tendency to coarser grain size in the matrix (i.e., they are not segregation veins).
277.0-287.0	Core from 277.0-284.5 is almost all leopard rock, in bands 1-3 inches thick separated by rock without relict vesicular structure. The spots are black glass, the glass in the lowest set (at 284.5) is irridescent. The olivine content of this zone is much higher than that in the preceding interval. From 285.0-287.0 the core is black glassy, and with moderately abundant coarse olivines. It is necked down and heavily corrugated as though quite plastic when drilled.
287.0-297.0	Core in this interval has a dark gray to black matrix. Glass content appears to be slightly higher toward the bottom. Coarse olivines sparse to moderately abundant. Whitish blocky crystals of olivine present throughout. Streaks of irridescent glass present from 289.7-290.5 ft = sheared leopard rock? Patches of leopard rock, some partly sheared, present from 294.0-296.4 ft.

Depth (feet)	Description of Core (KI81-1)
297.0-307.0	Black core with concentric fracture, sparse coarse green olivines, abundant whitish blocky crystals from 297-298.0. Leopard rock from 298.2-299.0. Olivine and glass-rich layer, between 299.2-299.3, is necked-down, corrugated as though plastic when drilled. Remaining core contains moderately abundant coarse olivines, many whitish blocky crystals (1-3 mm). Is otherwise uniform except for rare streaks, spots of black glass.
At 307.0	Hole terminated. Core still has a black, glassy matrix, with concentric fractures well-developed.

Core Recovery Log for KI81-2

Date	Interval drilled (in feet)	Core recovered (in feet)	Percent Recovery	Gaps (in feet)
4/16/81	0.0- 1.2	1.2	100	
	1.2- 3.8	2.5	93	
	3.8- 8.8	5.0	100	
4/17/81	8.8- 18.8	10.0	100	
	18.8- 28.8	10.0	100	
	28.8- 37.8	9.0	100	
	37.8- 39.8	2.0	100	
	39.8- 49.8	10.0	100	
	49.8- 60.0	10.2	100	
	60.0- 70.0	10.0	100	
	70.0- 80.0	10.0	100	
	80.0- 90.2	10.2	100	
	90.2-100.0	9.8	100	
4/20/81	100.0-110.1	10.1	100	
	110.1-120.1	10.0	100	
	120.1-130.1	10.0	100	
	130.1-140.1	9.5	95	130.1-130.6
	140.1-150.1	10.0	100	
	150.1-160.3	10.2	100	
	160.3-170.3	10.0	100	
4/21/81	170.3-180.5	10.2	100	
	180.5-190.5	10.0	100	
	190.5-200.7	10.2	100	
	200.7-210.9	10.2	100	
	210.9-220.9	4.0	40	(214.9-220.9)
4/22/81	215 -217	1.8	90	
	217 -226.0	9.0	100	
	226.0-236.0	9.8	98	

On the afternoon of 4/21/81 the hole was cased to a depth of 221 ft. Core taken above this depth was NX. The following day the driller re-entered with a narrower string, drilled out the core dropped the day before (between 215 and 221 ft) and extended the hole below the casing to 236.0 ft.

Petrographic Log for KI81-2

Depth (in feet)	Description of Core
0.0- 3.8	Highly vesicular olivine-rich core, slightly oxidized 0.0-2.0 ft, strongly oxidized 2.0-3.8 ft. Anhydrite/gypsum linings in vesicles present sporadically 0.0-3.8 ft.
3.8- 8.8	Oxidized core, olivine and vesicle content moderate to high. Minor segregation at 7.1 ft.
8.8- 18.8	Core oxidized 8.8-9.2; mostly fresher below that. This interval consists of segments of highly vesicular olivine-rich core, separated by denser layers at 9.2-9.3, 12.0-12.9, 13.8-14.2, 14.5-15.8 (spotted rock), 16.2-16.5, 17.2-17.3, and 18.7-18.8. Olivines up to 1 cm in length present. One segregation at 17.6-17.7, plus minor stringers of segregation material in vesicles or at the top of the dense layers, notably those at 16.2-16.5 and 17.2-17.3.
18.8- 28.8	Slightly oxidized olivine-rich core, vesicles smaller than above, but still abundant (18.8-22.0). From 22.0-25.4 the core is fresher, more coarsely vesicular, and with less olivine than in the overlying rock. Several of the larger vesicles contain patches of a whitish powdery deposit ($CaSO_4$? or Na_2SO_4? or other?). Below 25.4 the vesicles again decrease in size, the core is somewhat more oxidized, but the olivine content remains moderate.
28.8- 38.8	Slightly oxidized core, olivine content moderate. Scattered large olivines present. Some large, steeply dipping vesicles at 31.0-31.5. Otherwise vesicles are undeformed and mostly quite small. A vertical cooling crack (pre-existing) runs through the core from 32.5-38.8 ft.
38.8-49.8	Core slightly oxidized (38.8-47.8) fresh below that (47.8-49.8). Olivine content moderate; large olivines still present. Large stretched vesicles, most partly filled with segregation material, occur throughout. Their dips are low and quite variable, even within a single piece of core. Segregation at 43.8.

Depth (feet)	Description of Core (KI81-2)
49.8- 60.0	Core fresh throughout. Olivine content as in above interval. Most vesicles small, except where associated with minor segregation material. Some stretched vesicles present, dips variable. Segregations at 50.5, 57.7, 58.3.
60.0- 70.0	Core fresh. Finely vesicular except where segregation material present. Olivine content moderate to 63 ft, perceptibly less below that. Segregations at: 64.2, 65.6-66.6 (highly irregular, mostly runs up one side of the core) and 67.6 ft.
70.0- 80.0	Fresh, finely vesicular core. Olivine present, large crystals rare. One large, empty vesicle at 71.0 ft. Segregations at: 72.6-74.2, 78.1-78.8.
80.0- 90.2	Fresh finely vesicular gray core. Small olivines present, mostly quite sparse except at 85-88. Segregations at 83.0, 88.2-88.6 (this last has a spongy transitional zone below, separating the segregation proper from the matrix rock).
90.2-100.0	Fresh, finely vesicular to diktytaxitic gray core. Olivine sparse. Segregations at: 94.9-95.4, 99.3-100.0
100.0-110.1	Fresh gray diktytaxitic core. Olivine present, sparse by 110 ft. Large empty vesicle at 102.9 ft. Segregations at: 104.0-104.3, 107.1-107.3.
110.1-120.1	Fresh gray diktytaxitic core. Olivine sparse throughout. Core shattered during drilling (115-120 ft). Large empty vesicle at 112.4 ft. Segregations at: 112.5-114.2 ft (olivine-bearing), 116.8-117.1, 119.9-120.1 (olivine-bearing).
120.1-130.1	Fresh gray diktytaxitic to dense core. Olivine sparse (120-127), more abundant below 127 ft. Core shattered, locally with conchoidal fracture, especially from 126-130 ft. Sharp contact within matrix rock at 129 ft = olivine-poor diapir track? Segregation at 120.1-121.3 continuous from above interval.

Depth (feet)	Description of Core (KI81-2)
130.1-140.1	Dense gray core. Olivine present (130.6-131.6) and moderately abundant below 132 ft. Vertical olivine-rich bodies present below 136 ft. Much of core above that (131-136) has a slightly mottled appearance. Segregation at 137.4-138.3 (olivine-bearing, quite dense, just above olivine-rich body).
140.1-150.1	Dense gray core, olivine moderate to abundant throughout. Vertical olivine-rich bodies present throughout. These contain the first really coarse olivines (at 143.7-144.1) seen since 60 ft or higher. Na_2SO_4 bloom best developed at 147.6 ft. Segregations at 144.1-145.5 (This one bounded above and below by olivine-rich body; contacts dip 60°.) and 149.3-150.1. Neither contains olivine.
150.1-160.3	Dense gray core. Olivine content moderate to high. Vertical olivine-rich bodies well-developed throughout. These are associated with minor segregations (near their tops?) at 152.4-153.4 and at 155.6-157.6. There is an especially clear gradational contact between olivine-body and segregation at 157.6 ft. Segregation at: 157.0-157.6. This and all minor stringers dip 60° throughout this interval, but they are not parallel.
160.3-170.3	Dense gray core, olivine content moderate to high. Vertical olivine-rich bodies present throughout. Core breaks with hackly radial fracture from 165.1 ft on down. Segregation at: 161.1-161.8 (grain size quite variable).
170.3-180.5	Fresh dense core. Matrix color deepens from greenish gray to dark gray in this interval. Olivine content moderate to high. Vertical olivine-rich bodies present but not especially well-developed in this interval. Minor segregations at: 171.3, 171.5, 173.6, 174.9

Depth (feet)	Description of Core (KI81-2)
180.5-190.5	Dense core. Matrix dark gray to black. Olivine content and distribution as in preceeding interval. Concentric cooling fractures present from 189 ft on down.
	Minor glassy partings at 188.6, 189.5. Both underlain by olivine-rich pockets.
190.5-200.7	Black, olivine-rich core. Olivine distribution more irregular than in preceeding interval, with small layers and pockets high in olivine scattered throughout.
	Exterior of core finely corrugated (192-200.7).
200.7-210.9	Black, olivine-rich core. Glassier, more strongly corrugated below 206.8 ft.
	Olivine- and glass-rich areas at 209.4, 210.2 ft. Core otherwise uniform.
210.9-214.9	Dense, olivine-rich oxidized piece of rubble at top from gap at 130-130.5 ft.
	Black glassy core, corrugated exterior. Very olivine-rich. Upper 3-4 inches chilled by cooling water run during preceeding core lifting.
	Concentrations of coarse olivine + glass at 211.6 (vuggy) and 214.7.
215 -217	Black, olivine-rich core. Much devitrification from preceeding day's drilling water.
	No signs of flowage in core. This must be the core dropped yesterday, not material which moved up into the casing overnight.
217 -226	Black glassy olivine-rich core, with olivine-glass concentration present in four places.
	Olivine distribution uniform overall; these concentrations are more glass-rich, than olivine-rich.
226 -236.0	Black glassy olivine-rich core. Especially glassy 226-229 ft. Olivine distribution uniform as in above interval.

Core Recovery Log for KI81-3

Date	Interval drilled (in feet)	Core recovered (in feet)	Percent Recovery	Gaps (in feet)
4/8/81	0.0- 1.0	0.7	70	
	1.0- 2.0	0.9	90	
	2.0- 3.0	0.9	90	
	3.0- 4.0	1.0	100	
	4.0- 5.0	1.2	100+	
	5.0- 10.0	4.8	96	
4/9/81	10.0- 17.5	7.3	97	
	17.5- 22.0	2.5	100	
	22.0- 32.0	10.0	100	
	32.0- 42.0	10.0	100	
	42.0- 52.0	10.0	100	
4/10/81	52.0- 62.0	10.0	100	
	62.0- 72.0	10.0	100	
	72.0- 82.0	10.0	100	
	82.0- 92.0	10.0	100	
4/13/81	92.0-102.1	10.1	100	
	102.1-112.1	10.0	100	
	112.1-122.1	9.9	99	
	122.1-132.1	10.0	100	
4/14/81	132.1-142.1	10.0	100	
	142.1-152.2	10.1	100	
	152.2-162.2	10.0	100	
4/16/81	162.2-172.2	10.0	100	
	172.2-182.2	10.0	100	
	182.2-192.2	10.0	100	
	192.2-202.2	10.0	100	
	202.2-212.2	10.0	100	
	212.2-222.2	10.0	100	
	222.2-232.2	10.0	100	
	232.2-242.2	10.0	100	
4/17/81	242.2-252.3	10.1	100	
	252.3-258.8	1.8	28	254.1-258.8

Hole terminated because bit disintegrated in hole at 257 ft when driller tried to drill through rubble lost from core barrel.

Petrographic Log for KI81-3

Depth (in feet)	Description of Core
0.0- 5.0	Highly vesicular core, olivine content increasing downward. Rock mostly fresh. Anhydrite/gypsum present from 0.0-3.5 ft lining vesicles.
5.0- 10.0	Highly vesicular, olivine-rich core, slightly oxidized, except for slightly denser layer at 7.0-7.5 ft.
10.0-17.5	Highly olivine-rich, with very coarse olivines between 10.0-12.0. Vesicles and olivines both somewhat less abundant from 12.0 to 15.3. Much of this interval, especially from 13.5-15.3 is spotted rock. From 15.3-17.5, rock is as in 10.0-12.0 interval.
17.5-22.0	Vesicular, olivine-rich crust. Minor segregation material in the larger vesicles. Rock fresh throughout.
22.0-32.0	Olivine-rich, vesicular rock fresh except for the 25-26 ft interval. Zones of flattened, subhorizontal vesicles present intermittently from 22.5-32.0 ft. Most vesicles lined with minor segregation material.
32.0-42.0	Fresh vesicular olivine-rich rock (32.0-34.3) followed by a segregation vein (34.3-34.3). This is underlain by more fresh, vesicular olivine rich rock to 36.1 ft. Core between 36.1 and 37.4 ft is denser rock containing relatively little olivine. From 37.4 to 42.0, the core is slightly oxidized, with olivine moderately abundant. Vesicles are somewhat less abundant in this interval. There is a zone of stretched vesicles from 39.2-40.0 ft. Most vesicles frosted with minor segregation material, as in 22.0-32.0 interval.
42.0-52.0	Top of this interval (42.0-44.1 ft) is finely vesicular, oxidized, with moderate to high olivine content. This is underlain by a segregation vein (44.1-44.7). Matrix rock from 44.7 to 52.0 is finely vesicular to diktytaxitic, with olivine moderate to sparse. Major segregation at 48.3-50.1 ft. Contains much cristobalite in vesicles, no olivine.

Depth (feet)	Description of Core (KI81-3)
52.0-62.0	Core is finely vesicular to diktytaxitic. Olivine content increases somewhat with increasing depth within this interval. Minor stringers of segregation material are scattered throughout this section; some of these are very vuggy or partly line rare large vesicles, especially at 57-58 ft and 59.5-60.5 ft.
62.0-72.0	Finely vesicular rock, with olivine content moderate to high (62.0-67.0 ft). Olivine content and vesicle size decrease in core from 67.0-72.0 ft. Segregations at: 62.3 (dipping 60°), 64.9 (dipping 20°), 65.4-65.5, and 69.1-70.0. The upper contact of this last dips 70°, the lower contact is horizontal. All contain beads of cristobalite, are free of olivine.
72.0-82.0	Finely vesicular rock, olivine content moderate to high (higher than between 67-72 ft). Large olivines (|5 mm long) occur sporadically. Segregations at: 77.5-78.6 (cristobalite, no olivine) and 81.6-82.0 (olivine-bearing). Also present: occasional large vesicles with or without minor patches or infillings of segregation material (especially at 74.9-76.0).
82.0-92.0	Fresh gray finely vesicular to diktytaxitic rock. Olivine smaller, less abundant than in preceding interval. Segregations at: 82.5 (irregular) and 88.5-89.5. Upper contains olivine, projecting into vuggy area; lower is olivine-free.
92.0-102.1	Fresh gray finely vesicular to diktytaxitic rock. Olivines small, sparse. Segregations at 96.6-96.9 (dipping 20°) and 99.6-100.5 (dipping 60°), both olivine-free. One large empty vesicle at 98.7 ft.
102.1-112.1	Core as in above interval. No segregations.

Depth (feet)	Description of Core (KI81-3)
112.1-122.1	Fresh gray diktytaxitic rock. Olivine somewhat coarser, more abundant from 112.1-117.9 ft, again decreasing in size and abundance below that interval. Segregations at: 113.0, 115.7-116.3. Lower one is olivine-bearing, especially near its basal contact. Core breaks readily with conchoidal fracture 118-122.0.
122.1-129.3	Core broken into angular fragments with conchoidal fracture. Rock is fresh, diktytaxitic. Small olivines present. Segregations at: 124.6, 125.4.
129.3-132.1	Fresh diktytaxitic core. Olivines small, sparser than in above interval. Core still shattered, with high-angle fractures. Segregations at: 130.7-131.0.
132.1-142.1	Fresh gray diktytaxitic rock. Olivines increase markedly in size and abundance through this interval. Lowest section (140-142 ft) contains the first vertical olivine-rich body seen in this core, but the olivines in it are all fairly small (1-5 mm). Segregations at: 133.8-134.8, 136.7-136.9, 140.0-140.1. All contain olivine, very few vesicles.
142.1-152.2	Segregation vein (olivine-bearing) continues from above interval to 143.1 ft. Below that the core is gray, dense to diktytaxitic. Olivine continues to increase in grain size and abundance. Vertical olivine-rich bodies sporadically present throughout. Na_2SO_4 bloom at 145.3-149.0 ft. Segregations at: 150.1-150.7 and 152.2 (both olivine-bearing).
152.2-162.2	Light gray, dense to diktytaxitic olivine-rich core. Vertical olivine-rich bodies present, slightly vuggier than normal matrix. Segregations at: 152.2-152.5, 154.8-154.9. Also irregular, steeply dipping patches of very coarse-grained segregation material from 159.2-161.6.

Depth (feet)	Description of Core (KI81-3
162.2-172.2	Core as in above interval. Core breaks with hackly radial fracture below 169.0 ft. Segregations at: 167.3-167.5 (olivine-rich, for a segregation vein) and at 168.4.
172.2-182.2	Dense olivine-rich core, with light gray to greenish gray matrix. Coarse olivine (5-12 mm) more abundant than in above intervals. Small segregation at 174.0.
182.2-192.2	Dense olivine-rich core. Matrix darkens from dark gray to nearly black in this interval. Concentric cooling fractures well-developed. Small segregation at 185.4 ft is glassy in middle.
192.2-202.2	Olivine-rich core with black glassy matrix. Olivine + glass-rich areas scattered throughout; the glassiest of these (at 200.2) is quite vuggy. There is a glass-rich vein with small olivines present at 198.2-198.4. The crystals in it are no coarser than in the surrounding matrix (i.e., they do not have segregation type habits).
202.2-212.2	Blacker core than in above interval. Olivine-rich throughout. Olivine + glass-rich areas still present. Glassier-looking pocket at 204.0 ft, like vein at 198.2-198.4 in above interval.
212.2-222.2	Very black, olivine-rich core. Olivine distribution uniform. Some very coarse olivines (1 cm square) present.
222.2-232.2	Core as in above interval, except that it is more strongly corrugated on the outside. Olivine distribution uniform.
232.2-242.2	Core as in above interval. Olivine distribution still uniform.
242.2-252.3	Core very black, glassy and olivine-rich except for a small section at 242.6-243.0 ft, which is olivine-poor, vesicular, and appears to be more crystalline. The core from 245.0-252.3 ft is very heavily corrugated, like the core from the lowest parts of KI75-1 and KI79-1.
252.3-254.1	Very black, glassy, olivine-rich core, much deformed. Evidently cooling water circulation was very poor.

Core Recovery Log for KI81-4

Date	Interval drilled (in feet)	Core recovered (in feet)	Percent Recovery	Gaps (in feet)
4/28/81	0.0- 1.0	1.0	100	
	1.0- 3.0	0.3	15	?
	3.0- 3.5	0.5	100	
	3.5- 4.5	0.8	80	
	4.5- 5.0	0.5	100	
	5.0- 10.0	5.0	100	
	10.0- 12.1	2.1	100	
4/29/81	12.1- 22.1	10.0	100	
	22.1- 24.4	2.3	100	
	24.4- 32.4	8.0	100	
	32.4- 42.3	9.9	100	
	42.3- 52.4	10.1	100	
	52.4- 62.5	10.1	100	
	62.5- 72.6	10.1	100	
	72.6- 82.6	10.0	100	
	82.6- 92.6	10.0	100	
	92.6-102.4	9.8	100	
	102.4-112.4	10.1	100+	
	112.4-122.4	10.0	100	
	122.4-132.4	10.0	100	
4/30/81	132.4-142.4	10.0	100	
	142.4-152.5	10.1	100	
	152.5-162.5	10.0	100	
	162.5-172.5	10.0	100	
	172.5-181.7	9.2	100	

Petrographic Log for KI81-4

Depth (in feet)	Description of Core
0.0- 5.0	Highly vesicular core. Uppermost foot slightly oxidized, the rest fresh. Olivine content moderate. Anhydrite/gypsum present as vesicle lining throughout this interval.
5.0- 10.0	Highly vesicular, olivine-rich core, slightly oxidized, except for the core from 6.2-6.7 ft, which is denser and relatively fresh.
10.0- 22.1	From 10.0-13.0, the core is highly vesicular, olivine-rich and mostly slightly oxidized. This is underlain by a dense layer (13.0-13.4) which is fresher and has less olivine. From 13.4-16.7 the core is again very vesicular and olivine-rich, but the vesicles are mostly smaller than at 10.0-13.0 ft, and the rock is fresh. Between 16.7-18.2, the rock is mostly denser, with some spotted rock. From 18.2-22.1, the rock is again highly vesicular and olivine-rich, and is oxidized except for the 21-22 ft interval.
22.1- 32.4	Fresh core, highly vesicular and olivine-rich throughout. Some very coarse olivines present (1-2 cm long). Many of the larger vesicles are partly lined with segregation material. Segregations at: 22.9-23.1, 26.2-26.5.
32.4- 42.3	This interval consists of several layers of very vesicular, olivine-rich core, separated by denser layers or segregation veins, or both. Denser layers at: 33.4-33.9, 34.7-35.0, 36.3-36.5, 37.2-37.5, 41.0-41.1. Segregations at: 33.4, 33.9, 34.7, 36.3, 36.5, 37.2, 37.5, 39.0, 40.4, 41.0, 41.5, 42.3. There is a strong tendency for segregations to occur at the contact (especially the upper contact) of the dense layers with the more vesicular crust.

Depth (feet)	Description of Core (KI81-4)
42.2- 52.4	Uppermost core (42.3-43.5) is highly vesicular, with large flattened vesicles lightly coated with segregation material. From 43.5-52.4 the vesicle content is considerably lower, though large stretched vesicles, dipping 0-60°, are present throughout. As usual, dips vary considerably within a single piece of core. Olivine content initially high, decreases as vesicle content decreases. Large olivines present throughout.
52.4- 62.5	Moderately vesicular fresh core. Olivine content moderate; coarse olivines still present. Larger vesicles stretched out, lined with segregation material; dips variable. Segregation at: 55.2-55.4.
62.5- 72.6	Fresh core. Vesicles small except where associated with segregation material. Olivine phenocrysts fairly common; coarse olivines present throughout. Segregations at: 62.6-63.6, 64.6-64.8, 67.4-67.6, 70.7-70.8.
72.6- 82.6	Fresh gray, finely vesicular core. Olivine present; crystals mostly small (<3 mm). Segregation at 75.0-77.8.
82.6- 92.6	Fresh gray finely vesicular core. Olivines sparse, but rare large olivines (>5 mm) present even at 92.4 ft. Segregations at: 87.1-87.2, 87.4-88.6, 91.9-92.3.
92.6-102.4	Finely vesicular to diktytaxitic core. Olivines small, sparse. Segregations at: 96.9, 101.0, 101.2.
102.4-112.4	Core as in above interval. Segregations at: 106.5-106.8, 108.7-111.1.
112.4-122.4	Gray diktytaxitic core. Olivine sparse. Segregations at: 112.3-112.5, 113.9-117.4, 119.1-119.5.

Depth (feet)	Description of Core (KI81-4)
122.4-132.4	Core diktytaxitic to dense, much shattered by drilling. Olivine sparse.
	Segregation at: 127.7-128.6.
132.4-142.4	Gray diktytaxitic core, olivine content moderate to high. Most olivines small. Vertical olivine-rich bodies present especially at 137-140 ft.
	Segregation at: 133.7-135.5 (lower contact gradational-??), 141.0-141.9.
142.5-152.5	Dense gray core, olivine content moderate to high. Olivine-rich bodies present sporadically through the interval, but most olivines are not particularly coarse (1-5 mm).
	Segregations at: 143.8-143.9, 144.1-144.2, 146.6-147.5, 148.8-150.0, all olivine-bearing. The lowest one was melt in 1976.
152.5-162.5	Core as in above interval, except that olivines are coarser (up to 1 cm) especially in the vertical, olivine-rich bodies, and somewhat more abundant. Incipient hackly fracture at 162.5 ft.
	One large segregation at: 157.7-158.8.
162.5-172.5	Dense core, olivine-rich throughout. Radial hackly fracture well developed below 165.5 ft. Matrix varies from light gray to greenish gray within this interval, but is not consistent with depth.
	Vertical olivine-rich bodies, with very coarse olivines, prominent from 168-172.5.
172.5-181.7	Dense core, very olivine-rich. Matrix color deepens from greenish gray to almost black in this interval. Olivine-rich bodies present throughout.
	Many small segregations at: 173.4, 173.6, 175.1-175.5 (scattered pockets), 178.0-178.1, 178.6-179.0, 179.3. The last three are quite glassy.

Core Recovery Log for KI81-5

Date	Interval drilled (in feet)	Core recovered (in feet)	Percent Recovery	Gaps (in feet)
4/28/81	0.0- 1.2	1.2	100	
	1.2- 2.4	1.2	100	
	2.4- 5.0	1.5	58	?
	5.0- 10.0	5.0	100	
	10.0- 12.0	2.0	100	
	12.0- 17.0	5.0	100	
	17.0- 27.0	10.0	100	
	27.0- 37.0	9.9	99	
	37.0- 47.1	10.1	100	
	47.1- 57.1	10.0	100	
	57.1- 67.1	9.9	99	
	67.1- 77.3	10.2	100	
	77.3- 87.4	10.1	100	
4/29/81	87.4- 97.5	10.1	100	
	97.5-107.5	10.0	100	
	107.5-117.6	10.1	100	
	117.6-127.6	10.0	100	
	127.6-137.7	10.1	100	
	137.7-147.8	10.1	100	
	147.8-158.0	9.8	98	
	158.0-168.0	10.0	100	
	168.0-178.1	10.1	100	
	178.1-188.1	10.0	100	
4/30/81	188.1-198.1	10.0	100	
	198.1-208.1	9.9	99	
	208.1-218.1	8.0	100	216.1-218.1
	218.1-228.2	10.1	100	
	228.2-238.3	10.1	100	
	238.3-248.3	10.0	100	
	248.3-258.3	10.0	100	
	258.3-268.3	10.0	100	
5/ 1/81	268.3-278.3	9.9	99	
	278.3-282.3	3.7	92	
	282.3-288.3	5.5	92	
5/ 4/81	Drilled out 1-2 inches of ooze with olivine, plus part of the bit matrix broken off 5/1/81. Very flinty.			

Petrographic Log for KI81-5

Depth (in feet)	Description of Core
0- 1.6	Coarsely vesicular, moderately olivine rich core.
1.6- 2.4	Less vesicular, more olivine than above interval.
2.4- 5.0	Oxidized core, highly vesicular.
5.0- 10.0	Variably vesicular core with numerous finer-grained bands. Rich in olivine throughout. Broken and more oxidized near bottom of interval.
10.0- 12.0	Similar to 5-10 but oxidized throughout.
12.0- 13.4	Finely vesicular and oxidized, still olivine-rich.
13.4- 28.9	Highly variable in vesicularity with numerous fine grained gray bands; olivine-rich throughout, with concentrated olivine at 17.6-19.3, 20.3-20.8.
22.5- 24.2	First notable segregation at 16.2 (less than 1/10 ft wide), second at 23.6-23.7.
28.9- 38.8	More finely vesicular; vesicles seem to be flattened in planes 20° to the horizontal; abundant small (less than 1 mm) olivines; moderately oxidized throughout; planar vesicles become steeper, dipping up to 30° toward bottom of interval.
38.8- 47.4	Planar structure not as obvious, fine gray bands more obvious; coarse and irregularly distributed olivine. Scattered large vesicles associated with segregations. Segregation veins at: 39.95, 41.85, 42.3, 44-44.05 (30°), 44.9-44.95 (30°), 45 ft (irregular segregation material), 45.85-45.9 (30°), 46.0 ft, 46.25, 46.55-46.6 (30°).
47.4- 86.0	Finely vesicular, olivine rich; planar vesicles and gray bands rare. Core becomes gradually finer grained with less frequent segregations toward bottom of interval. Cristobalite coating fracture at 50.8 ft. Segregations at: 50.8, 54.0, 54.9 (45°), 56.8; 57.3, 58.1 (30°), 58.9-60.4 (20°), 60.9, 61.5-61.6, 61.7, 61.85-large ilmenite coated cavity, 62.15-62.25, 66.4-66.7 (20°), 68.0=ilmenite-coated cavity, 69.35-69.75, 73.2-73.7 (irregular boundaries, lower one quite steep), 78.2-78.6, 85.2-85.4.

Depth (feet)	Description of Core (KI81-5)
86.0-137.7	More finely vesicular than above, moderately abundant olivine. Cavities up to 1 cm coated with cristobalite and ilmenite (92.95, 100.35). Patchy coarse olivine at about 137 ft. Segregations at: 87.9, 89.7-89.85, 93.1, 93.25-93.45, 101.2-101.95 (45° top contact, irregular bottom contact), 103.7-104.6, 109-109.65, 113.65-114.9 (top contact 0°, bottom 20°), 119.2-120.8 (30°), 122-122.3 (20°), 123.7, 123.8-124.2 (low angles-15°), 131.4. Na_2SO_4 bloom on core at 127.8-128.4, 130.3-131.3, 133.7-134.5.
137.7-150.0	Alternating very olivine rich zones with less olivine rich zones marked by some gray bands. Olivine-rich zones: 137.7-138.3, 138.8-140.5, 141.1-141.7, 143.5, 144.2-144.3, 147.5-148.4, 149.0-149.2. Olivine-rich bands have irregular top and bottom contacts and are distinguished from adjacent core by somewhat coarser and much more abundant olivine. Segregations at: 138.4-138.5 (irregular contacts), 144.7-144.85 (20°), 149.55-149.8 (irregular segregation patches), 149.9-150.0 (45°).
150.0-188.1	Fine grained matrix with some gray bands. Irregularly distributed large olivine (1-4 mm) throughout interval. Core changes color from gray to dark gray toward base of interval. This reflects an increase in glass content. Olivine concentrations at 151.9-153.1, 167-167.3 (45°), 167.5-167.7 (nearly vertical), 180.5-180.9 (steep contacts, irregular). Segregations are coarser and quite irregular with a glassy matrix. Segregations at: 153.7 (45°), 153.85-154.1 (45°), 154.7, 158.8 (45°), 160.45-160.8 (steep, discontinuous contacts), 164.05-164.34 (discontinuous), 164.5-164.6 (45°), 168.6-168.7 (45°), 169.65-169.75 (30° irregular), 172.3-172.4 (irregular), 176.3-176.4 (irregular), 177.05-177.85 (vertical=running up one side of the core), 178.8-179.3 (vertical, glassy when collected), 181.7-181.9 (same as latter), 182.1 (45°, glassy stringer).
188.1-248.3	Olivine-rich glassy core throughout this interval. Core is marked by bluish finer grained (devitrified) intervals and by zones of olivine-glass concentrations. Blue zones: 188.1-188.6, 198.15-198.25, 218.15-218.3,

Depth (feet)	Description of Core (KI81-5)
	228.2-228.3, 242.6-242.75. These mark stoppages in the drilling, during which time the cooling water was left running. Olivine-glass zones: 195.8-196.3, 198.3-198.8, 200.9-201.1 (more glassy), 204.7-204.8, 206.1-206.3, 211.9-212.0, 212.7-212.85, 220.1-221.2 (very patchy), 223.0-223.1, 225.0, 225.3, 227.7-227.9 (high angle, patchy), 229.9-230.1, 236.4-236.5, 236.8-237.25, 239.5-239.8, 240.35, 241.8-242.0, 242.15-242.3 (45° lower contact).
248.3-268.5	Similar to last interval but somewhat smoother surfaces on core; rich in coarse olivine throughout. Blue devitrified zones at 248.35-248.45, 258.3-258.45. Two olivine rich segregations present; these differ from the olivine-glass concentrations in having a matrix of glass and acicular plagioclase: 256.6-256.8 and 259.3-260.85.
268.5-278.3	Smoother surfaces on core, finer grain size. Less olivine than previous interval, some more glass rich bands. Two zones: 268.5-268.9 and 272.0-272.1 are devitrified.
278.3-286.35	Leopard rock; one devitrified zone at 282.45 to 282.6 (with some segregation).
286.35-288.3	Normal core; abundant scattered coarse olivine in fine grained glassy matrix.

Core Recovery Log for KI81-6

Date	Interval drilled (in feet)	Core recovered (in feet)	Percent Recovery
4/20/81	0.0- 1.0	1.0	100
	1.0- 2.0	0.6	60
	2.0- 3.0	0.9	90
	3.0- 4.0	1.1	100+
	4.0- 5.0	0.8	80
	5.0- 10.0	4.5	90
4/21/81	10.0- 12.0	2.0	100
	12.0- 22.1	10.1	100
	22.1- 32.1	9.9	99
	32.1- 42.1	9.9	99
	42.1- 52.1	10.0	100
	52.1- 62.1	10.0	100
	62.1- 72.2	10.1	100
4/22/81	72.2- 82.0	9.8	100
	82.0- 92.0	10.0	100
	92.0- 93.6	1.6	100
	93.6-102.0	8.4	100
	102.0-112.0	10.0	100
	112.0-122.0	10.0	100
	122.0-127.7	5.7	100
	127.7-132.0	4.3	100
	132.0-142.0	10.0	100
4/23/81	142.0-152.0	10.0	100
	152.0-162.0	9.8	98
	162.0-172.0	10.0	100
	172.0-182.0	9.9	99
	182.0-192.0	10.0	100
	192.0-202.0	10.0	100
	202.0-205.1	3.1	100

Petrographic Log for KI81-6

Depth (in feet)	Description of Core
0.0- 5.0	Highly vesicular, fresh core. Olivine content moderate from 0.0-2.0, high from 2.0-5.0. Vesicle coatings of anhydrite/gypsum present between 0.0-3.6 ft.
5.0- 10.0	Highly vesicular, olivine-rich core, slightly oxidized. Denser layer at 7.1 ft. Small segregations at 8.0, 9.7.
10.0- 12.0	Vesicular olivine-rich core, fresh to slightly oxidized. Vesicles large at 10-11 ft. They are smaller, but still abundant at 11-11.5 ft. There is a dense layer with little olivine at 11.5-11.7, with more of the highly vesicular crust from 11.7-12.0.
12.0- 22.1	The core from 12.0-14.7 is fresh, with vesicle and olivine content both moderate. Spotted rock present at 12.5 and 14.5-14.7 ft. Below 14.7 ft, olivine and vesicle content is generally higher, the olivine being especially abundant. Slightly denser layers at 15.6-16.2 and 16.8-16.9 (spotted rock). Minor segregations at: 17.3, 18.9 and 19.8 (dipping 60°).
22.1- 32.1	Very olivine-rich vesicular rock (22.1-23.1) separated by a dense layer (23.1-23.3) from a zone of rock (23.3-30 ft) with larger, generally more abundant vesicles, but with less olivine, than the core between 22.1-23.1. From 30-32.1 the rock is denser, with irregular, stretched vesicles, but with olivine content as in the 23.3-30 ft interval. Core fresh from 22-30 ft, slightly oxidized from 30-32.1 ft.
32.1- 42.1	Core fresh, with vesicles and olivine moderately abundant 32.1-33.2. Rock is more coarsely vesicular, and slightly oxidized, from 33.2-37.3, with higher olivine content. Between 37.3-37.8 there is a zone of finely vesicular, very olivine-rich rock. Below that, the rock is denser, with occasional zones of large stretched vesicles to 42.1 ft. Olivine content in this last interval (37.8-42.1) is moderate, as in 32.1-33.2 interval.

Depth (feet)	Description of Core (KI81-6)
42.1- 52.1	Core slightly oxidized to 50 ft, fresh below that. Olivine content moderate, decreasing toward bottom of the interval. Most vesicles small, though still quite abundant. Large vesicles usually lined with segregation material. Segregation at: 44.2-44.7 ft.
52.1- 62.1	Fresh core, containing abundant small vesicles throughout. Olivine content moderate; most olivines small. Coarsely vuggy area with minor segregation material at 58.5 ft. Segregation at 60.8 ft.
62.1- 72.2	Fresh, finely vesicular core with small olivines moderately abundant. Segregations at: 62.7 ft, 71.9-72.2 plus minor irregular patches at 69.4 ft.
72.2- 82.0	Fresh gray core, finely vesicular throughout except for coarser vesicles associated with segregation material. Olivine content moderate from 73-78 ft, somewhat lower below that. Segregations at: 72.2-72.5 (continued from above) 77.7-78.0, 80.0, 80.5-81.0, 81.2, 81.8. The uppermost contains olivine. All have beads of cristobalite in their vesicles.
82.0- 92.0	Fresh gray core, finely vesicular except where segregation material present. Olivine content moderate except from 91.7-92.0 ft, where olivine is sparse. Olivines mostly small, but rare large crystals (6 mm long) also present. Segregations at: 83.5-84.7, 85.5, 90.0-91.7 ft. The top 0.5 ft of the latter is finer-grained than most segregations, though very vesicular and appears to be more of a border zone between the normal matrix and the typical diabasic segregation below. None of these contains olivine.
92.0-102.0	Finely vesicular to diktytaxitic fresh core. Olivines small, rather sparse. Segregations at: 96.3-97.6 (olivine-bearing), 101.0-101.2.

Depth (feet)	Description of Core (KI81-6)
102.0-112.0	Fresh gray finely vesicular to diktytaxitic core. Small olivines present. Segregations at: 105.6, 110.9-112.0.
112.0-122.0	Fresh gray diktytaxitic core, with rare large vesicles. Olivines small, sparse. Core broken into sharp angular fragments by drilling. Segregation at: 112.0-112.7, continued from above interval.
122.0-132.0	Fresh gray core, shattered by drilling. Olivine sparse 122-131.0; small olivines moderately abundant 131-132.0 ft. Segregations at 127.7-129.8 (olivine-bearing) 130.2-130.4.
132.0-142.0	Gray diktytaxitic core. Olivine content moderate. Olivines small to 140 ft. They increase in size below that, especially in the olivine-rich bodies present at 140-142 ft. Core in 132-135.9 ft interval shattered, as in above intervals. Segregation at 135.9-137.5 is fairly dense, olivine-bearing.
142.0-152.0	Gray diktytaxitic core. Olivine content increases downward. Olivine-rich bodies present throughout. Coarse olivines present, but not abundant. Na_2SO_4 bloom present 143-146 ft. Segregations at 142.2-143.3 (olivine-bearing) and 149.7-150.1 (dipping 60°).
152.0-162.0	Dense gray core. Olivine content higher. Olivine-rich bodies with abundant coarse olivine present, especially from 160.5-162.0. Segregations at 154.4-154.9, 155.5. The bigger one contains very coarse (1-2 cm long) olivines.
162.0-172.0	Dense gray rock, olivine moderate to abundant. Olivine-rich body with coarse olivines from 162.0-164.5, continues with that in 161.0-162.0 interval. Core breaks with radial hackly fracture below 168.3. Segregations at: 165.4-165.6, 167.6-167.9 (yellowish stains developed on this when core dried. Iron sulfate?)

Depth (feet)	Description of Core (KI81-6)
172.0-182.0	Dense core, olivine moderate to abundant, much of it very coarse. Olivine-rich bodies present locally (as at 176.4-176.7 ft). Matrix color deepens from light gray to dark greenish gray in this interval. One large vesicle present at 180.9 ft.
182.0-192.0	Dense olivine-rich rock. Matrix ranges from dark gray at 182.0 ft to black at 192.0. Olivine + glass-rich bodies present throughout, especially at 189-191 ft. Segregation at: 183.9-184.2 partly glassy.
192.0-202.0	Black olivine-rich rock. Concentric cooling fractures well-developed. Olivine + glass-rich bodies present throughout.
202.0-205.1	Core blacker, glassier. Very olivine-rich olivine- + glass-rich bodies especially conspicuous at 203 and 204 ft. The top 3-4 inches of this last section are devitrified by the cooling water used during hauling up the 192.0-202.0 core.

Core Recovery Log for KI81-7

Date	Interval drilled (in feet)	Core recovered (in feet)	Percent Recovery	Gaps (in feet)
4/23/81	0.0- 1.2	1.2	100	
	1.2- 2.2	1.0	100	
	2.2- 3.2	1.0	100	
	3.2- 5.0	0.6	33	?
	5.0- 12.0	7.0	100	
	12.0- 22.0	10.1	100+	
	22.0- 32.0	10.0	100	
4/24/81	32.0- 37.0	4.8	96	
	37.0- 47.0	10.0	100	
	47.0- 57.0	10.0	100	
	57.0- 67.0	10.0	100	
	67.0- 77.1	10.1	100	
	77.1- 87.1	10.0	100	
	87.1- 97.1	10.0	100	
	97.1-107.1	10.1	100+	
	107.1-117.2	10.1	100	
	117.2-127.2	10.1	100+	
4/27/81	127.2-137.2	10.0	100	
	137.2-147.2	10.0	100	
	147.2-157.2	10.0	100	
	157.2-167.2	10.0	100	

In lowering the overshot assembly down to the bottom at 167 ft, the driller let it drop too hard, breaking off the crown of the bit and thereby losing this hole.

Petrographic Log for KI81-7

Depth (in feet)	Description of Core
0.0- 5.0	Highly vesicular core, olivine content moderate to high. All core slightly oxidized. Minor anhydrite/gypsum in some vesicles (0.0-5.0 ft).
5.0- 12.0	Highly vesicular core, slightly oxidized throughout. Vesicles somewhat smaller than in above interval. Olivine content moderate to high.
12.0- 22.0	Oxidized, highly vesicular, olivine-rich rock (12.0-13.9) underlain by denser fresher layer with moderate olivine content (13.9-14.6). Spotted rock at 14.6 ft. This is underlain by another layer of highly vesicular, olivine-rich core (14.6-16.6), but less oxidized than that at 12.0-13.9. A thin dense layer (16.6-17.0) follows, which is underlain by more highly vesicular olivine-rich rock (17.0-22.0). The top of this layer (17.0-17.7) is spotted rock, in which only about half the vesicles present are filled with segregation material. Segregation at 16.7 is strongly oxidized.
22.0- 32.0	Most of this interval consists of highly vesicular, olivine-rich core. Vesicles decrease in size below 29 ft. Lowest part (31.2-32.0) is relatively dense, with little olivine. Some large vesicles are lined with minor segregation material.
32.0- 37.0	Core finely vesicular, generally denser than above intervals. Olivine content moderate, but individual olivine grains are quite coarse (up to 1 cm).
37.0- 47.0	Fresh core, vesicle content quite variable. Olivine content moderate. Some larger vesicles partly lined with minor segregation material.
47.0- 57.0	Fresh core, with small vesicles moderately abundant throughout. Olivine content moderate. Minor segregation at 56.6 ft.
57.0- 67.0	Fresh core, olivine content moderate. Vesicles small except where associated with segregation material. Segregations at: 60.3-61.1, 62.0-62.2 (top 1/3 of this vein is strongly oxidized. It is the only oxidized rock in the interval), 65.7-66.6 and 66.8 ft.

Depth (feet)	Description of Core (KI81-7)
57.0- 67.0 (cont.)	In addition, there are minor irregular blebs of segregation material between 63 and 65 ft.
67.0- 77.1	Fresh, finely vesicular core. Olivines present, but are mostly small. Segregations at: 68.9-71.0, 73.2-73.8, and 74.3-75.6. In addition there are two swarms of little segregations crisscrossing the core between 71.5 and 73.0, and between 76.0 and 77.1.
77.1- 87.1	Fresh finely vesicular core. Olivines as in preceding interval. Segregations at: 77.2-77.8. Also there is a highly vuggy vertical swirl of segregation material running along one side of the core at 79.4-80.4 ft.
87.1- 97.1	Finely vesicular fresh core, very uniform. Small olivines present. Most vesicles are lined with tiny vuggy crystals. Segregation at 90.3-90.5 (dense).
97.1-107.1	Finely vesicular to diktytaxitic core. Olivine present but is quite sparse by the bottom of the interval. Segregation at: 100.7-102.6 and 102.7. Also present: one large empty vesicle at 100.0 ft.
107.1-117.2	Gray diktytaxitic core, very uniform. Olivine sparse. Segregations at: 107.3-108.3 (vuggy near top) 111.2-111.4 (dense).
117.2-127.2	Gray diktytaxitic core, shattered into elongate flakes with conchoidal fracture during drilling. Small olivines common throughout all but the upper 1-2 ft of this interval. Segregations at: 120.9-122.6, 122.9, 125.6-127.1. The two big veins both contain olivine.
127.2-137.2	Finely diktytaxitic to dense gray core. Olivine content moderate to high. Vertical olivine-rich body at 135-136 ft. Segregations at: 130.8, 134.1-134.2. Both olivine-bearing.

Depth (feet)	Description of Core (KI81-7)
137.2-147.2	Dense gray core, olivine content moderate to high. Olivine-rich bodies present throughout, some with very coarse olivines (especially at 146-147 ft). Segregations at: 137.5, 138.1, 138.3, 141.1-142.1, 143.3-143.6. Relation between olivine-rich bodies and some segregation material well displayed, especially at 142.1-143.0 and 145.0-145.5.
147.2-157.2	Dense gray core. Olivine content moderate to high. Vertical olivine-rich bodies, slightly vuggy, well-displayed in several places. Segregation at: 147.9-148.8, 153.4 ft. A yellow stain appeared on the first as it dried.
157.2-167.2	Core as in above interval. Core first breaks with hackly radial fracture at 167.0 ft. Segregations at: 160.5-160.7 (yellow stain developed as above).