UNITED STATES DEPARTMENT OF THE INTERIOR

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WHOLE-ROCK ANALYSES OF CORE SAMPLES FROM THE 1967, 1975, 1979 AND 1981 DRILLINGS OF KILAUEA IKI LAVA LAKE, HAWAII

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INTRODUCTION

The purpose of this report is to make available 176 analyses of Kilauea Iki drill core, which were obtained between 1968 and 1990 by classical gravimetric analysis. A few of these analyses have been published previously (two in Helz, 1980; one in Wright and Fiske, 1971). In addition, analyses with MgO $< 11.00\%$ (through analytical batch BK52, completed 10/84) were presented as magnesia variation diagrams in Helz (1987a), and all analyses in this earlier part of the data set were presented graphically in Helz and others (1989). However it was not possible to publish the analyses themselves in either paper. In addition to presenting the analytical base for those two papers, this report includes 45 analyses of drill core obtained in four later analytical batches.

BACKGROUND AND PREVIOUS WORK

Kilauea Iki lava lake formed during the 1959 summit eruption of Kilauea Volcano, when lava ponded in the large pit crater just east of the summit caldera (Figure 1). An extended narrative of the eruption is given in Richter and others (1970); further details of the dynamics of magma resupply during the 1959 eruption can be found in Eaton and others (1987). A large suite of lava and pumice samples was collected during the 1959 eruption; bulk analyses of 23 samples of this erupted material were presented by Murata and Richter (1966). Wright (1973) and Helz (1987b) have investigated the role of magma mixing in this eruption, using both the chemical data of Murata and Richter (1966) and additional chemical and petrographic data.

Because Kilauea Iki lava lake has not yet been covered up by subsequent eruptive activity, it has been the object of extensive, long-term study. The earliest core, recovered in 1960-1962, was described by Richter and Moore (1966). Their report includes 20 major-element analyses, plus very detailed petrographic description and modal analysis of the 1960-62 drill core. Workers who wish to use this chemical data on the oldest core should note that some of the Na_2O and K_2O analyses are not correct in the original publication. The corrected analyses are presented in Table 4 of Wright and others (1976).

This report includes data from core recovered in 1967, 1975, 1979 and 1981. The locations of the 1967-1981 drill holes are shown in plan view in Figure 2 and in cross-section in Figure 3. Petrographic descriptions of the individual cores are given in Helz and others (1984) and Helz and Wright (1983). More detailed information on two of the 1979 cores, KI79-3 and ooze from KI79-1, may be found in Mangan and Helz (1986) and in Helz (1993) respectively. The core has

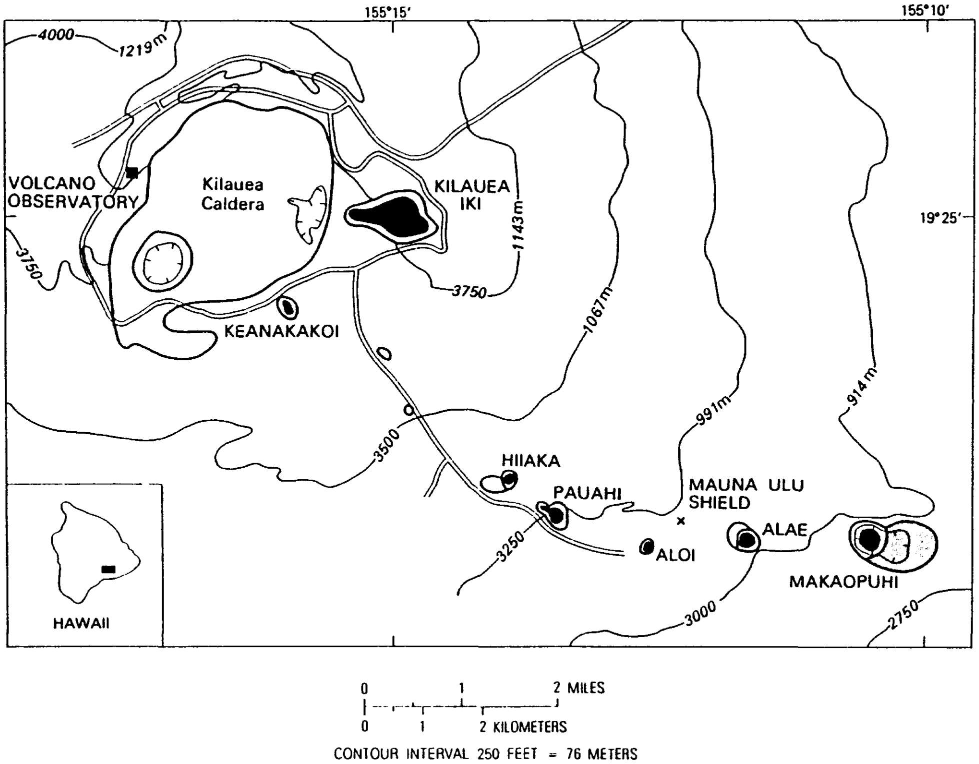


Figure 1. Index map of the summit area of Kilauea Volcano. All historic lava lakes formed to date (1994) are shown in black. The prehistoric Makaopuhi lava lake is shown in the stippled pattern. The historic lava lakes in Aloi, Alae, and Makaopuhi pit craters are now covered by lavas from the Mauna Ulu satellite shield, the summit of which is indicated by the "X".

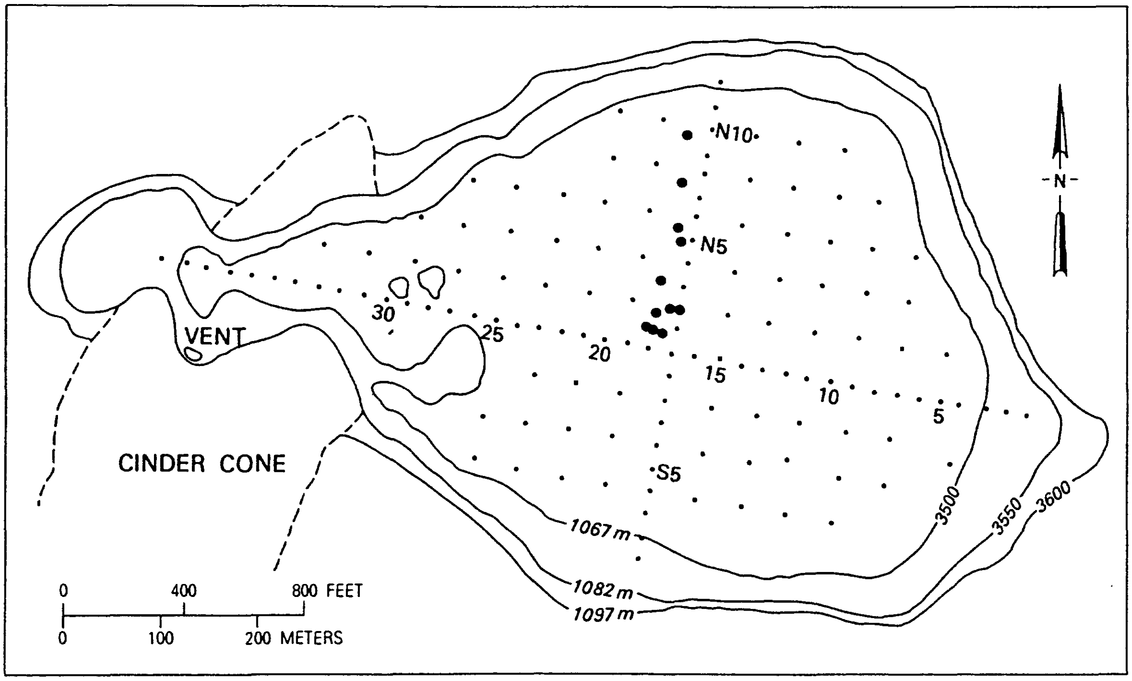


Figure 2. Plan view of the post-1959 surface of Kilauea Iki. The lake surface has a network of levelling stations, the locations of which are shown by the small dots. The larger dots indicate the locations of holes drilled from 1967 to 1981.

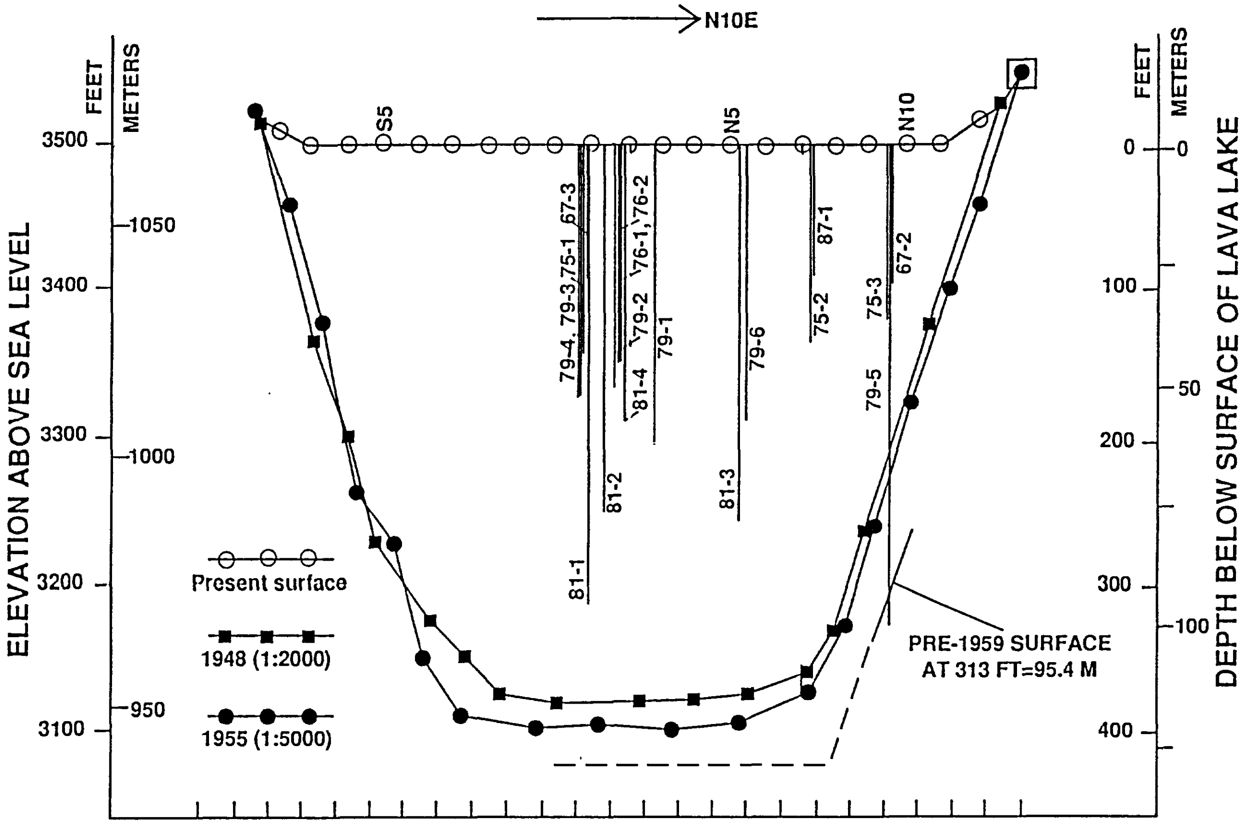


Figure 3. Cross-section of Kilauea Iki lava lake, taken along the N-S line of closely-spaced levelling stations shown in Figure 2. The present surface of the lava lake and two pre-eruption profiles are shown. The two pre-eruption profiles are taken from two different topographic maps: one (at 1:2000) is based on air photos taken in 1948; the other (at 1:5000) is based on air photos taken in 1955. Both maps were prepared by R. Jordan, U.S.G.S., Flagstaff. The present position of the lake bottom (dashed line) has been intersected only at the location of drill hole KI79-5. The vertical exaggeration is 4:1.

The drill holes, which mostly lie along a line 100 feet to the west of this section, are shown as vertical lines projected onto this cross section. Several of the drill hole locations have been reoccupied more than once, in order to sample the same section of the crust in several stages of development. Spacing between these closely-spaced holes is not to scale in this figure.

been sampled extensively, for petrographic and microprobe analysis as well as bulk analysis. Data on glass compositions and their significance were presented in Helz (1987a). In addition, the MgO and CaO contents of glasses in Kilauea Iki have been calibrated for use as empirical geothermometers and the results used to determine temperature profiles through the partially molten sections of the lake, where these were recovered as drill core (Helz and Thornber, 1987).

SAMPLING PROCEDURE

The drill core was sampled for bulk analysis as follows: for the 1967 and 1975 cores, the core was sampled, generally at intervals of 10 feet, down to the partially molten zone, and at closer intervals thereafter, to establish the gross vertical compositional variations within the lake. In addition, some of the internal differentiates of the lake, the segregation veins, were sampled. Lastly the deepest core recovered, whether mush or segregated melt (the "glass-in-bit" samples), was sampled, as were the oozes that flowed into the drill holes between re-entries of the drill string.

There is intentional overlap in the sampling of cores KI67-3 and KI75-1 (see Tables 3 and 4), to the maximum depth of the 1967 core (87 feet). As shown in Figure 3, each of the three 1975 holes was drilled right next to one of the three 1967 holes. The purpose of reoccupying the sites was to allow us to extend the chemical and petrographic section at particular localities. The reason for the overlap in analytical samples from the one locality was to see if there were lateral variations that might occur in the lake even over distances of 1-2 meters. Lateral variations on this scale were found to be minor. Thus, analyses from drill holes within a cluster can be spliced together as a single analytical profile, without introducing serious distortion in the chemical sections.

Having defined the chemical variation in the upper part of the lake at three different sites (see drill hole locations in Figure 3), we sampled the later cores, recovered in 1979 and 1981, more sparingly. Three of the six 1979 cores have been at least partially analyzed: KI79-3 was sampled because it is in the same cluster as KI67-3 and KI75-1. This allowed us to continue the chemical section at that location to 173 feet; as can be seen in Table 8, only the lower parts of that core, recovered from depths below the bottom of KI75-1, were analyzed. The KI79-1 core was sampled between 80 and 204 feet (see Table 7); this core was selected to fill in the rather large gap between the analyzed section in the middle of the lake, and the next section to the north, at the KI67-1/KI75-2 location (see Figure 3). Lastly KI79-5 (Table 9) was sampled extensively both because it reoccupied the KI67-2/KI75-3 locality, and because it was and is still the only core to pass completely through the lava lake.

Of the seven 1981 cores recovered, only one has been sampled extensively for analysis. That one is KI81-1, the deepest hole in the center of the lake, at the locality that was occupied in 1967, 1975 and 1979. Data from this core, in Table 10, extend the chemical section in that part of the lake to 307 feet. The only other sample of 1981 core analyzed to date is the "vein-in-vein" sample from one of the thick segregation veins in core KI81-2. This highly differentiated sample (Table 11) is an unusually large example of a layer produced by pull-apart and melt segregation within a segregation vein, and is the most fractionated sample recovered from the lava lake.

Subsequently, some fill-in sampling was done, focussing on particular problems. A suite of samples was taken from KI81-1, consisting of core from just above a segregation vein, a sample of the vein, core just below the vein, and a last sample one meter (3 feet) below the vein. These samples (in job no. BW59) were analyzed to try to determine whether the liquid in the segregation veins comes from the adjacent mush, of from farther away. Also some of the more interesting oozes recovered during repeated re-entry of the 1979 holes, were sampled for analysis (job no. BT73, data in Tables 7a and 8a). Two of the ooze samples in Table 7a, with MgO = 3.4-3.5%, are unique in the collection. They correspond to liquids that apparently cannot segregate in the lake under natural circumstances, but will flow into an open bore hole (see discussion in Helz, 1987a, on the limits of differentiation in the lava lake).

Each sample to be analyzed was cut from the core with a diamond sawblade, using water as the coolant. All subsequent sample preparation was done in the analytical laboratories of the USGS in Reston. In general the freshest material was selected, and samples were chosen to be representative of the ten-foot interval from which they came. In a few cases, as noted above, internal differentiates such as segregation veins and vorbs (vertical, olivine-rich bodies, see discussion in Helz, 1993) were selected for analysis. In places where the core included such heterogeneities, care was taken that the analytical sample be either normal core only, or the variant rock only. The only sample that appears to be inadvertently compound is KI79-5-240 in Table 9. Subsequent examination of both the thin section and the analysis suggest that the piece of rock submitted for analysis contained a smear of segregation-vein material in it that was not recognized at the time.

ANALYTICAL METHODS

All of the analyses presented here were obtained by classical gravimetric analysis in U.S. Geological Survey laboratories in Denver and Reston. The earliest analyses [job nos. 955(DCS) and PD99 in the tables] were done in Denver, following the procedures described in Peck (1964). All subsequent analyses were done in Reston, following the procedures outlined in Kirschenbaum (1983). These analyses include FeO, $H_2O\pm$, and CO_2 determinations, made as described in the references cited.

In addition to those components determined by standard gravimetric analysis, most of these analyses include determinations of Cr, Cl and F. Cr was originally analyzed using a colorimetric determination (E. Engleman and H. Kirschenbaum analyses, plus the J.W. Marinenko analyses in jobs BD02 and BD25). The method used was that of Maxwell (1968) and Sandell (1959). Subsequently (in the later J. W. Marinenko analyses), Cr was determined by flame AA, as described in Aruscavage and Crock (1987). Cl was analyzed colorimetrically in the Engleman and Kirschenbaum analyses, while F was analyzed by ion-specific electrode, as described in Jackson and others (1987). Later analyses (major elements by J. W. Marinenko) used the ion specific electrode method for both Cl (as described in Jackson and others, 1987) and F (as modified by Kirschembaum, 1988). In addition, all samples in job 955(DCS), originally done in Denver, were reanalyzed by H. Kirschenbaum for F and Cl using the ion chromatograph in Reston (under new job no. BJ25).

Samples in several of the earlier jobs (nos. PE74, PH48, BA23, BA56 and BD02, comprising 80 samples) were analyzed for total sulfur, as described in Jackson and others (1987). However, as sulfur was always found to be below the limit of detection, this determination was not made for subsequent samples.

Many analytical chemists of the U.S. Geological Survey have been involved in obtaining this data set. The bulk of the analyses were the work of coauthors H. Kirschenbaum and J. W. Marinenko, including many of the Cr, Cl and F analyses. Other analysts who performed gravimetric analyses include G. Riddle [job no. 955(DCS)], and E. Engleman (job no. PD99). Some of the minor and trace element work involved other members of the Branch of Analytical Chemistry: some of the Cr determinations were done by J.G. Crock, M. Doughten and W.M. d'Angelo, while C. Skeen and D. Kobilis helped with the Cl and F analyses.

DESCRIPTION OF ANALYTICAL TABLES

The analytical tables are presented at the end of this report. Each table contains analyses of core from one drill hole. For example, all core from the oldest hole (KI67-1, the first hole drilled in 1967) is in Table 1. Where the hole was re-entered more than once, and extensive sections of ooze were recovered in the second or subsequent passes, analyses of the later cores are given in a separate table. Thus, analyses of the first core recovered from holes KI79-1 and KI79-3 are in Tables 7 and 8, respectively, while Table 7a and Table 8a present analyses of ooze from the redrilling of those two holes. Samples are listed within the tables by depth, with the shallowest samples first, and the deepest recovered material last. The "field no." given for each sample gives the drill core number, followed by the depth of the sample in feet: sample KI67-1-52.1 comes from core KI67-1, 52.1 feet below the surface of the lava lake.

The "lab no." is the sample number given to each individual sample by the Branch of Analytical Chemistry (BAC). The "job no." is the number assigned to each group of samples submitted for analysis, and is given in the tables because it is necessary to know that number to recover these and related data from the BAC computer system. The initials of the analyst responsible for the major-element data are given for each analysis.

Gravimetric data and the results on additional minor elements are normally reported to two decimal places, and that convention has been followed here, except for the analytical results for F and Cl, which have been reported to three decimal places. A dash in the table indicates that the particular element was not determined in that sample. A value of 0.00 in the table indicates that that element was analyzed for but not detected.

At the bottom of the page, below the analyses, the tables contain some further information on the samples. Where the space opposite "Type of sample" is blank, the piece of core selected for analysis was relatively featureless, normal core, varying principally in its olivine phenocryst and glass content. Other descriptions indicate that the sample was an internal differentiate of the lake, or was anomalous in some other way. Internal differentiates include the ferrodiabasic segregation veins, and even more extremely differentiated veins, some of them internal differentiates of the segregation veins ("vein-in-vein" samples). Other anomalous samples are the very glassy samples such as the "glass-in-bit" samples (segregations of nearly pure melt that represent the deepest core recovered from several of the 1967 and 1975 drill holes). The samples designates as "oozes" are material that flowed back up open drill holes, which was recovered when the holes were re-entered in various (usually futile) efforts to go deeper. The composition and mechanism of formation of internal differentiates of the lake were summarized in Helz (1987a); data on the oozing history of the various drill holes, and on the significance of the "glass-in-bit" samples, was presented in Helz and Wright (1983). Another category of anomalous core noted in the tables includes samples of foundered crust, that is, material that was originally at the surface of the lake, but sank to some depth below the surface during or very shortly after the 1959 eruption. The nature, distribution and textural variants of foundered crust are discussed in Helz (1993). Other terms used are self-explanatory.

The tables also note whether the sample analyzed contains glass (= quenched melt) or not. Finally the core has been put into one of three categories, depending on its pre-quenching temperature. "High" samples are those quenched from temperatures above the solidus, which lies at 970-980°C; these contain glass interpreted as having been a stable melt phase prior to quenching. "Medium" samples are those quenched from temperatures below the solidus but above the boiling point of water (approximately 110°C for the geothermal system in the lake, as the water contains some dissolved salts). "Low" temperature samples are those that were quenched from 110°C, and hence had been in contact with liquid water prior to drilling. This information is included because it bears on the freshness of the material analyzed, though all of the core is pristine by normal geologic standards.

QUALITY OF THE ANALYSES

The overall quality of these analyses is high, and the internal consistency of the data set is exceptional. The reproducibility of the method used was tested formally, as reported in Flanagan and Kirschenbaum (1987). Their results suggested thatanalyses of new samples could be expected to be consistent with older data analyzed in the same laboratories, by the same methods, with the expected differences no greater than the reproducibility of repeated analyses on the same sample. This is important, as the analyses reported here were obtained over the period 1968 [for job 955(DCS)] to 1990 (for final results on jobs BW59, BT73 and BX99.

The first and simplest criterion used to judge the results was the analytical summation. As shown in Figure 4, the bulk of the analyses in this report have summations lying between 99.80 and 100.29 percent by weight. Of the five analyses with higher summations, three are from a particular job (BK52, involving samples from drill core KI79-1), in which the SiO_2 analyses ran somewhat high. Two BK52 samples were reanalyzed, and found to have lower SiO_2; the other three (not reanalyzed) presumably have the same defect. Similarly, the one analysis with a summation below 99.60 (KI79-5-151, from job no. BR98) is low because of a low SiO_2 value.

Other, more empirical rules, developed over the years of working with samples from Kilauea Iki, provided a quick check on certain components of the

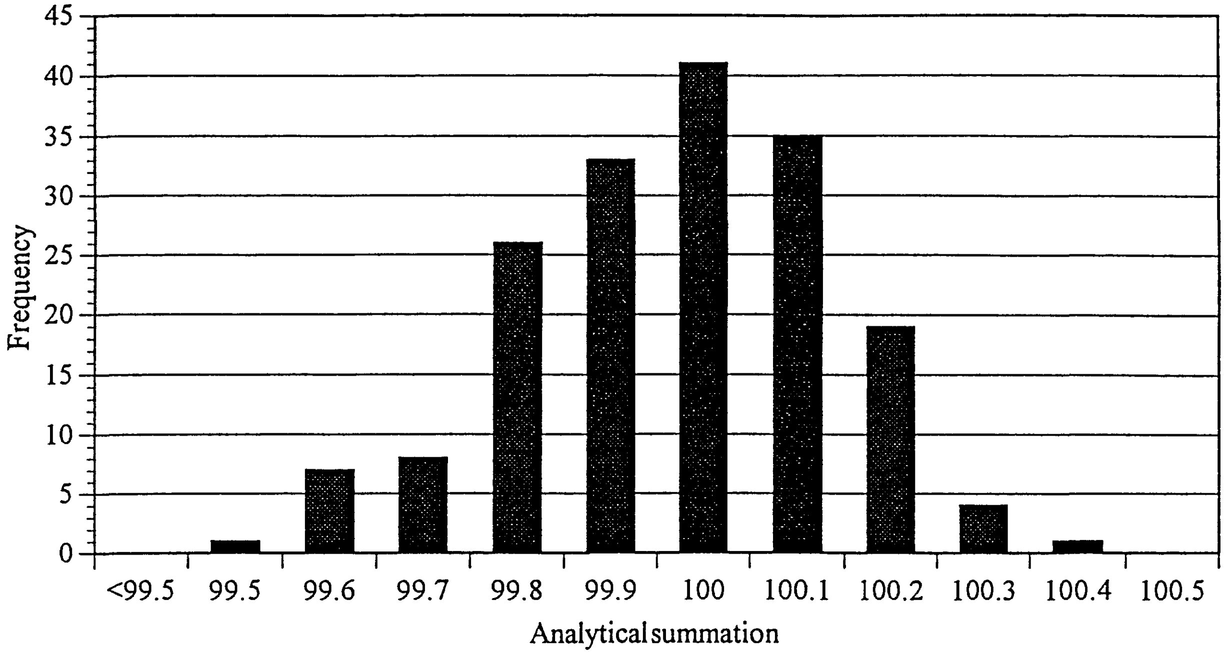


Figure 4. Histogram showing the range of summations reported for the 176 samples of 1967-1981 drill core analyzed by classical methods and presented in this report.

analysis. One of these rules was that the ratio of P_2O_5/K_2O should be essentially constant, as there was no process operating in the lake that would cause that ratio to vary, over the range of compositions for which we have whole-rock data. The data for P_2O_5 vs. K_2O are shown in Figure 5; the linearity of this plot substantiates the validity of this assumption. Similarly, it was observed that the P_2O_5 content was almost exactly one-tenth of the TiO_2 content, for all samples with MgO > 5.0% (that is, for all olivine-phyric samples and most of the diabasic segregation veins). Again, the data support this, as shown in Figure 6. The few samples with lower bulk MgO contents, such as the more differentiated oozes and vein-in-vein samples have bulk compositions which reflect fractionation of Fe-Ti oxides. These samples define an upper limb for the variation of P_2O_5 vs TiO_2, along which P_2O_5 continues to increase as TiO_2 decreases (see Figure 6). For both these criteria, the occasional deviant sample was submitted for rechecking as the results came in, and was almost always found to have been in error. Exceptional samples include foundered crust and ooze, where migration of very differentiated liquids has produced slightly anomalous bulk compositions.

Initially, the analyses were also formally evaluated by performing least-squares calculations (Wright and Doherty, 1970). Each new analysis of drill core, from the 1967 and 1975 drill holes, was checked to see if it was equivalent to some combination of selected samples of the 1959 eruption pumices, plus or minus olivine+ chromite. This was the method used in Wright (1973) to determine that all 1959 eruption samples could be represented as mixtures of the two most differentiated samples ± (olivine + chromite). For the lava lake, samples from between 0-40 feet had compositions that could be so represented, just as precisely as the eruption samples evaluated by Wright in the 1973 paper had been. This result established, among other things, that the analyses of 1967 and 1975 drill core were fully consistent with the much earlier analyses of Murata and Richter (1966), also produced in the USGS labs in Denver. However, as discussed in Helz (1980), using plots of TiO_2 and Na_2O vs. MgO to illustrate the point, samples from deeper in the lake showed systematic deviations from eruption-pumice chemistry. The deviations from eruption-pumice chemistry were systematic with depth, and consistent from one drill core to the next, making it extremely unlikely that analytical problems were involved.

After recovery and analysis of the 1979 and 1981 core, Helz and others (1989) evaluated the variation of core composition with depth systematically, down to depths of 307 feet below the surface of the lava lake. Two principal, mutually complementary zones were identified: an upper zone enriched in the melt that would be present in the lava lake at or just below the temperature where plagioclase first crystallizes, and a deeper zone depleted in this same melt composition. As the density of this melt is lower than that of all other melts present in the lake above 1100°C, Helz and others hypothesized that the zonation was produced by upward migration of this minimum-density melt within the core of the lake. In addition, it was found that core affected by extraction of the Fe- and Ti-rich liquid equivalent to the diabasic segregation veins could be readily

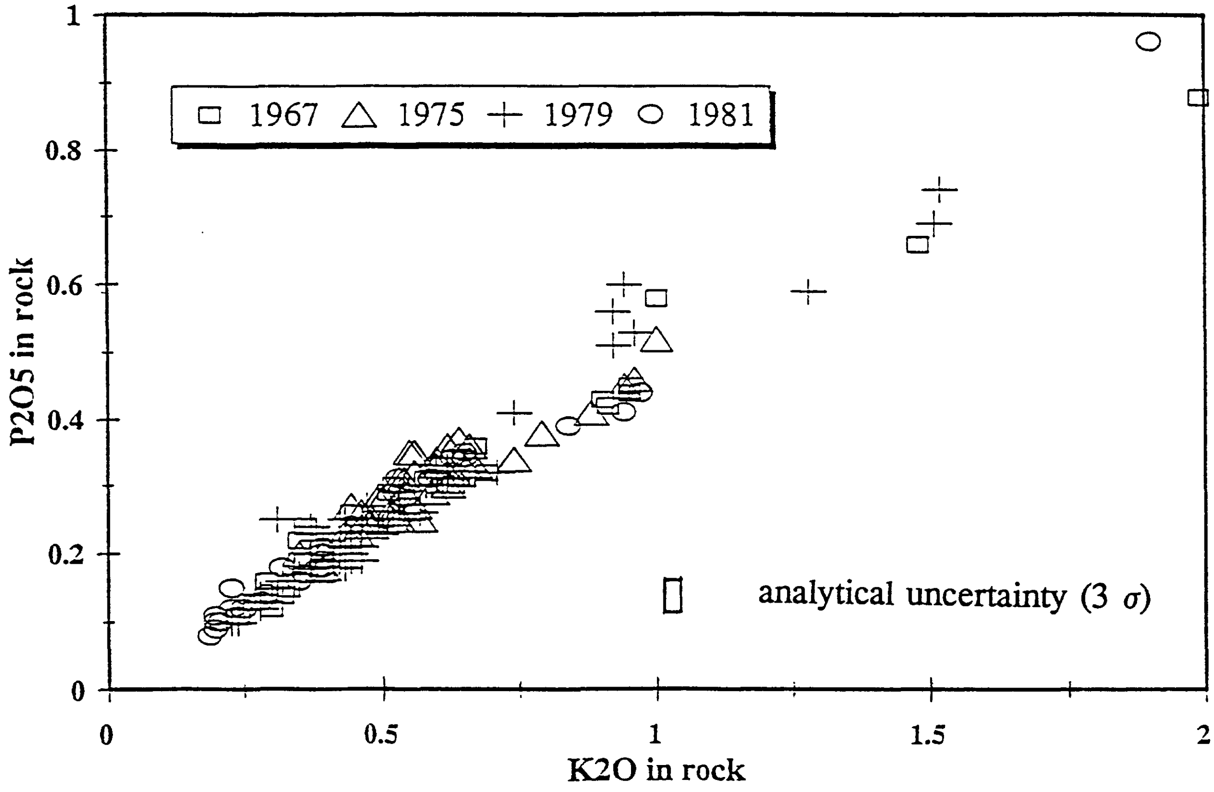


Figure 5. P_2O_5 content of each rock sample vs. its K_2O content, for all analyses in this report. All quantities in weight percent. The box in the lower right-hand corner shows the analytical uncertainty associated with each analysis, which is comparable to the size of the symbols used in this figure.

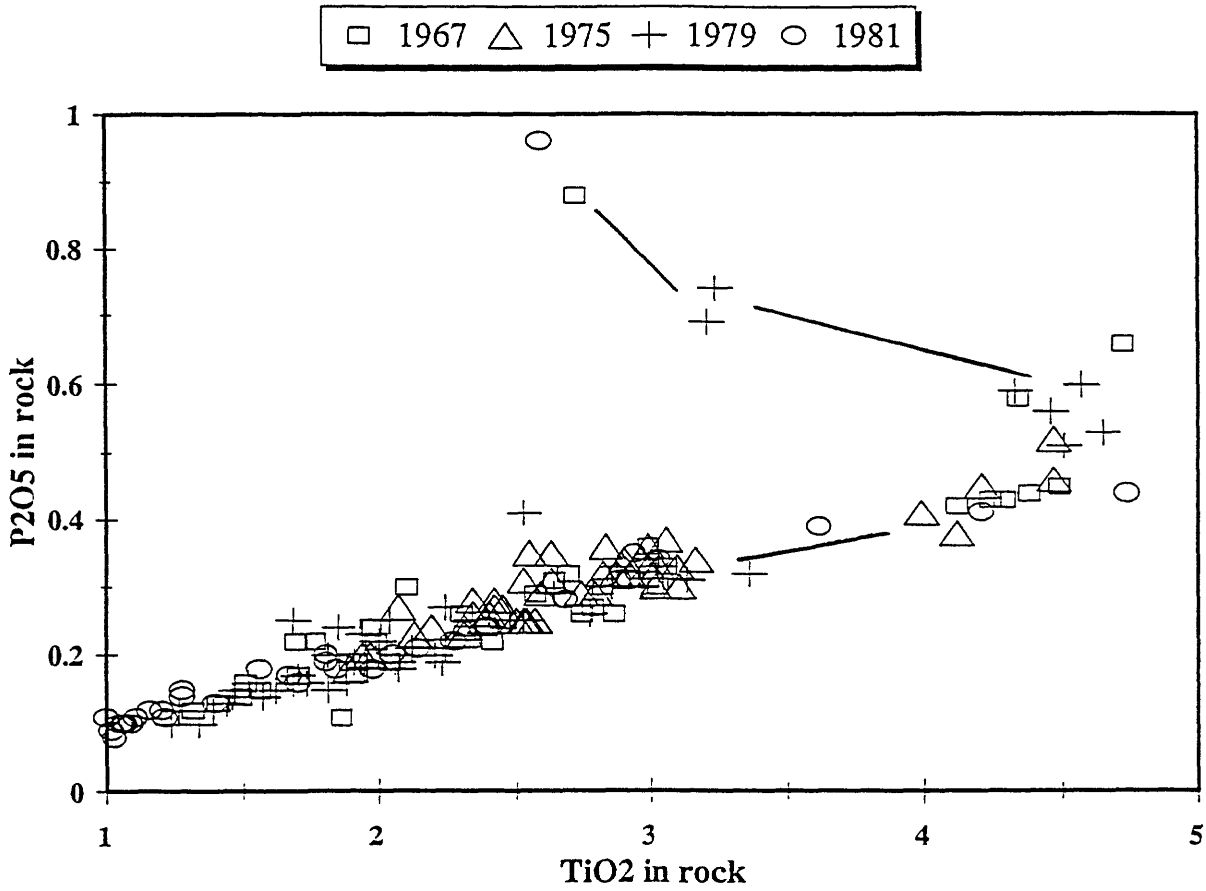


Figure 6. P_2O_5 content of each rock sample vs. its TiO_2 content, for all analyses in this report. All quantities in weight percent. The line is the liquid line of descent for Kilauea Iki, as it appears in this projection.

identified by its pattern of deviation from eruption-pumice chemistry.

For purposes of this report it is important to note that (1) these deviations from eruption-pumice chemistry with depth are highly systematic, (2) the deviations are consistent with the composition of particular melts that occupy unique positions on the liquid line of descent of the lava lake (as defined in Helz, 1987a) and (3) that in all cases both halves of a process can be identified in the core. That is, the complementary enriched and depleted zones are both present, and both are recognizable by their chemical compositions. If the samples had been subject to subsequent alteration, or if the analyses had been less than excellent, the resulting noise could easily have produced an incoherent, uninterpretable pattern.

CHEMICAL VARIATIONS IN KILAUEA IKI SAMPLES

The range and character of the chemical variations within the lava lake samples can be most effectively displayed in a series of magnesia variation diagrams. MgO is chosen as the abcissa first because it varies over a greater range (2.37% to 27.41%) than any other component. In addition, it is known from the experimental work of Helz and Thornber (1987) that MgO in Kilauea Iki melts increases linearly with temperature over the range from about 1.0% to 12.4%, so that the lower part of the variation can be read as varying temperature. The variation in MgO in the upper part of the bulk compositional range (12.4-27.5%) reflects varying amounts of phenocrystic olivine in the core, as discussed in Helz (1987b) and Helz and others (1989); this variation may not be linear with temperature over the whole range. The various magnesia variation diagrams are shown as Figures 7a-f, with MgO decreasing from left to right. Thus temperature decreases, and the extent of differentiation increases, to the right in each plot.

Figure 7a shows the magnesia variation diagrams for SiO_2 and Cr_2O_3. Silica increases steadily, along a well-defined olivine control line (Wright, 1971) over most of the range. The composition of the olivine defining this line is $Fo_{86.5-87.0}$ (Helz, 1987b; Murata and Richter, 1966). The onset of crystallization of augite and then plagioclase at or below MgO = 7.5-7.0% mark the end of olivine controlled variation. Their appearance has little effect on the trend of SiO_2 vs. MgO, however, as their silica contents are not all that different from the liquids, and they tend to cancel each other out. The first marked change in trend, at MgO = 5.0%, is produced by the incoming of the Fe-Ti oxides; because these phases contain essentially no SiO_2, the trend of SiO_2 vs MgO shifts sharply upward at that point. The upper plot, Cr_2O_3 vs. MgO, shows the data for the only component in the major element analyses that decreases as MgO decreases, throughout its entire range. This pattern results from the fact that Cr_2O_3 is concentrated in chrome spinel, a very early-crystallizing phase, which is present in the drill core almost exclusively as inclusions in the olivine phenocrysts. The Cr_2O_3 content of

Figure 7. Oxide-oxide plots showing the compositional variation of the 1967-1981 core samples as a function of their MgO content. All quantities are in weight percent. The different symbols correspond to the year in which a given sample was recovered. In all cases, the symbols are larger than the analytical uncertainty of each determination.

a. SiO_2 and Cr_2O_3 vs. MgO
b. Al_2O_3 and CaO vs. MgO
c. TiO_2, FeO and MnO vs. MgO
d. Na_2O and K_2O vs. MgO
e. P_2O_5, F and Cl vs. MgO
f. CO_2, H_2O- and H_2O+ vs. MgO

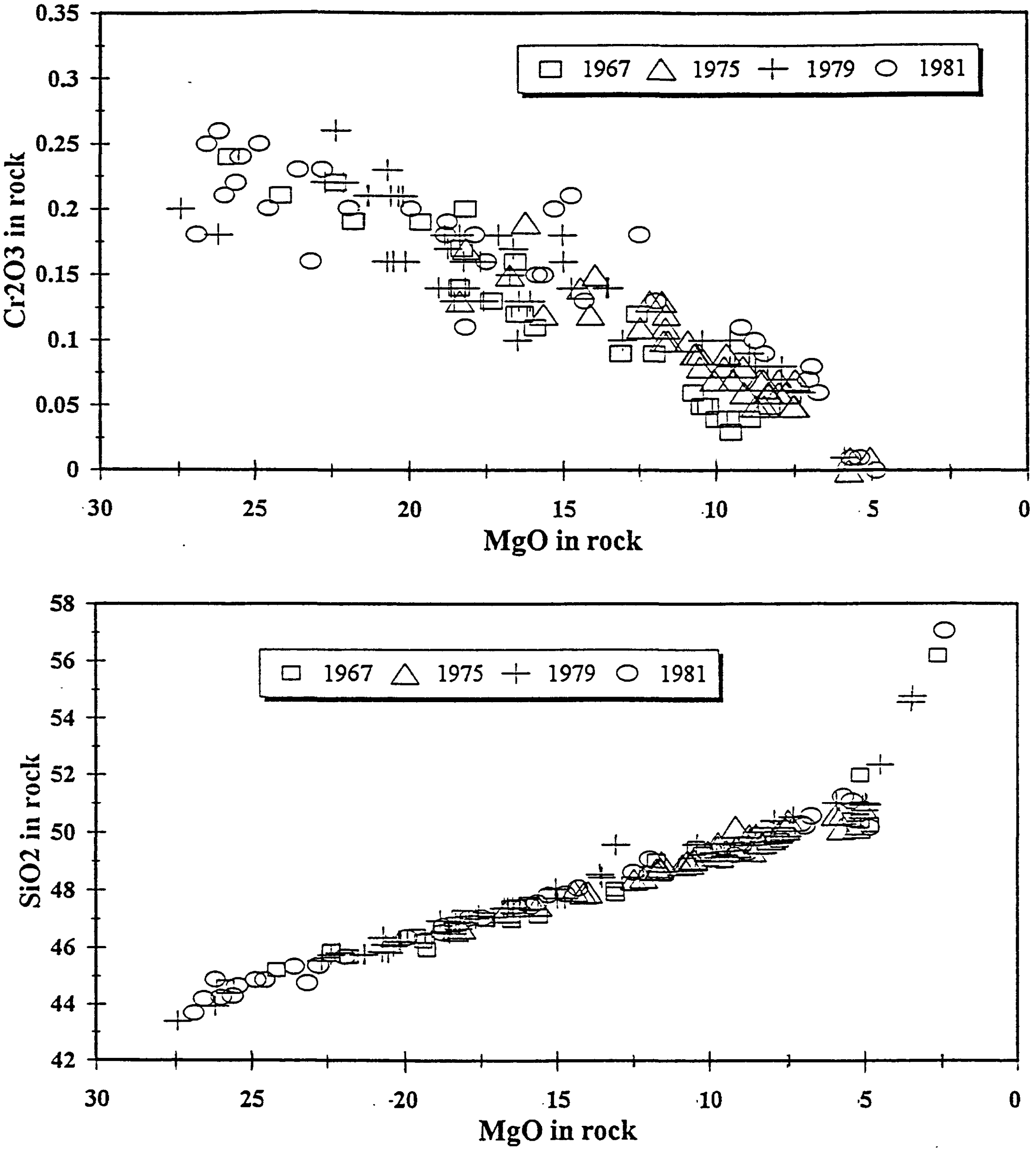


Figure 7a. SiO_2 and Cr_2O_3 vs. MgO

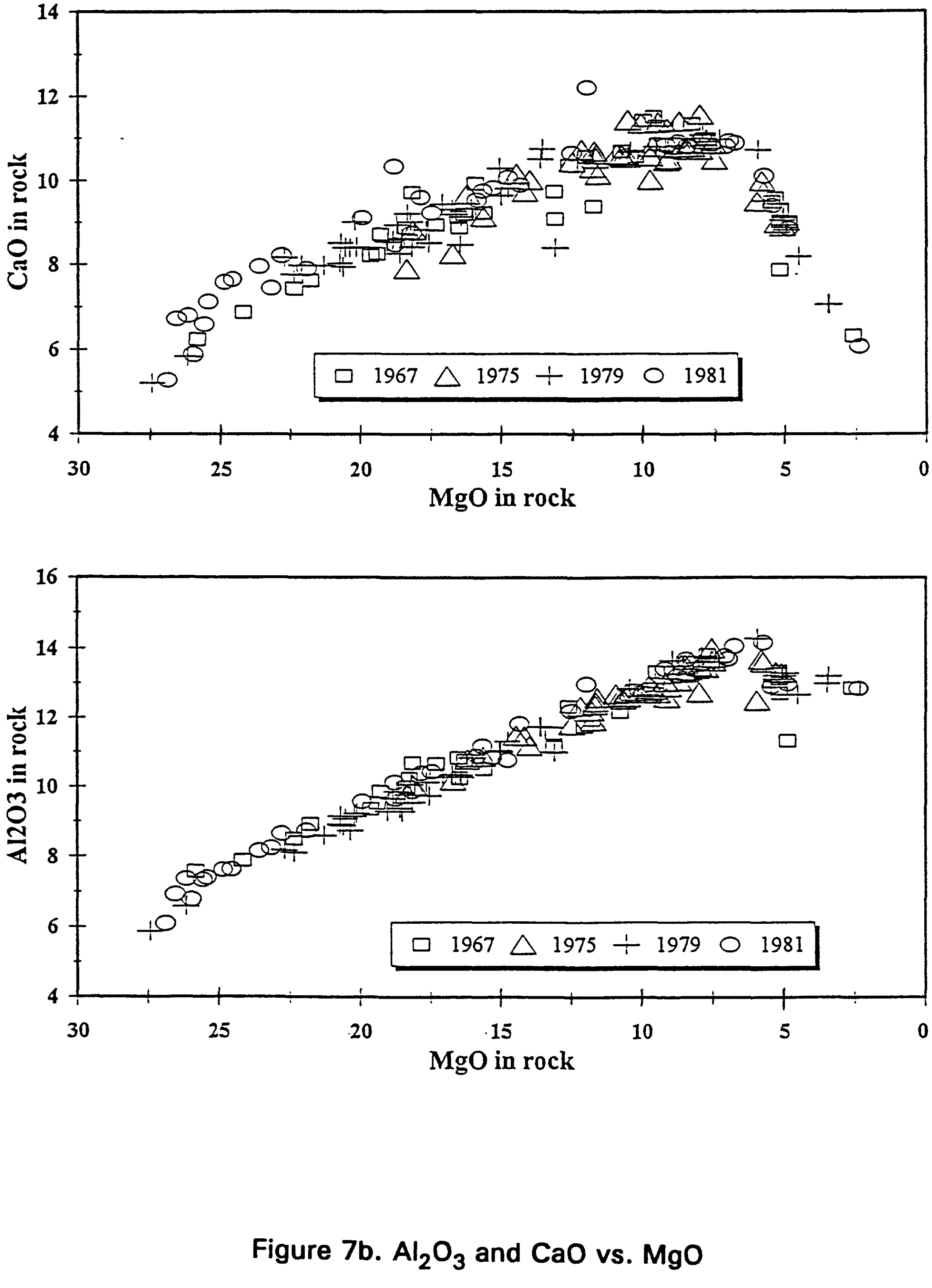


Figure 7b. Al_2O_3 and CaO vs. MgO

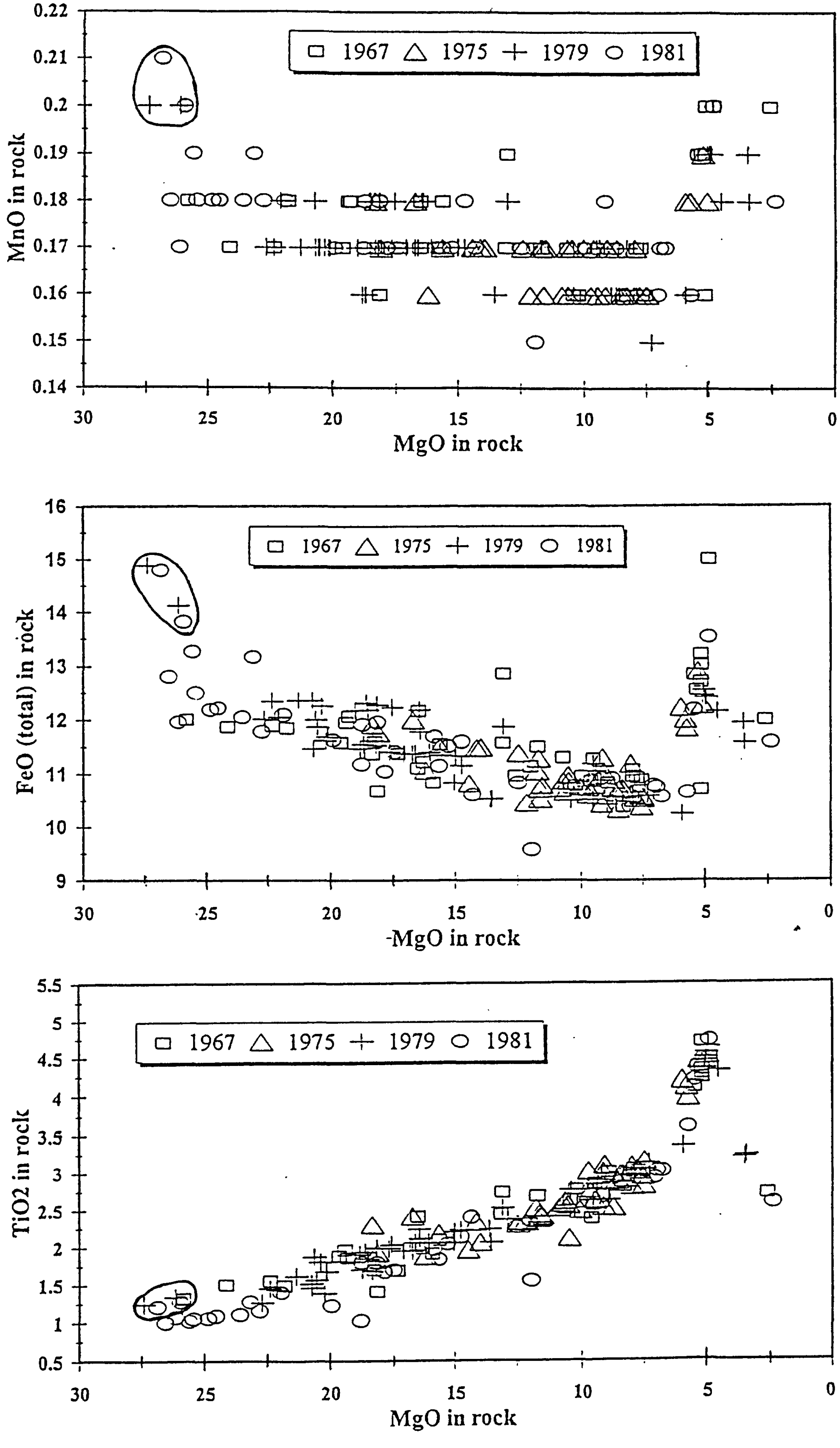


Figure 7c. TiO_2, FeO and MnO vs. MgO

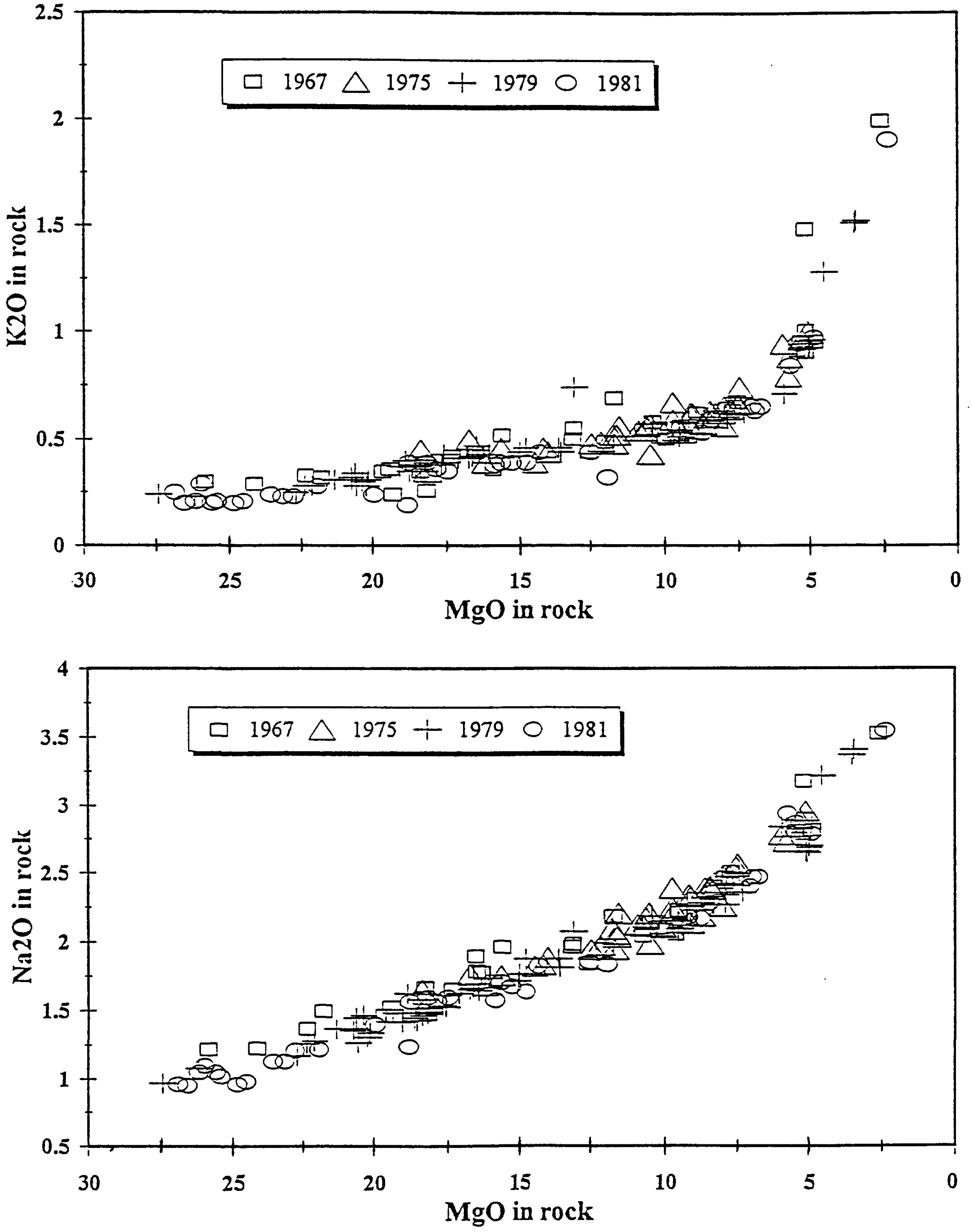


Figure 7d. Na_2O and K_2O vs. MgO

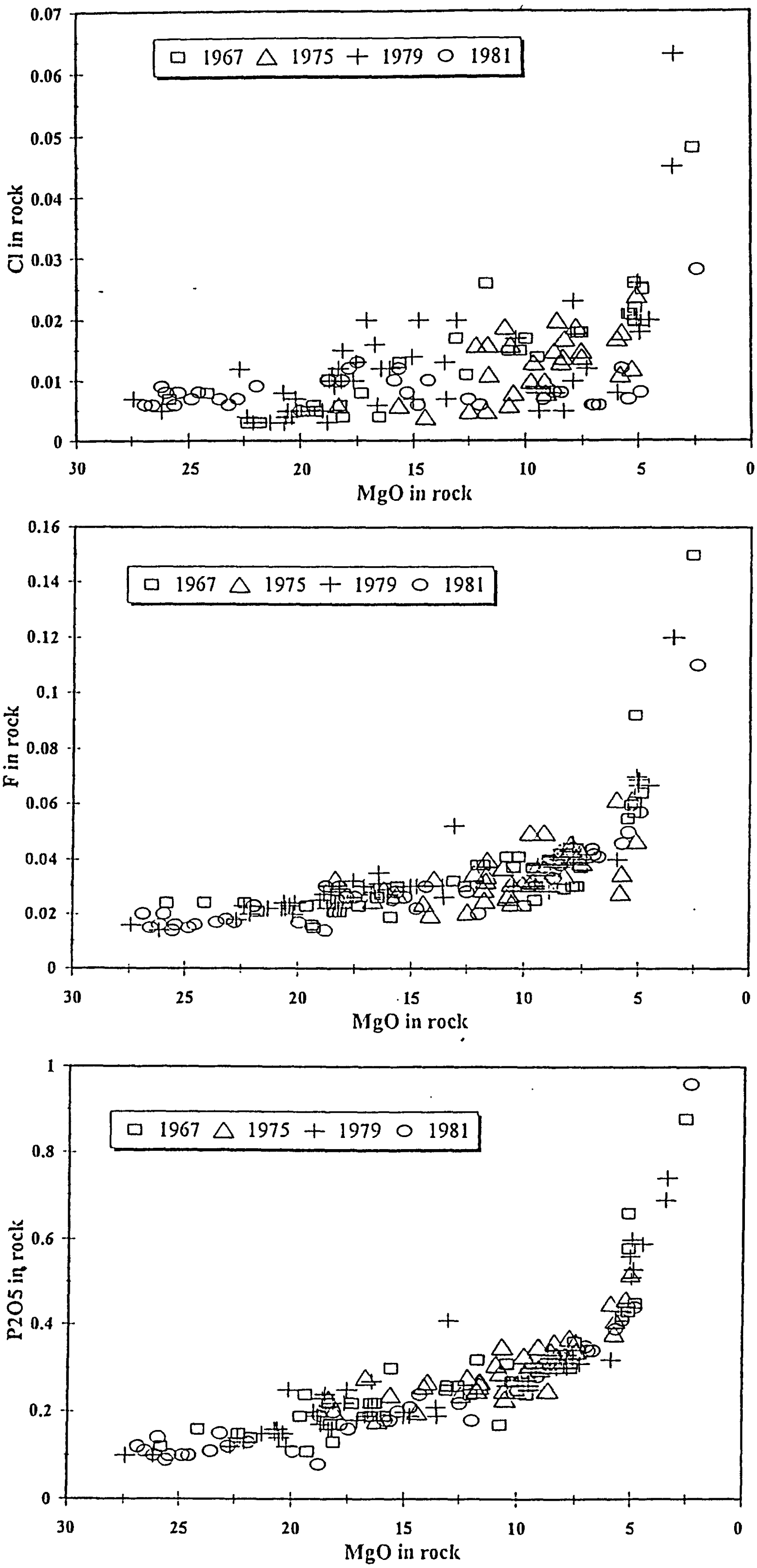


Figure 7e. P_2O_5, F and Cl vs. MgO

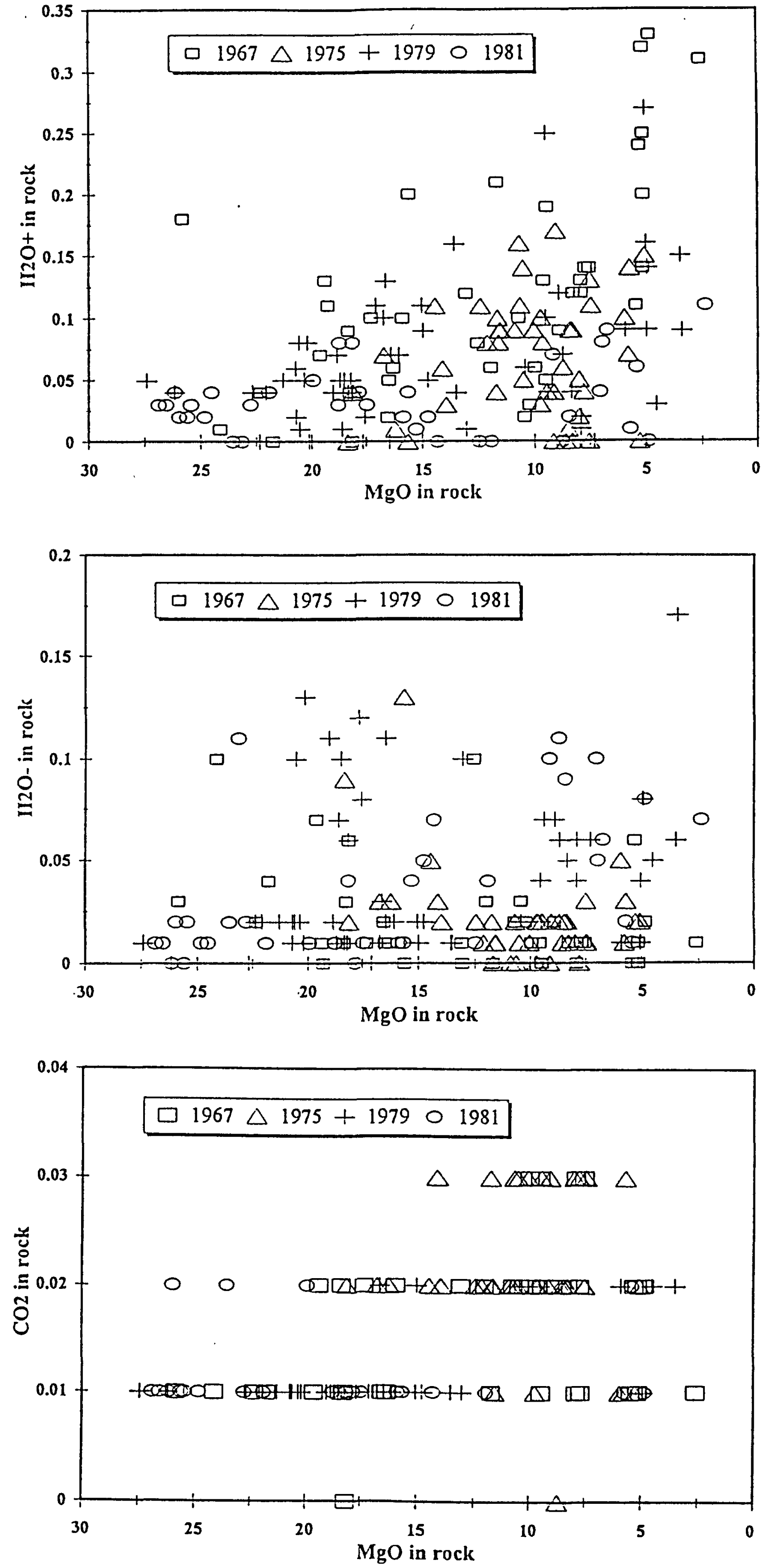


Figure 7f. CO_2, H_2O- and H_2O+ vs. MgO

the analysis thus reflects directly the olivine phenocryst content of the core: it is higher in the more olivine-rich samples and decreases as the olivine phenocryst content decreases, reaching zero at MgO = 5.0%, where the core is completely free of phenocrystic olivine. The Cr_2O_3 content of the segregation veins, oozes, and extreme differentiates is below the limit of detection (effectively 100 ppm).

Figure 7b shows how Al_2O_3 and CaO vary as a function of MgO content. By plotting these two oxides together as one figure, we can see clearly the relative positions of the incoming of augite and plagioclase, the two principal silicate minerals found in the core. These two minerals, together with olivine, make up 95%+ of the norm of any sample of Kilauea Iki core. CaO rises as MgO decreases until somewhere between 10.0% and 7.5% MgO, where it flattens out, before decreasing strongly below 7.0%. Al_2O_3 rises until 6.0-7.0% MgO; as discussed in Helz (1987a) in detail, its subsequent variation is complex, but it is always lower than it is at 6.0-7.0% MgO. From these patterns, we can infer that augite begins to crystallize first, and is followed by plagioclase at a slightly lower MgO content and temperature. The patterns seen in Figure 7b are consistent with the available experimental results (Thompson and Tilley,1969; Helz and Thornber,1987.)

Figure 7c shows the variation of TiO_2, of total iron as FeO and of MnO, as a function of MgO content, together on one page. These oxides show more complex patterns of variation, including more cross-trend variability relative to the olivine-control trend, than most of the oxides discussed so far. The pattern for TiO_2 is the simplest: it increases as MgO decreases, following the olivine-control trend to MgO = 7.0%. It then rises steeply to a peak of almost 5.0% TiO_2 at 5.0% MgO, and declines very sharply thereafter. The glass data of Helz (1987a) show that the limiting value for TiO_2 is actually 5.5%, but we do not have a whole-rock sample that catches this most extreme level of TiO_2 enrichment. The peak marks the point at which the first Fe-Ti oxide, either ilmenite or ferropseudobrookite (as discussed in Helz, 1987a), begins to crystallize.

The trends for FeO and MnO are very similar, reflecting the fact that Mn proxies for ferrous iron in all of the iron-bearing minerals in the lava lake. The patterns not only look similar: individual outliers in the two plots also correspond, in almost all cases. The patterns are complicated by the presence of the four samples enclosed in a circle: these are analyses of "vorbs", the vertical, olivine-rich bodies originally described in Helz (1980). The vorbs have subsequently been recognized as diapir tracks, created by the passage of vesicle-rich plumes from the lower mush zone in the lake to the upper mush zone (Helz, 1987a; Helz and others, 1989). Vorbs are enriched in the Fe- and Ti-rich liquid characteristic of the segregation veins, and are enriched in olivine relative to the surrounding rock. This enrichment in olivine was achieved at a stage when the olivine phenocrysts had re-equilibrated significantly, to more Fe-rich compositions. Hence instead of lying on the slope of the original olivine-control line (which owes its slope to the variable amounts of $Fo_{86.5-87.0}$ phenocrysts present in the core), the vorbs define a steeper slope (approximately Fo_{80}). This steeper slope implies that the vorbs formed at a relatively late stage, and at a lower temperature (T= 1130-1140°) than the temperature at which the original olivine settling occurred [T=1180-1190°C, see discussion in Helz (1987a); Helz and others (1989)]. Their enrichment in MnO parallels their enrichment in FeO, and reflects the tendency for Mn in olivine to increase as the Fe content increases. Below MgO = 6.0%, and the incoming of the iron-free mineral plagioclase, FeO in the rocks and residual liquids rises steeply, passing through a peak at roughly the same point TiO_2 does. The FeO content declines subsequently, as the various Fe-Ti oxide phases, first ilmenite or ferropseudobrookite and subsequently magnetite, begin to crystallize. Note that, although MnO rises with FeO and TiO_2, to MgO = 5.0%, it does not decline sharply thereafter in the whole-rock samples available, down to 2.4% MgO. As the glass data of Helz (1987a) show, MnO does eventually decline toward zero, but lags behind FeO: this reflects the relative concentrations of the two oxides in magnetite, where FeO makes up 68-76% by weight while MnO is present at the 0.3-0.6% level.

The variation patterns for the alkalies vs. MgO are shown in Figure 7d. Both Na_2O and K_2O increase as MgO decreases, with some increase in slope (especially for K_2O) below MgO = 5.0%. The whole-rock samples do not extend to the range where the glass data (Helz, 1987a) suggest that Na_2O may pass through a peak and decline: that point is not reached until MgO = 1.0%. Both the whole-rock and glass data show K_2O increasing monatonically all the way to the solidus. In whole-rock samples, the maximum K_2O observed is about 2%, seen in the vein-in-vein sample from KI81-2 (Table 11) and in a similarly differentiated ooze from a partially molten segregation vein intersected by hole KI67-2 (KI67-2-85.7 in Table 2). By contrast K_2O reaches values of over 5% by weight in the last residual glasses (Helz, 1987a). The rate of increase is higher for K_2O than for Na_2O below 5% MgO because the concentration of Na_2O in plagioclase (the only alkali-bearing phase to crystallize in the lava lake) is much higher than the concentration of K_2O in plagioclase. Alkali feldspar, as a separate phase, is not observed in any glass-bearing sample from the lava lake, although plagioclase feldspar may be zoned to very sodic compositions: the most sodic and potassic rim composition so far observed in any Kilauea Iki sample is $An_{8.7}Ab_{69.8}Or_{21.5}$ (Helz, unpublished data).

Figure 7e shows P_2O_5, F, and Cl together on one page, in order to facilitate comparison among them. The analyzed values for F and Cl were reported to three decimal places rather than the usual two, for most of the analyses presented in this report, for purposes of comparing data within this data set. The observation that the concentration in F rises smoothly as MgO decreases suggests that these determinations are better than normal two-place reporting would imply. Cl is noisier, but even there, the third decimal place appears to have some information value. (If one wishes to compare these results with other kinds of analyses or analyses from other laboratories, the numbers should probably be rounded off to the normal two decimal places.) There is obviously great similarity between the pattern for P_2O_5 and those of both halogens, especially that of fluorine. This is because the only phase in the lava lake (other than the melt) that can take up any of these components is apatite, which begins to crystallize at about 2.5% MgO. The glass data (Helz, 1987a) show that P_2O_5 peaks at that point and declines at lower MgO contents; the whole-rock data in Figure 7e extend just to the point where apatite saturation is reached, so the subsequent falling-off in P_2O_5 (and presumably F and Cl) is not observed in the present figure. Until apatite begins to crystallize, all three of these components remain in the melt, their concentration increasing as crystallization proceeds, in a pattern almost identical to that of K_2O.

The last set of MgO variation diagrams, shown in Figure 7f, are those for the highly volatile components H_2O and CO_2. H_2O is divided, by virtue of customary analytical technique, into H_2O+ and H_2O-. H_2O+ is "structural" or dissolved water, which can be driven off from the sample only at high temperatures, while H_2O-, which can be driven off at temperature of 110°C, is loosely bound or even adsorbed water. These components are shown separately in this figure, in the tables, and elsewhere in this report.

The only phases in the lava lake that can accomodate water are the melt and apatite. The upper bound of the H_2O+ variation does correlate roughly with increasing melt content, suggesting that some of this water is really in the melt and that it is behaving predictably. The pattern is otherwise noisy, however. The plot of H_2O- vs. MgO is essentially random: this is as expected for the loosely-held water, which may even be a late-stage contaminant, possibly introduced during drilling, cutting or grinding of the sample. Note that H_2O- concentrations are restricted to very low levels compared with the range of values for H_2O+.

In addition to the H_2O data in the tables, we have IR spectroscopic determinations of the water contents of a few samples. These samples were chosen for IR investigation because either they were very glass-rich or had large pools or areas of glass in them. These previously unpublished data are shown in Table A (with the permission of Dr. J.E. Dixon, of the University of Miami, who did the analyses), along with the bulk H_2O contents reported here for most of same samples. The IR analyses have an uncertainty of ± 10% of the amount present, or ±0.01-0.02 absolute. For two of the melt-rich "glass-in-bit" samples, the IR determinations of dissolved H_2O agree very well with the total H_2O contents reported in the analyses of those same samples. For the third (KI67-3-87.0), Dixon reports that the section she analyzed was rather thin, which may contribute to the discrepancy between the two H_2O determinations for that sample.

For one of the other IR samples (KI79-3-172.9), we have a bulk analysis, but the sample consists mostly of crystal-rich mush, with only a few large pools of glass. If one assumes all the H_2O is in the glass, we can estimate the fraction of glass present from the ratio of the bulk H_2O to glass H_2O (0.06/0.15), giving a melt fraction of about 40% by weight. This is in good agreement with the observed mode, and suggests that both water contents are correct. The remaining sample, KI79-6-190.3, is reported as having only 0.11% water in the glass, for reasons that are not yet clear. We do not have a bulk analysis for this sample, so

Table A. Comparison of bulk H_2O analyses (H_2O+, H_2O- as given in this report) with water contents of Kilauea Iki glasses determined by IR spectroscopy. The IR analyses are unpublished data of Dr. J.E. Dixon. All quantities in weight percent.

Sample no.	IR data (glass only)	H_2O+, H_2O- (bulk rock)	Comments
KI67-3-87.0	0.17	0.11, 0.00	glass in bit
KI67-2-98.0	0.12	0.14, 0.00	glass in bit
KI75-2-138.7	0.17	0.15, 0.02	glass in bit
KI79-3-172.9	0.15	(0.05, 0.01)	crust/melt interface*
KI79-6-190.3	0.11	-----	crust/melt interface*

*Both of these samples contain a sharp interface between overlying "crust" and an underlying layer of crystal-poor melt. In each case, this was the deepest piece of core recovered from the hole, and the underlying melt has been found to be a segregation of interstitial, differentiated melt, as discussed in Helz and Wright (1983). It is not equivalent in bulk composition to the overlying crust. The IR measurements were made on the glass in the melt-rich layer, while the bulk H_2O contents (where determined) were made on the overlying crystal-rich mush.

cannot cross-check the IR determination. In general, however, the IR results agree well with the bulk H_2O determinations, which suggests that the latter are generally reliable.

The CO_2 values in these analyses have been reported to two decimal places only, so the values in Figure 7f lie at 0.01, 0.02 or 0.03, with no data at intermediate positions. The sense of the plot is that the very tiny amount of CO_2 present is in the melt, because the upper limit of the CO_2 contents rises as bulk MgO decreases. The levels are very low, however, and there is no phase in the lake other than the melt in which CO_2 can be retained, so in the subsolidus samples CO_2 must occur strictly as accidental inclusions, or be loosely adsorbed on the surface of mineral grains.

BEHAVIOR OF VOLATILE COMPONENTS IN KILAUEA IKI LAVA LAKE: A DISCUSSION

The availability of this large suite of intrinsically very fresh samples, which have been subjected to very painstaking classical analysis, gives us an opportunity to assess how the various volatile (or potentially volatile) components in the original magma behaved as the lava lake cooled and crystallized. The components of interest here are sulfur, water, and the halogens fluorine and chlorine.

The magma contains these volatiles in the first place because they were present in the source region in the mantle. The sulfur was present as separate sulfide phase(s), while the water and halogens were derived from the host minerals for K and for P (phlogopite and perhaps hornblende, plus apatite). The volatile contents of an original primary magma (MgO ≈ 16%) have been inferred to be 0.47% H_2O and 0.09% sulfur (Dixon and others, 1990), based on observed volatile contents of glasses from the submarine extension of Kilauea's east rift zone. Gerlach and Graeber estimate the volatile contents of a "parental" magma to be 0.30% H_2O, 0.65% CO_2, 0.13% sulfur, 0.0087 % Cl and 0.0354% F, and state that most of the CO_2 and about half of the initial sulfur are lost during storage prior to eruption. The volatile contents of stored, reservoir-equilibrated magma are estimated by Gerlach and Graeber (1985) to be 0.27% H_2O, 0.034 CO_2, and 0.07% sulfur, with Cl and F the same as in the parental magma.

Early Volatile Loss

The 1959 summit eruption was notable for its very high fire fountains, especially unusual in a summit eruption. This has led to the inference (Helz, 1987b) that the magma must have been somewhat more gas-rich than usual. In addition to degassing during the vigorous fountaining, the new lava lake produced voluminous amounts of fume, especially prior to development of a stable crust (Richter and others, 1970). Gas samples collected over the lake at this stage

(Heald and others, 1963) show the evolved gases becoming richer in H_2O with time, while becoming poorer in CO_2 and sulfur species. A similar trend can be seen in the data of Anderson and Brown (1993), in which the maximum CO_2 content of melt inclusions in olivines decreases as the MgO content of the melt in the inclusion decreases. The early lake and glass inclusion data support the model of Gerlach (1986) and Gerlach and Graeber (1985), which has CO_2 being lost first, followed by sulfur species, with H_2O being exsolved from the melt last. Nevertheless, in spite of the early loss of sulfur, H_2O and especially CO_2, the crusted-over lake did initially contain enough primary magmatic volatiles for it to be possible for Rawson (1960) to collect a respectable gas sample from the bottom of one of the earliest drill holes (analysis presented in Heald and others, 1963).

In addition to the above data, Murata (1966) reported the occurrence of an unusual HCl-rich vapor, collected from a fumarole on the main 1959 cinder cone, away from the main vent and away from the lava lake. Similar high-HCl gas samples have occasionally been reported at Kilauea, but they are rare. Murata described and analyzed the sample thoroughly, but in considering its origin and significance he stated that it "raises more geochemical questions than it answers".

Later Degassing: CO_2 and Sulfur

Essentially all of the CO_2 dissolved in the 1959 magma was lost during the eruption: that is the obvious message of the low and incoherent values for CO_2 presented in Figure 7f. The bulk chemistry of samples from lava lake can tell us nothing useful about the behavior of CO_2 in Kilauea Iki, though an investigation of the CO_2 content of melt inclusions in olivine phenocrysts in the drill core might be useful.

Bulk sulfur contents are even less informative: as noted above, sulfur was never present in detectable quantities in any core sample. Nevertheless, we have quite a bit of information on the timing of sulfur degassing in the lake, from field and petrographic observations. Helz and Wright (1983) summarized the available field observations on degassing of sulfur from drill holes, reporting that noticeable amounts of sulfur were emitted from drill holes in 1967, 1975 and 1976, as soon as the partially molten zone was reached. Later, during the 1979 and 1981 drilling episodes, the drill holes emitted only odorless steam. At this stage of sulfur depletion, even after sulfur was no longer detectable to the nose in the steam, droplets of immiscible sulfide were still observed in all glassy samples core from the 1979 and 1981 cores quenched from below $T = 1060°C$ (Helz, unpublished data). This pattern of occurrence of sulfide droplets is the same as in all earlier (1960-1976) core. Direct microprobe analysis of sulfur in these interstitial glasses gives values of $S = 0.013\text{-}0.026\%$ by weight. A third level of sulfur depletion has been observed in the core recovered in 1988; in those cores, only glassy core from below the thermal maximum contained immiscible sulfide: apparently the melt in the upper half of the partially molten zone had lost essentially all its dissolved sulfur. The significance of these observations is, as discussed in Helz and Wright

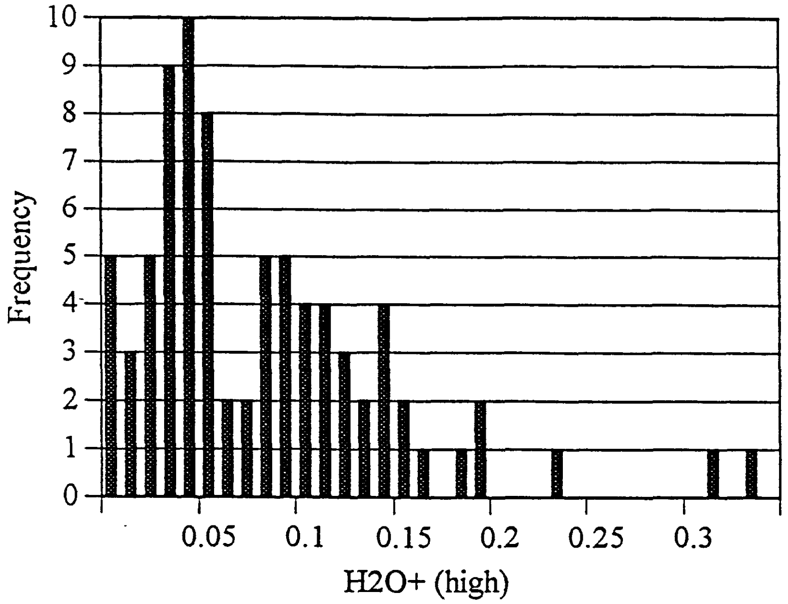
(1983), that sulfur loss was proceeding faster than the overall crystalliztion of the lake, with the entire body of melt being depleted in sulfur in the process. This argues for distillation and transport of sulfur by a through-going vapor phase, because the sulfur contents themselves are far too low to generate a sulfur-rich vapor.

The Dominant Volatile: H_2O

The obvious carrier gas for the extraction of sulfur from the melt is H_2O, in the form of pervasive, low-density dry steam. All thin sections of glassy material from the lava lake contain at least a few scattered vesicles in the interstitial glass. Vesicle contents in the partially molten intervals of the l979 and 1981 cores are typically 1-3% (data presented in Figures 7 and 8 of Barth and others, 1993; also in Mangan and Helz, 1986). So the question arises, why was there so much degassing of steam so late in the history of the lake, when sulfur degassing was practically over?

To answer this question we should first consider the distribution of H_2O in the lava lake. It was noted above that water is divisible into two components, of different significance: a more tightly bound H_2O+ component and the very loosely bound H_2O- component. The magnesia variation diagrams presented above showed a difference in behavior between H_2O+, which exhibited some systematic variation with bulk MgO content, and H_2O-, which was random. In Figures 8 and 9, we have set up histograms of these two components, in order to examine the behavior of water in the lake samples a little more closely. In these figures, the 80 melt-bearing samples (quenched from high temperatures, as noted in the analytical tables) are plotted separately from the 95 subsolidus samples (quenched from medium and low temperatures, also as noted in the analytical tables).

Figure 8 includes all of the bound water (H_2O+) analyses. The most striking feature of these two histograms is that the frequency distribution of the melt-bearing and subsolidus samples is very similar over much of the range. The one difference is the shift in the population in the three lowest ranges (0.00-0.02%). For melt-bearing samples, only 13 samples (or 16% of the population) have $H_2O+ = 0.00$ to 0.02%. However, in the population of subsolidus samples, 28 of them (or 29% of the analyses) have H_2O+ values in the range 0.00 to 0.02%. The only phases that can contain water are the melt and apatite; therefore the water content of the core would be expected to decrease (strictly speaking to zero) as the last melt crystallizes. While there is some shift to lower values, the shift is not as marked as one might expect. Evidently much of the tightly bound H_2O+ is either in melt inclusions within crystalline phases, or in vapor inclusions, or in some surface film, from which it cannot be extracted until high temperatures are reached. This surface film would presumably be a metastable glass. The occurrence of such a persistent glass film has already been hypothesized, based on



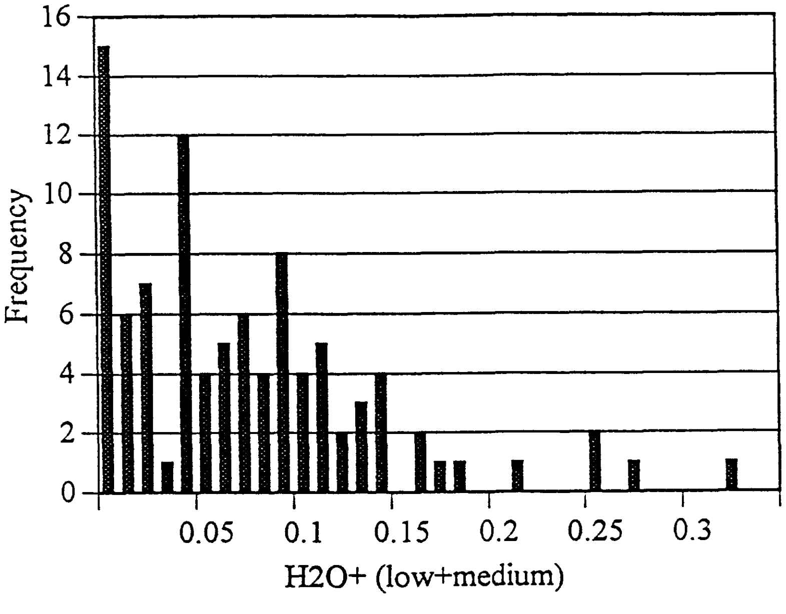
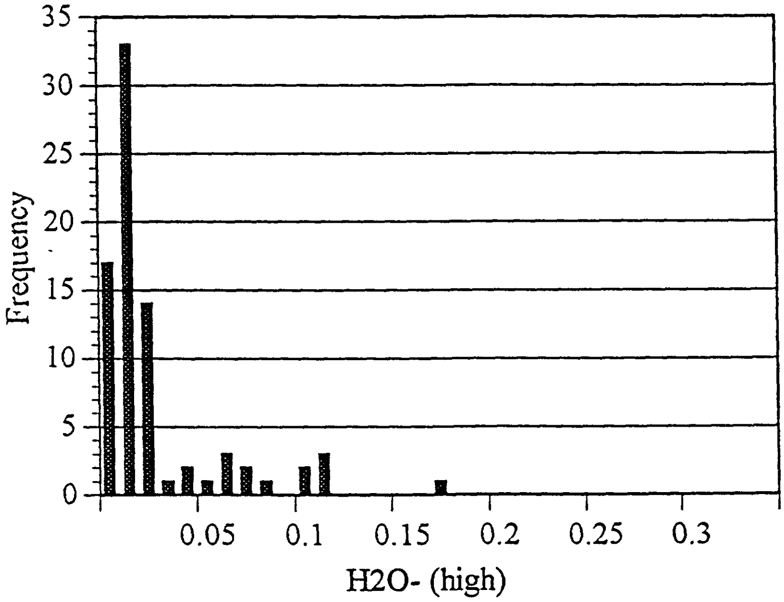


Figure 8. Histogram of H_2O+ values reported for analyzed samples of 1967-1981 drill core. The upper plot shows H_2O+ values for 80 samples quenched from high temperatures, that is, samples which were quenched from within the melting range of the basalt, as indicated by the presence of glass in the groundmass. The lower plot shows H_2O+ values for 95 samples quenched from below the solidus (T< 980°C).



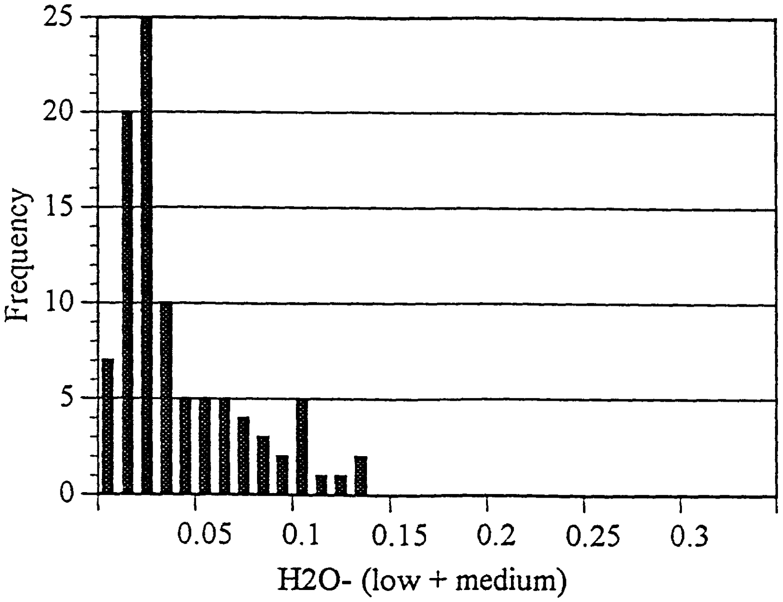


Figure 9. Histogram of H_2O- values reported for analyzed samples of 1967-1981 drill core. As in Figure 6, the upper plot shows H_2O- values for 80 samples quenched from within the melting range of the basalt (T>980°C), while the lower plot shows H_2O- contents for the 95 subsolidus samples.

the fracturing behavior of the lake, as reviewed in Helz (1993); the H_2O+ data offer further support for its presence, even in samples where no glass can be seen with the microscope.

In any case, there is no evidence for progressive depletion of the melt in H_2O with time, as crystallization of the lake proceeds. All of the available data, whether the H_2O+ contents in Figures 7f and 8, or the IR determinations of the water contents of glasses from 1967-1979 given in Table A, show water contents being maintained at saturation levels in the melt. The data on vesicle populations in the partially molten 1979 and 1981 core, cited above, are consistent with the idea that H_2O in the melt is not being depleted, even though sulfur, the other principal retained volatile, was nearly exhausted sometime between 1976 and 1979. Clearly H_2O was being added to the lake. Because the lake is perched well above the water table, in highly porous rocks, the source of this H_2O must be the abundant rain that falls on that part of Kilauea. (The local rainfall is about 150 inches per year on the rim of Kilauea Iki pit crater.) Exactly how meteoric water gets into the body of the melt is still unclear.

Figure 9 shows the equivalent histograms for the H_2O- determinations. Here there is an obvious change in the frequency distribution between melt-bearing and subsolidus samples. Samples quenched from the melting range overwhelmingly have H_2O- values of 0.00-0.02%, with only 16 samples out of 80 (or 20%) having more adsorbed water. Clearly these are very fresh samples; it is evident from these very low H_2O- values that the copious water used during drilling to cool the drill string and the hot core (see discussions of drilling techniques in Helz and Wright, 1983, and Helz, 1993) has not introduced significant water into the drill core. By contrast, the subsolidus samples contain more H_2O-: 43 samples out of 95 (or 45%) have adsorbed-water contents of 0.03 or higher. The results for the melt-bearing samples show that these levels cannot be blamed on the water used during drilling. The extra H_2O- must represent water added to the subsolidus samples after the last melt crystallized, and before drilling. That is, this extra water represents the first traces of alteration of the core by reaction with the steam and/or geothermal fluids in the upper part of the lake. Further evidence for the presence of trace amounts of alteration products in subsolidus Kilauea Iki core is presented by Anderson (1987), who hypothesized the presence of clays and zeolites in shallow (6.0-6.7 m depth) samples, based on the electrical conductivity of those samples.

The Halogens

F and Cl are often thought of as "volatiles", that is, components that will be partitioned into a vapor or fluid phase, and be lost as crystallization proceeds. The occurrence of the HCl-rich vapor reported by Murata (1966) suggests that under some circumstances this is true at Kilauea. In the lava lake, however, the magnesia variation diagrams for F and Cl (Figure 7e, discussed above) show that both halogens behave like highly incompatible minor elements, and exhibit no

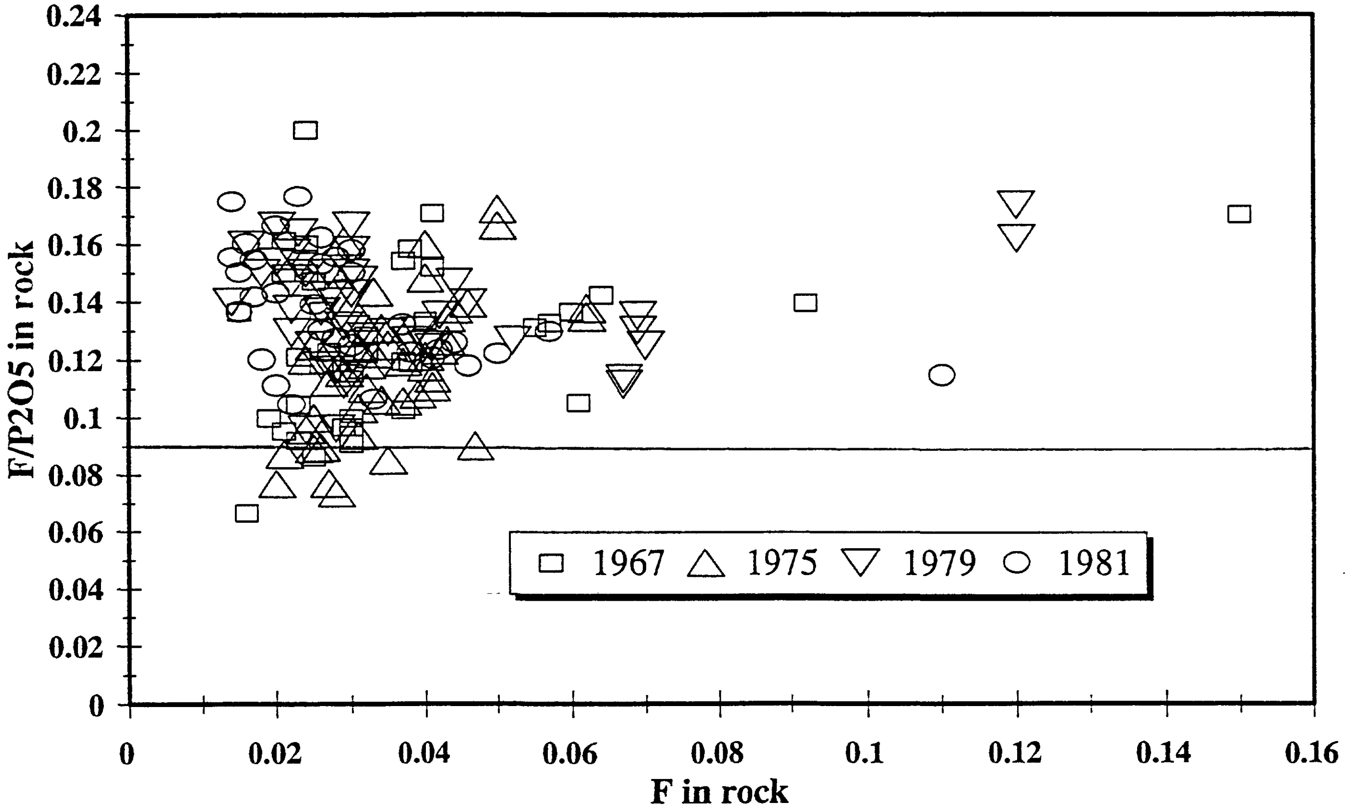


Figure 10. F/P_2O_5 vs. F in samples from Kilauea Iki lava lake. All quantities are in weight percent. The horizontal line indicates the F/P_2O_5 ratio in fluorapatite. Sample plotting above the line thus have F in excess of what can be put into apatite.

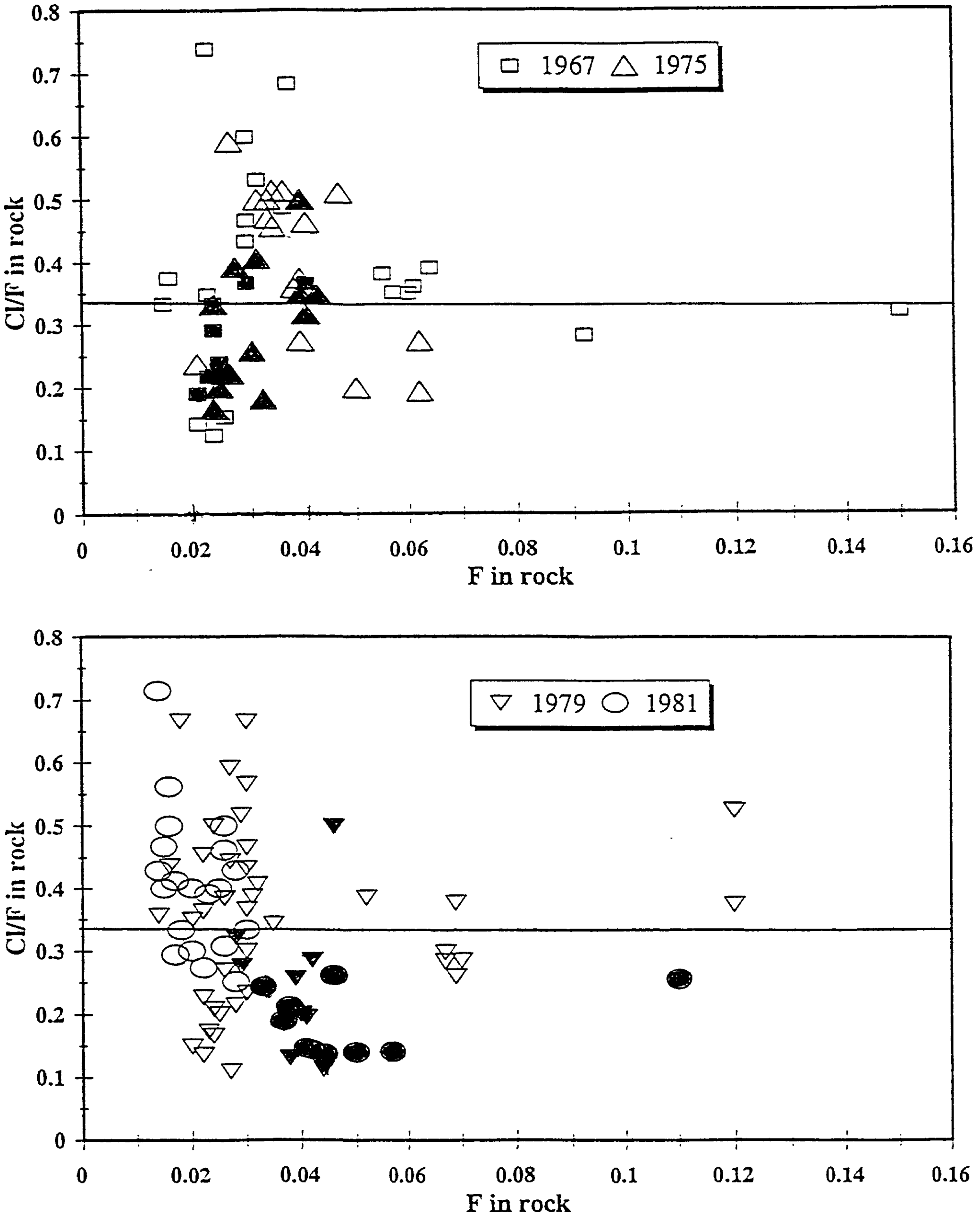


Figure 11. Cl/F vs F in samples from Kilauea Iki lava lake. All quantities are in weight percent. The upper plot shows data from the earlier core (1967, 1975), while the lower plot includes data from more recent drillings (1979, 1981). The open symbols indicate core samples quenched from high or medium temperatures. The filled symbols indicate core quenched from T = 110°C, that is, core that had been exposed to liquid water. The horizontal line is at Cl:F = 1:3, which is close to the average Cl:F ratio for Kilauea Iki.

discernable tendency to be lost to the vapor phase, down to bulk compositions as differentiated as 2.5% MgO.

This would be expected to change as the last melt disappears. The only crystalline phase so far recognized in the core that can take up Cl and F is apatite. Figure 10 shows the ratio F/P_2O_5 vs. F for all lake samples; the ratio of F/P_2O_5 in fluorapatite, which is 0.09 (see analyses in Deer and others, 1992), is indicated by the horizontal line in this figure. Almost all lake samples fall above this line; that is, almost all lake samples have more F than can be accomodated in apatite, even if the apatite in the lake were pure fluorapatite. These samples also contain some Cl and some H_2O+, which also can be accomodated only in apatite or in the melt, so these components are notably more abundant than can be explained by the apatite content of the core.

Figure 11 shows plots of Cl/F vs F for the whole-rock analyses, with the 1967-75 core in the upper plot and the 1979-81 core in the lower plot. "Hot" and "medium" samples (open symbols) scatter about the horizontal 1:3 line that is close to the average Cl:F ratio in the lake, in both the upper and lower plots. The amount of scatter is quite large. It is not clear whether the scatter reflects real initial variability, or analytical problems, or possibly redistribution of Cl vs. F in the samples at some time prior to 1967. The shift to slightly lower F levels in the later core reflects the greater depth and hence, higher olivine phenocryst and bulk MgO content, of the hot zone samples from 1979 and 1981, not loss of F.

Cl has been lost relative to F from the lowest-temperature samples in the 1979 and 1981 core. In the earlier core, the low temperature samples show relatively little loss of Cl relative to F. Thus Cl is somewhat more easily removed from the rocks than F, but even it is largely retained in the drill core. There is no evidence that F is lost at all. The excess halogens may be accomodated either (1) in films of metastable glass, especially in the "medium" temperature samples [those subsolidus samples that have not been exposed to liquid water], or (2) in the core from $T<110°C$, in trace amounts of zeolites or other alteration products formed by the hydrothermal alteration of pre-existing metastable glass. Thus the retention of the halogens, like the retention of H_2O+, supports the idea that there are persistent glass films in the intermediate-temperature samples, and alteration products in the lowest-temperature core. In any case, the halogens do not enter the steam phase at any stage of the development of Kilauea Iki lava lake; only leaching by liquid water has any effect, and then only on Cl.

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Table 1. Analyses of Core from Kilauea Iki Drill Hole KI67-1

	1	2	3	4	5	6	7	8
Field No.	KI67-1-9.5	KI67-1-17.1	KI67-1-25.3	KI67-1-48.6	KI67-1-52.0	KI67-1-52.1	KI67-1-54.9	KI67-1-69.6
Lab no.	W-232722	W-232723	W-232724	D-102041	D-102042	D-102043	D-102044	D-102045
Job no.	BR98	BR98	BR98	955(DCS)	955(DCS)	955(DCS)	955(DCS)	955(DCS)
Analyst	JWM	JWM	JWM	GR	GR	GR	GR	GR
SiO_2	46.42	45.24	47.09	46.25	45.94	51.98	49.05	47.13
Al_2O_3	9.37	7.90	10.69	9.55	9.86	13.35	11.95	10.51
Fe_2O_3	2.47	2.50	1.10	2.45	2.20	4.43	1.62	7.65
FeO	9.37	9.63	9.70	9.76	10.10	6.73	10.06	4.68
MgO	19.63	24.14	18.15	19.40	19.29	5.16	11.73	15.61
CaO	8.23	6.89	9.74	8.28	8.73	7.89	9.41	9.26
Na_2O	1.47	1.23	1.48	1.53	1.47	3.18	2.19	1.97
K_2O	0.35	0.29	0.26	0.36	0.24	1.48	0.69	0.52
H_2O^+	.07	.01	< .01	.13	.11	.25	.21	.20
H_2O^-	.07	0.10	.06	.01	.00	.01	.00	.00
TiO_2	1.89	1.51	1.41	1.97	1.86	4.72	2.69	2.10
P_2O_5	0.19	0.16	0.13	0.24	0.11	0.66	0.32	0.30
MnO	0.17	0.17	0.16	0.18	0.18	0.16	0.17	0.18
CO_2	.01	.01	< .01	.02	.00	.01	.01	.00
Cl	.005	.008	.004	.006	.005	.026	.026	.013
F	.023	.024	.021	.016	.015	.092	.038	.030
S	-	-	-	-	-	-	-	-
Cr_2O_3	.19	.21	.20	-	-	-	-	-
Subtotal	99.93	100.02	100.19	100.15	100.11	100.13	100.16	100.15
Less O=Cl,F	.01	.01	.01	.01	.01	.05	.02	.02
Total	99.92	100.01	100.18	100.14	100.10	100.08	100.14	100.13
Type of sample				foundered crust	foundered crust	segregation vein	leopard rock	foundered crust with black olivines
Contains glass?	no	no	no	no	no	no	no	yes
Temperature before quench	low	low	low	medium	medium	medium	medium	high

Table 1. (continued)

	9	10	11	12	13
Field no.	KI67-1-76.7	KI67-1-79.0	KI67-1-82.4	KI67-1-85.3	KI67-1-89.0
Lab. no.	D-103988	D-103989	D-103990	D-103991	D-102046
Job no.	PH48	PH48	PH48	PH48	955(DSC)
Analyst	HK	HK	HK	HK	GR
SiO2	46.84	49.03	49.42	49.10	50.26
Al2O3	10.00	12.71	12.60	12.73	11.34
Fe2O3	1.60	2.23	1.36	1.40	3.54
FeO	9.95	9.29	9.66	9.71	11.82
MgO	18.36	9.51	9.60	9.98	4.83
CaO	8.89	11.31	11.53	11.45	9.02
Na2O	1.60	2.23	2.06	2.09	2.82
K2O	0.35	0.51	0.51	0.50	0.95
H2O+	.09	.05	0.13	.06	.33
H2O-	.01	.00	.01	.01	.02
TiO2	1.76	2.57	2.39	2.46	4.49
P2O5	0.22	0.29	0.24	0.25	0.45
MnO	0.17	0.17	0.17	0.17	0.20
CO2	.02	.03	.02	.03	.02
Cl	-	-	-	.017	.025
F	.021	.025	.037	.023	.064
S	.00	.00	.00	.00	-
Cr2O3	0.14	.03	.04	.04	-
Subtotal	100.02	99.99	99.78	100.02	100.18
Less O=Cl,F	.01	.01	.02	.01	.03
Total	100.01	99.98	99.77	100.02	100.15
Type of sample					glass in bit
Contains glass?	yes	yes	yes	yes	yes
Temperature before quench	high	high	high	high	high

Table 2. Analyses of Core from Kilauea Iki Drill Hole KI67-2

	1	2	3	4	5	6	7	8
Field no.	KI67-2-0.5	KI67-2-17.0	KI67-2-40.4	KI67-2-59.8	KI67-2-79.9	KI67-2-85.9	KI67-2-85.7	KI67-2-89.5
Lab. no.	W-232721	W-214299	W-214300	W-214301	W-214302	D-102049	D-102048	D-102050
Job no.	BR98	BD25	BD25	BD25	BD25	955(DCS)	955(DCS)	955(DCS)
Analyst	JWM	JWM	JWM	JWM	JWM	GR	GR	GR
SiO_2	48.23	46.72	45.71	47.42	45.90	50.17	56.21	47.89
Al_2O_3	12.32	10.24	8.94	10.83	8.51	13.28	12.88	11.14
Fe_2O_3	1.50	2.20	1.68	1.25	0.66	2.26	1.57	1.57
FeO	9.63	9.63	10.35	9.99	11.31	10.54	10.62	11.47
MgO	12.58	18.26	21.77	16.53	22.34	5.31	2.60	13.07
CaO	10.37	8.58	7.64	9.15	7.44	9.60	6.33	9.10
Na_2O	1.85	1.67	1.50	1.90	1.37	2.75	3.53	1.99
K_2O	0.44	0.39	0.32	0.44	0.33	0.95	1.99	0.55
H_2O+	.08	.04	.00	.02	.04	0.24	0.31	0.12
H_2O-	.10	.03	.04	.02	.02	.06	.01	.00
TiO_2	2.30	1.70	1.49	2.04	1.56	4.38	2.72	2.74
P_2O_5	0.26	0.17	0.14	0.19	0.15	0.44	0.88	0.26
MnO	0.17	0.17	0.18	0.17	0.17	0.19	0.20	0.19
CO_2	< .01	.01	.01	.01	.01	.02	.01	.02
Cl	.011	.006	.003	.004	.003	.021	.048	.017
F	.030	.025	.021	.026	.024	.060	0.15	.032
S	-	-	-	-	-	-	-	-
Cr_2O_3	.12	0.17	0.19	0.16	0.22	-	-	-
Subtotal	99.99	100.01	99.98	100.15	100.06	100.27	100.06	100.16
Less O=Cl,F	.01	.01	.01	.01	.01	.03	.07	.02
Total	99.98	100.00	99.97	100.14	100.05	100.24	99.99	100.14
Type of sample						segregation vein	ooze 7/6/67	leopard rock
Contains glass?	no	no	no	no	yes	yes	yes	yes
Temperature before quench	low	low	medium	medium	high	high	high	high

Table 2. (continued)

	9	10	11	12	13
Field no.	KI67-2-91.4a	KI67-2-94.6a	KI67-2-97.0a	KI67-2-98.0	KI67-2-70.0a
Lab. no.	D-103992	D-103993	D-103994	D-102051	D-102047
Job no.	PH48	PH48	PH48	955(DCS)	955(DCS)
Analyst	HK	HK	HK	GR	GR
SiO2	46.96	47.54	46.99	50.41	50.38
Al2O3	10.25	10.74	10.66	13.15	12.85
Fe2O3	1.62	1.40	1.16	2.19	2.29
FeO	10.73	9.59	10.34	11.07	11.16
MgO	16.49	15.91	17.31	5.15	5.16
CaO	8.90	9.96	8.96	9.31	9.04
Na2O	1.79	1.72	1.66	2.81	2.79
K2O	0.44	0.36	0.42	0.90	0.90
H2O+	.05	0.10	0.10	0.14	0.32
H2O-	.01	.01	.01	.00	.00
TiO2	2.41	1.92	1.69	4.24	4.29
P2O5	0.22	0.19	0.22	0.43	0.43
MnO	0.18	0.17	0.17	0.19	0.20
CO2	.01	.02	.02	.01	.02
Cl	-	-	.008	.021	.020
F	.026	.019	.023	.057	.057
S	.00	.00	.00	-	-
Cr2O3	0.12	0.11	0.13	-	-
Subtotal	100.21	99.76	99.87	100.08	99.91
Less O=Cl,F	.01	.01	.01	.03	.03
Total	100.20	99.75	99.86	100.05	99.88
Type of sample	leopard rock	foundered crust	deepest core	glass in bit 7/19/67	ooze 7/27/67
Contains glass?	yes	yes	yes	yes	devitrified
Temperature before quench	high	high	high	high	medium

Table 3. Analyses of Core from Kilauea Iki Drill Hole KI67-3

	1	2	3	4	5	6	7	8
Field no.	KI67-3-6.8	KI67-3-16.9	KI67-3-27.5	KI67-3-39.0	KI67-3-47.8	KI67-3-58.0	KI67-3-65.4	KI67-3-69.1
Lab. no.	W-214121	D-103975	D-103976	D-103977	D-103978	D-103979	D-103980	D-103981
Job no.	BD02	PH48	PH48	PH48	PH48	PH48	PH48	PH48
Analyst	JWM	HK	HK	HK	HK	HK	HK	HK
SiO2	44.63	47.44	48.61	48.90	48.05	49.64	49.30	49.48
Al2O3	7.58	10.74	11.74	12.16	11.54	12.97	12.79	12.68
Fe2O3	2.10	2.10	3.30	4.14	1.97	1.68	1.30	1.84
FeO	10.13	9.34	8.19	7.59	9.82	9.34	9.63	9.10
MgO	25.83	16.30	12.01	10.73	13.10	8.91	10.23	10.44
CaO	6.25	9.22	10.59	10.71	9.76	10.70	10.60	10.55
Na2O	1.22	1.78	1.95	2.05	1.97	2.31	2.11	2.14
K2O	0.30	0.42	0.49	0.54	0.50	0.62	0.55	0.58
H2O+	0.18	.06	.06	0.10	0.12	.09	.03	.02
H2O-	.03	.01	.03	.02	.01	.02	.02	.03
TiO2	1.32	1.99	2.31	2.48	2.44	3.01	2.78	2.64
P2O5	0.12	0.22	0.24	0.24	0.25	0.30	0.27	0.31
MnO	0.18	0.17	0.17	0.17	0.17	0.17	0.16	0.16
CO2	.01	.01	.02	.02	.02	.02	.02	.02
Cl	.007	-	-	.015	-	-	.015	-
F	.024	.027	.038	.041	.032	.040	.041	.037
S	-	.00	.00	.00	.00	.00	.00	.00
Cr2O3	0.24	0.12	.09	.06	.09	.04	.05	.05
Subtotal	100.15	99.95	99.84	99.97	99.84	99.86	99.90	100.08
Less O=Cl,F	.01	.01	.02	.02	.01	.02	.02	.02
Total	100.14	99.94	99.82	99.95	99.83	99.84	99.88	100.06
Type of sample								
Contains glass?	no	no	no	no	no	no	trace	trace
Temperature before quench	low	low	low	low	medium	medium	medium	medium/ high

Table 3. (continued)

	9	10	11	12	13	14	15	16
Field no.	KI67-3-74.0	KI67-3-75.0	KI67-3-76.2	KI67-3-78.3	KI67-3-81	KI67-3-83.0	KI67-3-83.8	KI67-3-84.0
Lab. no.	D-103982	D-102052	D-102053	D-103983	D-103984	D-103985	D-103986	D-103987
Job no.	PH48	955(DCS)	955(DCS)	PH48	PH48	PH48	PH48	PH48
Analyst	HK	GR	GR	HK	HK	HK	HK	HK
SiO2	49.81	49.37	50.82	49.66	49.75	49.82	49.93	49.93
Al2O3	13.60	13.33	12.72	13.32	13.53	13.57	13.61	13.81
Fe2O3	1.73	1.53	2.14	1.89	1.70	1.78	1.92	1.73
FeO	8.83	9.54	10.80	9.27	9.41	9.48	9.18	9.13
MgO	8.27	9.47	5.14	7.90	7.73	7.91	7.54	7.69
CaO	11.37	10.87	9.34	11.00	11.00	10.80	10.80	10.88
Na2O	2.40	2.21	2.90	2.43	2.46	2.47	2.46	2.51
K2O	0.60	0.56	1.00	0.60	0.63	0.64	0.67	0.65
H2O+	0.12	.19	.20	0.12	0.14	0.13	0.14	0.14
H2O-	.01	.00	.00	.01	.01	.00	.01	.01
TiO2	2.82	2.86	4.34	3.06	3.03	2.99	2.99	2.99
P2O5	0.30	0.26	0.58	0.33	0.30	0.31	0.36	0.31
MnO	0.16	0.17	0.20	0.17	0.17	0.17	0.16	0.16
CO2	.02	.01	.01	.01	.02	.03	.03	.01
Cl	-	.014	.022	-	-	-	.018	.018
F	.029	.030	.061	.030	.030	.030	.037	.030
S	.00	-	-	.00	.00	.00	.00	.00
Cr2O3	.05	-	-	< .02	< .02	< .02	< .02	< .02
Subtotal	100.12	100.41	100.27	99.80	99.91	100.13	99.86	100.00
Less O=Cl,F	.01	.02	.03	.01	.01	.01	.02	.02
Total	100.11	100.39	100.24	99.79	99.90	100.12	99.84	99.98
Type of sample			segregation vein					
Contains glass?	yes	yes	yes	yes	yes	yes	yes	yes
Temperature before quench	high	high	high	high	high	high	high	high

Table 3. (continued)

	17
Field no.	KI67-3-87.0
Lab. no.	D-102054
Job no.	955(DCS)
Analyst	GR
SiO2	50.44
Al2O3	13.07
Fe2O3	2.38
FeO	10.71
MgO	5.44
CaO	9.51
Na2O	2.81
K2O	0.91
H2O+	0.11
H2O-	.00
TiO2	4.12
P2O5	0.42
MnO	0.19
CO2	.01
Cl	.021
F	.055
S	-
Cr2O3	-
Subtotal	100.20
Less O=Cl,F	.03
Total	100.17
Type of sample	glass in bit
Contains glass?	yes
Temperature before quench	high

Table 4. Analyses of Core from Kilauea Iki Drill Hole KI75-1

	1	2	3	4	5	6	7	8
Field no.	KI75-1-17.8	KI75-1-28.7	KI75-1-38.9	KI75-1-50.8	KI75-1-60.9	KI75-1-70.2	KI75-1-75.2	KI75-1-79.6
Lab. no.	DD-103840	D-103841	D-103842	D-103843	D-103844	D-103845	D-103846	D-103847
Job no.	PE74	PE74	PE74	PE74	PE74	PE74	PE74	PE74
Analyst	HK	HK	HK	HK	HK	HK	HK	HK
SiO_2	47.99	48.70	48.39	49.52	49.13	49.05	50.13	50.24
Al_2O_3	11.48	11.91	11.78	12.91	12.72	12.61	13.69	13.64
Fe_2O_3	1.54	2.06	1.52	1.78	1.57	1.52	1.80	1.69
FeO	9.45	9.45	10.03	9.45	9.58	9.52	10.40	9.06
MgO	14.44	11.70	12.46	9.07	10.52	10.71	5.77	7.50
CaO	10.19	10.72	10.47	10.54	10.57	10.61	10.01	10.88
Na_2O	1.83	1.95	1.95	2.33	2.21	2.12	2.73	2.48
K_2O	0.39	0.48	0.48	0.62	0.57	0.54	0.79	0.66
H_2O+	0.11	0.10	0.11	0.17	0.14	0.16	0.07	0.13
H_2O-	.05	.00	.02	.02	.01	.02	.01	.03
TiO_2	1.97	2.38	2.31	3.11	2.57	2.59	4.12	2.83
P_2O_5	0.20	0.25	0.24	0.30	0.25	0.29	0.38	0.36
MnO	0.17	0.17	0.17	0.17	0.17	0.17	0.18	0.16
CO_2	.02	.02	.02	.03	.02	.02	.02	.02
Cl	.004	.005	.005	.008	.008	.006	.011	.014
F	.024	.025	.021	.031	.024	.026	.028	.039
S	.00	.00	.00	.00	.00	.00	.00	.00
Cr_2O_3	.14	0.10	0.11	.06	.09	.09	< .01	.05
Subtotal	100.00	100.02	100.09	100.12	100.15	100.05	100.14	99.78
Less O=Cl,F	.01	.01	.01	.01	.01	.01	.01	.02
Total	99.99	100.01	100.08	100.11	100.14	100.04	100.13	99.76
Type of sample							segregation vein	
Contains glass?	no	no	no	no	no	no	no	no
Temperature before quench	low	low	low	low	low	low	low	low

Table 4. (continued)

	9	10	11	12	13	14	15	16
Field no.	KI75-1-85.5	KI75-1-89.9	KI75-1-95.0	KI75-1-104.9	KI75-1-110	KI75-1-114.9	KI75-1-115.5	KI75-1-121.5
Lab. no.	D-103848	D-103849	D-103850	D-103851	D-103852	D-103853	D-103854	D-103855
Job no.	PE74	PE74	PE74	PE74	PE74	PE74	PE74	PE74
Analyst	HK	HK	HK	HK	HK	HK	HK	HK
SiO2	49.64	49.67	49.21	49.37	49.67	50.17	50.13	50.00
Al2O3	13.37	13.33	12.88	13.53	13.61	13.34	14.00	13.46
Fe2O3	1.74	1.82	1.55	1.57	1.81	2.29	1.70	1.64
FeO	9.18	9.09	9.54	9.24	9.09	10.85	8.85	9.07
MgO	8.33	8.43	9.64	8.59	8.27	5.26	7.53	7.77
CaO	10.92	10.76	10.81	10.80	10.81	9.00	10.90	11.00
Na2O	2.38	2.40	2.23	2.39	2.43	2.90	2.55	2.49
K2O	0.60	0.62	0.54	0.60	0.62	0.96	0.66	0.64
H2O+	.09	.09	.08	.00	.00	.00	.00	.04
H2O-	.02	.02	.02	.01	.01	.02	.01	.00
TiO2	2.99	2.99	2.74	2.90	2.92	4.47	2.96	3.06
P2O5	0.33	0.36	0.29	0.34	0.32	0.46	0.34	0.37
MnO	0.16	0.16	0.17	0.16	0.16	0.19	0.16	0.16
CO2	.02	.02	.02	.02	.02	.01	.02	.03
Cl	.014	.013	.013	.020	.017	.012	.015	.019
F	.040	.041	.032	.040	.034	.062	.043	.041
S	.00	.00	.00	.00	.00	.00	.00	.00
Cr2O3	.06	.05	.09	.07	.06	< .01	.05	.06
Subtotal	99.88	99.86	99.85	99.65	99.85	99.99	99.92	99.85
Less O=Cl,F	.02	.02	.02	.02	.02	.03	.02	.02
Total	99.86	99.84	99.83	99.63	99.83	99.96	99.90	99.84
Type of sample						segregation vein		
Contains glass?	no	no	no	no	no	no	no	no
Temperature before quench	low	low	low	low	medium	medium	medium	medium

Table 4. (continued)

	17	18	19	20	21	22	23	24
Field no.	KI75-1-125.0	KI75-1-130.5	KI75-1-133.4	KI75-1-134.5	KI75-1-139.3	KI75-1-141.9	KI75-1-143.8	KI75-1-138.2
Lab. no.	W-214316	D-103837	D-103856	D-103857	D-103858	D-103859	D-103860	D-103861
Job no.	BD25	PD99	PE74	PE74	PE74	PE74	PE74	PE74
Analyst	JWM	EE	HK	HK	HK	HK	HK	HK
SiO_2	50.62	49.66	48.96	48.90	48.77	48.82	48.46	50.64
Al_2O_3	12.51	12.78	12.53	12.69	12.37	12.46	12.33	13.62
Fe_2O_3	2.18	1.59	1.56	1.57	1.54	1.64	1.61	2.00
FeO	10.28	9.18	9.26	9.33	9.34	9.06	9.02	10.06
MgO	5.94	9.73	10.65	10.90	11.64	11.62	12.15	5.72
CaO	9.52	10.60	10.57	10.64	10.56	10.65	10.76	9.75
Na_2O	2.78	2.25	2.18	2.13	2.06	2.04	1.98	2.84
K_2O	0.94	.59	0.56	0.54	0.52	0.52	0.49	0.88
H_2O+	0.10	.03	0.11	.09	.08	.09	.08	0.14
H_2O-	.05	.00	.00	.00	.01	.01	.01	.03
TiO_2	4.21	2.79	2.63	2.53	2.45	2.40	2.34	3.99
P_2O_5	0.45	.29	0.35	0.31	0.27	0.26	0.28	0.41
MnO	0.18	.16	0.16	0.16	0.16	0.16	0.16	0.18
CO_2	.01	.01	.03	.02	.02	.02	.02	.03
Cl	.017	.01	.016	.019	.016	.016	.016	.018
F	.062	.05	.027	.037	.032	.034	.035	.035
S	-	-	.00	.00	.00	.00	.00	.00
Cr_2O_3	< .01	.08	.09	0.10	0.11	0.12	0.13	.01
Subtotal	99.85	99.80	99.69	99.97	99.95	99.92	99.86	100.35
Less O=Cl,F	.03	.02	.02	.02	.02	.02	.02	.02
Total	99.82	99.78	99.67	99.95	99.93	99.90	99.84	100.33
Type of sample	segregation vein							ooze
Contains glass?	yes	yes	yes	yes	yes	yes	yes	devitrified
Temperature before quench	medium	high	high	high	high	high	high	medium

Table 5. Analyses of Core from Kilauea Iki Drill Hole KI75-2

	1	2	3	4	5	6	7	8
Field no.	KI75-2-33.5	KI75-2-34.0	KI75-2-34.2	KI75-2-44.7	KI75-2-45.4	KI75-2-86.2	KI75-2-100.0	KI75-2-110.0
Lab. no.	D-103862	W-232726	W-232727	D-103863	D-103864	D-103865	D-103866	D-103867
Job no.	PE74	BR98	BR98	PE74	PE74	PE74	PE74	PE74
Analyst	HK	JWM	JWM	HK	HK	HK	HK	HK
SiO2	47.90	46.62	47.47	47.27	46.70	49.37	48.75	49.94
Al2O3	11.46	9.82	10.87	10.20	10.05	12.71	12.20	13.56
Fe2O3	1.51	1.33	1.62	1.28	1.08	1.39	2.15	1.95
FeO	10.13	10.73	10.06	10.86	10.80	9.52	9.13	8.58
MgO	14.12	18.34	15.63	16.72	18.12	10.04	11.76	8.47
CaO	9.76	7.92	9.16	8.28	8.84	11.37	10.34	10.81
Na2O	1.84	1.66	1.76	1.77	1.57	2.11	2.10	2.40
K2O	0.46	0.45	0.46	0.50	0.35	0.53	0.52	0.63
H2O+	.06	< .01	< .01	.07	.04	.09	.04	.01
H2O-	.03	.09	0.13	.03	.02	.01	.02	.02
TiO2	2.34	2.31	2.19	2.42	1.94	2.50	2.53	2.87
P2O5	0.26	0.23	0.24	0.28	0.20	0.25	0.25	0.32
MnO	0.17	0.18	0.17	0.18	0.17	0.17	0.17	0.16
CO2	.03	.01	< .01	.02	.02	.03	.03	.02
Cl	-	.006	.006	-	-	-	-	-
F	.020	.033	.027	.025	.025	.031	.029	.043
S	.00	-	-	.00	.00	.00	.00	.00
Cr2O3	0.12	0.13	0.12	0.15	0.17	.07	0.13	.07
Subtotal	100.21	99.86	99.91	100.06	100.10	100.19	100.15	99.85
Less O=Cl,F	.01	.01	.01	.01	.01	.01	.01	.02
Total	100.20	99.85	99.90	100.05	100.09	100.18	100.14	99.83
Type of sample	foundered crust	spotted rock	foundered crust	spotted rock	foundered crust			
Contains glass?	no	no	no	no	no	no	no	no
Temperature before quench	low	low	low	low	low	low	low	medium

Table 5. (continued)

	9	10	11	12	13
Field no.	KI75-2-115.2	KI75-2-119.2	KI75-2-129.3	KI75-2-132.9	KI75-2-138.7
Lab no.	D-103868	D-103869	D-103838	D-103870	D-103871
Job no.	PE74	PE74	PD99	PE74	PE74
Analyst	HK	HK	EE	HK	HK
SiO2	50.06	50.41	50.21	49.52	50.86
Al2O3	13.49	13.74	13.04	12.94	13.31
Fe2O3	1.93	2.16	1.70	1.76	2.38
FeO	8.90	8.60	8.91	9.17	10.15
MgO	7.98	7.46	9.14	9.73	5.07
CaO	10.75	10.52	10.49	10.05	8.92
Na2O	2.48	2.57	2.34	2.39	2.96
K2O	0.65	0.74	0.62	0.67	1.00
H2O+	.02	0.11	.00	0.10	0.15
H2O-	.01	.01	.00	.02	.02
TiO2	3.10	3.17	3.02	3.03	4.47
P2O5	0.33	0.34	0.30	0.33	0.52
MnO	0.16	0.16	0.16	0.16	0.18
CO2	.03	.03	.00	.02	.02
Cl	-	-	.01	-	.024
F	.046	.042	.05	.031	.047
S	.00	.00	-	.00	.00
Cr2O3	.07	.07	.08	.08	.01
Subtotal	100.01	100.13	100.07	100.00	100.09
Less O=Cl,F	.02	.02	.02	.01	.03
Total	99.99	100.11	100.05	99.99	100.06
Type of sample				lowest piece of crust	glass in bit
Contains glass?	no	no	yes	yes	yes
Temperature before quench	medium	medium	high	high	high

Table 6. Analyses of Core from Kilauea Iki Drill Hole KI75-3

	1	2	3	4	5	6	7	8
Field no.	KI75-3-99.4	KI75-3-100.9	KI75-3-106.0	KI75-3-116.0	KI75-3-123.2	KI75-3-132	KI75-3-138.9	KI75-3-144.4
Lab. no.	D-103872	D-103873	D-103874	D-103875	D-103839	W-214303	D-103876	D-103877
Job no.	PE74	PE74	PE74	PE74	PD99	BD25	PE74	PE74
Analyst	HK	HK	HK	HK	EE	JWM	HK	HK
SiO_2	49.09	49.53	49.79	49.39	49.93	49.03	47.95	47.46
Al_2O_3	12.60	12.59	12.75	12.73	13.07	12.58	11.18	10.79
Fe_2O_3	2.42	2.31	2.89	1.50	1.62	1.38	1.66	1.32
FeO	8.70	9.24	8.60	9.45	9.30	9.56	10.01	9.89
MgO	10.51	9.12	7.98	9.45	8.71	11.56	13.95	16.20
CaO	11.46	11.26	11.59	11.40	11.43	10.17	10.04	9.71
Na_2O	1.99	2.14	2.26	2.17	2.19	2.21	1.89	1.69
K_2O	0.43	0.55	0.56	0.53	0.57	0.56	0.44	0.39
H_2O+	.05	.04	.05	.04	.06	.09	.03	.01
H_2O-	.01	.00	.01	.02	.02	.01	.02	.03
TiO_2	2.13	2.55	2.82	2.63	2.54	2.42	2.07	1.89
P_2O_5	0.23	0.35	0.32	0.31	0.25	0.27	0.27	0.18
MnO	0.17	0.17	0.17	0.16	0.17	0.17	0.17	0.16
CO_2	.03	.02	.03	.03	.00	.01	.02	.02
Cl	-	-	-	-	.015	.011	-	-
F	.031	.037	.044	.037	.04	.040	.033	.029
S	.00	.00	.00	.00	.00	-	.00	.00
Cr_2O_3	.08	.08	.06	.07	.05	0.10	0.15	0.19
Subtotal	99.93	99.99	99.92	99.98	99.91	100.17	99.88	99.96
Less O=Cl,F	.01	.02	.02	.02	.02	.02	.01	.01
Total	99.92	99.97	99.90	99.86	99.89	100.15	99.87	99.95
Type of sample								
Contains glass?	no	no	no	no	no	yes	yes	yes
Temperature before quench	low	low	low	low	medium	high	high	high

Table 7. Analyses of Core from Kilauea Iki Drill Hole KI79-1

	1	2	3	4	5	6	7	8
Field no.	KI79-1-80.6	KI79-1-90.4	KI79-1-100.4	KI79-1-110.3	KI79-1-119.1	KI79-1-123.3	KI79-1-131.8	KI79-1-135.9
Lab. no.	W-241457	W-241458	W-241459	W-241460	W-241461	W-241462	W-241463	W-241464
Job no.	BX99	BX99	BX99	BX99	BX99	BX99	BX99	BX99
Analyst	JWM	JWM	JWM	JWM	JWM	JWM	JWM	JWM
SiO2	49.36	49.66	49.82	49.39	50.02	50.41	50.54	50.19
Al2O3	13.01	13.66	13.50	13.01	13.41	13.60	13.61	13.78
Fe2O3	1.24	1.54	1.45	1.60	1.88	1.74	1.88	1.86
FeO	9.41	9.05	9.27	9.63	8.84	9.10	8.91	8.77
MgO	9.52	8.91	8.71	9.39	8.31	7.89	7.29	7.88
CaO	10.82	11.20	10.66	10.59	11.02	10.84	10.99	11.11
Na2O	2.15	2.23	2.28	2.12	2.27	2.34	2.36	2.27
K2O	0.54	0.53	0.60	0.58	0.59	0.62	0.62	0.59
H2O+	0.25	0.12	.07	.04	.04	.02	< .01	.01
H2O-	.04	.07	.06	.07	.05	.06	.06	.04
TiO2	2.77	2.64	2.87	2.85	2.96	3.03	3.14	2.97
P2O5	0.26	0.29	0.33	0.30	0.30	0.33	0.31	0.30
MnO	0.16	0.16	0.16	0.17	0.17	0.16	0.15	0.16
CO2	< .01	< .01	< .01	< .01	< .01	< .01	< .01	< .01
Cl	.008	.009	.008	.005	.005	.023	.012	.010
F	.029	.028	.041	.038	.044	.046	.042	.039
S	-	-	-	-	-	-	-	-
Cr2O3	.10	.09	.08	.08	.08	.07	.06	.08
Subtotal	99.67	100.20	99.91	99.86	99.98	100.28	99.97	100.06
Less O=Cl,F	.01	.01	.02	.02	.02	.02	.02	.02
Total	99.66	100.19	99.89	99.84	99.96	100.26	99.95	100.04
Type of sample								
Contains glass?	no	no	no	no	no	no	no	no
Temperature before quench	low	low	low	low	low	low	low	low

Table 7. (continued)

	9	10	11	12	13	14	15	16
Field no.	KI79-1-141.0	KI79-1-150.3	KI79-1-159.5	KI79-1-170.2	KI79-1-175.0	KI79-1-180.1	KI79-1-184.5	KI79-1-189.0
Lab. no.	W-223014	W-223013	W-223012	W-223011	W-223010	W-210874	W-210875	W-210876
Job no.	BK52	BK52	BK52	BK52	BK52	BA56	BA56	BA56
Analyst	JWM	JWM	JWM	JWM	JWM	HK	HK	HK
SiO2	49.60	47.74	48.56	48.06	47.07	46.87	47.39	45.85
Al2O3	12.84	11.30	11.74	11.04	10.27	9.77	10.34	8.93
Fe2O3	1.38	1.07	1.32	1.12	1.15	1.13	1.44	1.09
FeO	9.27	10.20	9.34	9.84	10.35	10.61	10.08	11.39
MgO	10.42	14.75	13.57	15.03	17.08	18.33	16.73	20.72
CaO	10.70	9.84	10.53	10.32	9.47	9.23	9.34	8.05
Na2O	2.19	1.88	1.88	1.72	1.63	1.47	1.66	1.36
K2O	0.57	0.46	0.46	0.42	0.41	0.35	0.41	0.32
H2O+	.06	.05	0.16	0.11	0.11	.04	0.10	.06
H2O-	.02	.02	.01	.02	< .01	.01	.01	.01
TiO2	2.77	2.23	2.24	2.06	1.96	1.68	1.95	1.52
P2O5	0.26	0.19	0.21	0.19	0.18	0.16	0.19	0.16
MnO	0.16	0.17	0.16	0.17	0.17	0.17	0.17	0.18
CO2	.02	.01	.01	.01	.01	.01	.01	.01
Cl	.017	.020	.013	.014	.02	.012	.016	.008
F	.03	.03	.03	.03	.03	.024	.027	.022
S	-	-	-	-	-	-	-	-
Cr2O3	.10	0.14	0.14	0.18	0.18	0.18	0.15	0.16
Subtotal	100.41	100.10	100.37	100.33	100.09	100.05	100.01	99.84
Less O=Cl,F	.01	.02	.01	.01	.02	.01	.01	.01
Total	100.40	100.08	100.36	100.32	100.07	100.04	100.00	99.83
Type of sample								
Contains glass?	no	no	yes	yes	yes	yes	yes	yes
Temperature before quench	medium	medium	high	high	high	high	high	high

Table 7. (continued)

	17	18
Field no.	KI79-1-197.3	KI79-1-203.7
Lab. no.	W-210877	W-210878
Job no.	BA56	BA56
Analyst	HK	HK
SiO_2	46.24	45.55
Al_2O_3	9.15	8.19
Fe_2O_3	1.13	1.16
FeO	10.61	10.98
MgO	20.20	22.68
CaO	9.04	8.17
Na_2O	1.31	1.17
K_2O	0.28	0.25
H_2O+	.08	.04
H_2O-	.01	.00
TiO_2	1.39	1.27
P_2O_5	0.12	0.12
MnO	0.17	0.17
CO_2	.01	.01
Cl	.007	.012
F	.020	.018
S	.00	.00
Cr_2O_3	0.21	0.22
Subtotal	99.98	100.01
Less O=Cl,F	.01	.01
Total	99.97	100.00
Type of sample	foundered crust(?)	foundered crust(?)
Contains glass?	yes	yes
Temperature before quench	high	high

Table 7a. Analyses of Oozes Recovered During Re-entry of Kilauea Iki Drill Hole KI79-1

	1	2	3	4	5	6
Field no.	KI79-1R1-167.8	KI79-1R1-170.0	KI79-1R1-170.9	KI79-1R1-175.2	KI79-1R1-176.8	KI79-1R2-173.8
Lab. no.	W-235378	W-235379	W-235380	W-235381	W-235382	W-235383
Job no.	BT73	BT73	BT73	BT73	BT73	BT73
Analyst	JWM	JWM	JWM	JWM	JWM	JWM
SiO2	54.78	49.58	54.59	47.13	46.57	46.89
Al2O3	13.22	10.99	13.01	9.75	9.39	9.57
Fe2O3	1.88	1.30	1.86	1.15	1.09	1.12
FeO	9.92	10.71	10.30	11.21	11.35	11.28
MgO	3.42	13.05	3.48	17.55	18.60	18.15
CaO	7.08	8.41	7.07	8.52	8.28	8.43
Na2O	3.41	2.08	3.37	1.53	1.45	1.48
K2O	1.52	0.74	1.51	0.43	0.38	0.39
H2O+	.09	.01	0.15	.02	.01	.04
H2O-	0.17	0.10	.06	.08	.07	.06
TiO2	3.24	2.53	3.21	2.04	1.94	2.00
P2O5	0.74	0.41	0.69	0.25	0.23	0.22
MnO	0.18	0.18	0.19	0.18	0.18	0.18
CO2	< .01	.01	.02	< .01	< .01	< .01
Cl	.063	.020	.045	.013	.011	.015
F	0.12	.052	0.12	.032	.030	.029
S	-	-	-	-	-	-
Cr2O3	< .01	0.10	< .01	.13	.14	.14
Subtotal	99.85	100.27	99.68	100.02	99.72	99.99
Less O=Cl,F	.064	.025	.060	.016	.015	.015
Total	99.79	100.24	99.62	100.00	99.71	99.98
Type of sample	Partially crystalline melt layer	Olivine-phyric matrix with melt spots	Partially crystalline melt layer	Olivine-phyric matrix with melt spots	Bottom of 1R1	Top of 1R2
Contains glass?	yes	yes	yes	yes	yes	devit
Temperature before quench	high	high	high	high	high	high

Table 7a. (continued)

	7	8	9	10
Field no.	KI79-1R2-177	KI79-1R3-173.8	KI79-1R3-178.5	KI79-1R3-181.3
Lab no.	W-235384	W-235385	W-235386	W-235387
Job no.	BT73	BT73	BT73	BT73
Analyst	JWM	JWM	JWM	JWM
SiO2	47.22	46.49	47.41	46.52
Al2O3	10.27	9.29	10.33	9.30
Fe2O3	1.29	1.10	1.34	1.25
FeO	10.63	11.21	10.99	11.07
MgO	16.41	18.51	16.45	19.03
CaO	9.16	8.64	8.48	8.55
Na2O	1.65	1.43	1.70	1.42
K2O	0.43	0.37	0.47	0.37
H2O+	.07	.05	< .01	.04
H2O-	.02	0.10	0.11	0.11
TiO2	2.12	1.85	2.24	1.81
P2O5	0.21	0.24	0.27	0.20
MnO	0.18	0.18	0.18	0.17
CO2	.01	.01	< .01	.01
Cl	.012	.009	.012	.005
F	.031	.028	.035	.025
S	-	-	-	-
Cr2O3	.13	.13	0.10	0.14
Subtotal	99.84	99.64	100.12	100.01
Less O=Cl,F	.016	.014	.018	.012
Total	99.82	99.63	100.10	100.00
Type of sample	Bottom of 1R2	Top of 1R3	Cooler block in plastic matrix	Bottom of 1R3
Contains glass?	yes	devit	no?	yes
Temperature before quench	high	high	high	high

Table 8. Analyses of Core from Kilauea Iki Drill Hole KI79-3

	1	2	3	4	5	6	7	8
Field no.	KI79-3-100.0	KI79-3-145.1	KI79-3-150.4	KI79-3-158.0	KI79-3-160.3	KI79-3-166.1	KI79-3-169.1	KI79-3-172.8
Lab. no.	W-214315	W-210495	W-210496	W-214317	W-210497	W-210498	W-210499	W-210500
Job no.	BD25	BA23	BA23	BD25	BA23	BA23	BA23	BA23
Analyst	JWM	HK	HK	JWM	HK	HK	HK	HK
SiO2	51.03	43.94	48.44	52.36	47.37	43.40	46.67	46.58
Al2O3	14.28	6.59	11.72	12.68	10.82	5.88	10.07	9.86
Fe2O3	1.74	1.12	1.36	2.67	1.38	1.14	1.22	1.25
FeO	8.69	13.12	9.32	9.77	10.17	13.86	10.44	10.44
MgO	5.91	26.16	13.51	4.50	16.05	27.41	18.21	18.71
CaO	10.75	5.84	10.77	8.20	9.35	5.21	9.04	8.97
Na2O	2.84	1.08	1.82	3.22	1.74	0.97	1.52	1.49
K2O	0.71	0.23	0.44	1.28	0.43	0.24	0.35	0.35
H2O+	.09	.04	.04	.03	.07	.05	.05	.05
H2O-	.01	.00	.01	.05	.02	.01	.01	.01
TiO2	3.36	1.34	2.07	4.33	2.07	1.24	1.73	1.70
P2O5	0.32	0.10	0.19	0.59	0.18	0.10	0.16	0.16
MnO	0.16	0.20	0.16	0.18	0.17	0.20	0.17	0.17
CO2	.02	.01	.01	.02	.01	.01	.01	.01
Cl	.008	.005	.007	.020	.012	.007	.010	.010
F	.040	.014	.026	.067	.027	.016	.022	.022
S	-	.00	.00	-	.00	.00	.00	.00
Cr2O3	.01	0.18	0.14	< .01	0.13	0.20	0.16	0.17
Subtotal	99.97	99.97	100.03	99.97	100.00	99.94	99.84	99.95
Less O=Cl,F	.02	.01	.01	.03	.01	.01	.01	.01
Total	99.95	99.96	100.02	99.94	99.99	99.93	99.83	99.94
Type of sample	segregation vein	vorb		segregation vein		vorb		
Contains glass?	devitrified	trace	no	yes	yes	yes	yes	yes
Temperature before quench	low	medium	medium	high	high	high	high	high

Table 8a. Analyses of Oozes Recovered During Re-entry of Kilauea Iki Drill Hole KI79-3.

Field no.	KI79-3R1-157.0	KI79-3R1-165.4	KI79-3R2-161	KI79-3R2-168
Lab. no.	W-235388	W-235389	W-235390	W-235391
Job no.	BT73	BT73	BT73	BT73
Analyst	JWM	JWM	JWM	JWM
SiO_2	50.76	50.94	51.00	50.94
Al_2O_3	13.22	13.30	13.07	13.12
Fe_2O_3	2.30	2.38	2.47	2.35
FeO	10.49	10.28	10.20	10.35
MgO	5.01	4.92	4.97	5.07
CaO	9.14	8.83	8.95	9.07
Na_2O	2.65	2.70	2.69	2.66
K_2O	0.92	0.96	0.94	0.92
H_2O+	0.16	0.14	.09	0.27
H_2O-	.04	.08	.08	.01
TiO_2	4.51	4.65	4.57	4.46
P_2O_5	0.51	0.53	0.60	0.56
MnO	0.19	0.19	0.19	0.19
CO_2	< .01	.01	< .01	.01
Cl	.026	.018	.019	.020
F	.069	.069	.067	.070
S	-	-	-	-
Cr_2O_3	< .01	< .01	< .01	< .01
Subtotal	100.00	100.00	99.91	100.07
Less O=Cl,F	.035	.033	.032	.033
Total	99.97	99.97	99.88	100.04
Type of sample	ooze, top of 3R1	ooze, bottom of 3R1	ooze, top of 3R2	ooze, top of 3R2
Contains glass?	devitrified	devitrified?	devitrified	devitrified?
Temperature before quench	medium	medium	medium	medium

Table 9. Analyses of Core from Kilauea Iki Drill Hole KI79-5

	1	2	3	4	5	6	7	8
Field no.	KI79-5-151.1	KI79-5-160.0	KI79-5-180.5	KI79-5-200.0	KI79-5-220.0	KI79-5-230	KI79-5-240.0	KI79-5-260.0
Lab. no.	W-232718	W-214304	W-214305	W-214306	W-241456	W-232719	W-214308	W-214309
Job no.	BR98	BD25	BD25	BD25	BX99	BR98	BD25	BD25
Analyst	JWM	JWM	JWM	JWM	JWM	JWM	JWM	JWM
SiO_2	45.82	45.82	46.35	45.77	45.76	46.19	46.06	46.95
Al_2O_3	9.09	8.58	9.16	8.62	8.12	9.25	8.75	9.67
Fe_2O_3	0.91	0.87	1.02	1.06	1.20	1.02	1.02	1.17
FeO	11.06	11.28	10.56	11.42	11.28	10.78	11.35	10.42
MgO	20.53	22.08	20.70	21.30	22.35	20.12	20.35	18.84
CaO	8.42	7.99	8.52	7.99	7.76	8.43	8.40	8.60
Na_2O	1.27	1.28	1.37	1.37	1.26	1.34	1.47	1.63
K_2O	0.28	0.28	0.30	0.31	0.28	0.31	0.30	0.40
H_2O+	.01	.04	.02	.05	< .01	< .01	.05	.07
H_2O-	0.10	.02	.02	.02	.02	0.13	.02	.02
TiO_2	1.57	1.44	1.47	1.62	1.46	1.68	1.81	1.91
P_2O_5	0.14	0.13	0.15	0.15	0.14	0.25	0.15	0.19
MnO	0.17	0.18	0.17	0.17	0.17	0.17	0.17	0.16
CO_2	< .01	.01	.01	.01	< .01	< .01	.01	.01
Cl	.005	.003	.003	.003	.004	.005	.004	.003
F	.022	.020	.022	.022	.023	.024	.023	.027
S	-	-	-	-	-	-	-	-
Cr_2O_3	.16	0.22	0.23	0.21	0.26	0.16	0.21	0.18
Subtotal	99.56	100.24	100.09	100.09	100.09	99.86	100.14	100.25
Less O=Cl,F	.01	.01	.01	.01	.01	.01	.01	.01
Total	99.55	100.23	100.08	100.08	100.08	99.85	100.13	100.24
Type of sample							contains minor segregation	
Contains glass?	no	no	trace	trace	no	no	no	no
Temperature before quench	medium	medium	high	high	medium	medium	medium	medium

Table 9. (continued)

	9	10	11	12	13
Field no.	KI79-5-281.2	KI79-5-289.9	KI79-5-300.5	KI79-5-310.6	KI79-5-313.5
Lab. no.	W-214310	W-232720	W-214311	W-214312	W-214313
Job no.	BD25	BR98	BD25	BD25	BD25
Analyst	JWM	JWM	JWM	JWM	JWM
SiO2	46.10	47.02	47.40	47.73	49.22
Al2O3	8.89	10.13	10.35	11.01	12.56
Fe2O3	2.33	1.43	1.72	1.74	5.26
FeO	9.92	10.13	9.84	9.77	6.47
MgO	20.60	17.66	16.61	14.99	9.51
CaO	7.95	8.84	9.21	9.66	11.32
Na2O	1.45	1.54	1.67	1.77	2.07
K2O	0.34	0.38	0.42	0.44	0.51
H2O+	.08	< .01	0.13	.09	0.10
H2O-	.02	0.12	.03	.01	.02
TiO2	1.88	1.99	2.07	2.20	2.53
P2O5	0.16	0.22	0.20	0.20	0.25
MnO	0.17	0.17	0.17	0.17	0.17
CO2	.01	.01	.02	.02	.02
Cl	.004	.010	.006	.007	.009
F	.024	.026	.028	.030	.030
S	-	-	-	-	-
Cr2O3	0.21	0.16	.17	0.16	.08
Subtotal	100.13	99.84	100.05	100.00	100.13
Less O=Cl,F	.01	.01	.01	.01	.02
Total	100.12	99.83	100.04	99.99	100.11
Type of sample	vorb				lower chilled contact of lake
Contains glass?	no	no	no	no	no
Temperature before quench	medium	medium	medium	medium	medium

Table 10. Analyses of Core from Kilauea Iki Drill Hole KI81-1

	1	2	3	4	5	6	7	8
Field no.	KI81-1-86.0	KI81-1-86.2	KI81-1-88.7	KI81-1-90.4	KI81-1-114.3	KI81-1-117.8	KI81-1-119.2	KI81-1-120.3
Lab. no.	W-239449	W-214314	W-239450	W-239451	W-239452	W-239453	W-239454	W-239455
Job no.	BW59	BD25	BW59	BW59	BW59	BW59	BW59	BW59
Analyst	JWM	JWM	JWM	JWM	JWM	JWM	JWM	JWM
SiO_2	49.33	51.23	49.24	49.92	50.31	50.18	50.57	50.24
Al_2O_3	13.21	14.16	13.41	13.68	13.79	12.98	14.06	13.71
Fe_2O_3	1.69	1.87	1.55	1.50	1.89	2.36	1.61	1.81
FeO	9.41	8.98	9.54	9.27	9.10	11.42	9.13	9.13
MgO	8.74	5.70	9.17	8.43	7.05	4.86	6.74	6.95
CaO	10.94	10.13	10.85	10.82	10.83	8.86	10.91	10.96
Na_2O	2.17	2.94	2.18	2.28	2.40	2.79	2.47	2.47
K_2O	0.53	0.84	0.54	0.59	0.65	0.97	0.65	0.63
H_2O^+	< .01	.01	.07	.02	.04	.00	.09	.08
H_2O^-	0.11	.02	0.10	.09	0.10	.08	.06	.05
TiO_2	2.92	3.62	2.68	2.88	2.94	4.74	3.03	3.03
P_2O_5	0.31	0.39	0.28	0.31	0.35	0.44	0.34	0.34
MnO	0.17	0.16	0.18	0.16	0.16	0.20	0.17	0.17
CO_2	< .01	.01	< .01	< .01	< .01	.01	< .01	< .01
Cl	.008	.012	.007	.008	.006	.008	.006	.006
F	.033	.046	.037	.038	.044	.057	.041	.042
S	-	-	-	-	-	-	-	-
Cr_2O_3	.10	.01	.11	.09	.07	.00	.06	.08
Subtotal	99.67	100.13	99.94	100.09	99.72	99.96	99.94	99.70
Less O=Cl,F	.02	.02	.02	.02	.02	.03	.02	.02
Total	99.65	100.11	99.92	100.07	99.70	99.93	99.92	99.68
Type of sample	above segregation	segregation	below segregation		above segregation	segregation	below segregation	
Contains glass?	no	no	no	no	no	no	no	no
Temperature before quench	low	low	low	low	low	low	low	low

Table 10. (continued)

	9	10	11	12	13	14	15	16
Field no.	KI81-1-146.0	KI81-1-146.6	KI81-1-147.7	KI81-1-148.7	KI81-1-160.1	KI81-1-169.9	KI81-1-180.2	KI81-1-190.1
Lab. no.	W-239456	W-214318	W-239457	W-239458	W-214101	W-214102	W-214103	W-214104
Job no.	BW59	BD25	BW59	BW59	BD02	BD02	BD02	BD02
Analyst	JWM	JWM	JWM	JWM	HK	HK	JWM	HK
SiO_2	47.89	51.09	48.63	47.84	47.45	43.71	47.04	45.69
Al_2O_3	10.76	12.91	12.18	10.83	10.88	6.10	10.39	8.75
Fe_2O_3	1.40	2.62	1.12	1.15	1.22	1.24	1.10	1.15
FeO	10.35	9.84	9.84	10.49	10.60	13.68	10.06	11.07
MgO	14.75	5.41	12.49	15.27	15.85	26.87	17.84	21.91
CaO	10.09	9.41	10.66	9.85	9.55	5.28	9.62	7.91
Na_2O	1.64	2.87	1.86	1.68	1.58	0.96	1.57	1.22
K_2O	0.39	0.94	0.44	0.39	0.38	0.25	0.36	0.28
H_2O+	.02	.06	< .01	.01	.02	.03	.04	.04
H_2O-	.05	.01	.01	.04	.01	.01	.00	.01
TiO_2	2.14	4.21	2.27	2.05	1.98	1.21	1.67	1.40
P_2O_5	0.21	0.41	0.22	0.20	0.18	0.12	0.17	0.13
MnO	0.18	0.19	0.17	0.17	0.17	0.21	0.17	0.18
CO_2	< .01	.02	< .01	< .01	.01	.01	.01	.01
Cl	.006	.007	.007	.008	.010	.006	.012	.009
F	.022	.050	.028	.026	.025	.020	.026	.023
S	-	-	-	-	.00	.00	-	.00
Cr_2O_3	.21	.01	.18	.20	0.15	0.18	0.18	0.20
Subtotal	100.10	100.06	100.10	100.10	100.07	99.89	100.26	99.98
Less O=Cl,F	.01	.02	.01	.01	.01	.01	.01	.01
Total	100.09	100.04	100.09	100.09	100.06	99.88	100.25	99.97
Type of sample	above segregation	segregation	below segregation			vorb		
Contains glass?	no	no	no	no	no	yes	yes	yes
Temperature before quench	medium	medium	medium	medium	medium	high	high	high

Table 10. (continued)

	17	18	19	20	21	22	23	24
Field no.	KI81-1-200.4	KI81-1-210.0	KI81-1-220.0	KI81-1-230.6	KI81-1-239.9	KI81-1-250.0	KI81-1-260.0	KI81-1-270.2
Lab. no.	W-214105	W-214106	W-214107	W-214108	W-214109	W-214110	W-214111	W-214112
Job no.	BD02	BD02	BD02	BD02	BD02	BD02	BD02	BD02
Analyst	JWM	HK	JWM	HK	JWM	HK	JWM	HK
SiO2	44.27	44.87	45.34	44.87	44.21	44.66	45.39	46.54
Al2O3	6.79	7.64	8.17	7.62	6.92	7.40	8.66	10.13
Fe2O3	1.01	1.10	0.87	0.90	0.98	1.20	0.97	1.59
FeO	12.93	11.24	11.28	11.39	11.93	11.43	10.92	9.76
MgO	25.96	24.53	23.56	24.83	26.55	25.43	22.77	18.79
CaO	5.89	7.66	7.96	7.59	6.73	7.14	8.22	10.36
Na2O	1.10	0.98	1.13	0.96	0.95	1.02	1.21	1.24
K2O	0.29	0.21	0.24	0.20	0.20	0.21	0.23	0.19
H2O+	.02	.04	.00	.02	.03	.03	.03	.03
H2O-	.02	.01	.02	.01	.01	.02	.02	.01
TiO2	1.28	1.09	1.11	1.06	1.00	1.05	1.16	1.03
P2O5	0.14	0.10	0.11	0.10	0.11	0.10	0.12	.08
MnO	0.20	0.18	0.18	0.18	0.18	0.18	0.18	0.17
CO2	.02	.01	.02	.01	.01	.01	.01	.01
Cl	.008	.008	.007	.007	.006	.008	.007	.010
F	.020	.016	.017	.015	.015	.016	.017	.014
S	-	.00	-	.00	-	.00	-	.00
Cr2O3	0.21	0.20	0.23	0.25	0.25	0.24	0.23	0.18
Subtotal	100.16	99.88	100.24	100.01	100.08	100.14	100.14	100.13
Less O=Cl,F	.01	.01	.01	.01	.01	.01	.01	.01
Total	100.15	99.87	100.23	100.00	100.07	100.13	100.13	100.12
Type of sample	olivine-glass body							less olivine
Contains glass?	yes	yes	yes	yes	yes	yes	yes	yes
Temperature before quench	high	high	high	high	high	high	high	high

Table 10. (continued)

	25	26	27	28	29	30	31	32
Field no.	KI81-1-273.6	KI81-1-280.0	KI81-1-281.6	KI81-1-289.3	KI81-1-290.2	KI81-1-294.4	KI81-1-294.7	KI81-1-297.9
Lab. no.	W-214113	W-214114	W-214115	W-214116	W-214117	W-232728	W-232729	W-214118
Job no.	BD02	BD02	BD02	BD02	BD02	BR98	BR98	BD02
Analyst	JWM	HK	JWM	HK	JWM	JWM	JWM	HK
SiO2	49.11	44.89	46.76	44.31	46.35	44.76	48.08	47.59
Al2O3	12.96	7.36	9.66	7.34	9.58	8.25	11.81	11.17
Fe2O3	1.47	0.98	0.95	1.89	1.20	.88	1.23	2.02
FeO	8.26	11.09	11.07	11.57	10.56	12.39	9.51	9.34
MgO	11.95	26.15	18.74	25.58	19.94	23.14	14.30	15.64
CaO	12.22	6.82	8.48	6.61	9.13	7.46	9.90	9.77
Na2O	1.84	1.05	1.57	1.05	1.40	1.13	1.83	1.71
K2O	0.32	0.21	0.39	0.20	0.24	0.23	0.44	0.39
H2O+	.00	.04	.08	.02	.05	< .01	< .01	.04
H2O-	.04	.00	.01	.00	.01	0.11	.07	.01
TiO2	1.56	1.07	1.80	1.02	1.22	1.28	2.40	1.84
P2O5	0.18	0.10	0.19	.09	0.11	0.15	0.24	0.18
MnO	0.15	0.17	0.18	0.19	0.17	0.19	0.17	0.17
CO2	.01	.01	.01	.01	.02	< .01	.01	.01
Cl	.006	.009	.010	.006	.005	.006	.010	.012
F	.020	.016	.030	.014	.017	.018	.030	.028
S	-	.00	-	.00	-	-	-	.00
Cr2O3	0.13	0.26	0.19	0.22	0.20	0.16	0.13	0.15
Subtotal	100.23	100.23	100.12	100.12	100.20	100.15	100.16	100.07
Less O=Cl,F	.01	.01	.02	.01	.01	.01	.01	.01
Total	100.22	100.22	100.10	100.11	100.19	100.14	100.15	100.06
Type of sample	"vein"	matrix to leopard rock	leopard rock	coarse olivines	typical matrix	adjacent matrix	leopard rock	relatively olivine-poor core
Contains glass?	yes	yes	yes	yes	yes	yes	yes	yes
Temperature before quench	high	high	high	high	high	high	high	high

Table 10. (continued)

	33	34
Field no.	KI81-1-300.2	KI81-1-306.9
Lab. no.	W-214119	W-214120
Job no.	BD02	BD02
Analyst	JWM	HK
SiO2	46.86	47.06
Al2O3	9.87	10.42
Fe2O3	1.40	2.01
FeO	10.71	9.61
MgO	18.15	17.47
CaO	8.76	9.25
Na2O	1.60	1.60
K2O	0.39	0.35
H2O+	.08	.03
H2O-	.04	.01
TiO2	1.80	1.70
P2O5	0.20	0.16
MnO	0.18	0.17
CO2	.01	.01
Cl	.010	.013
F	.030	.026
S	-	.00
Cr2O3	0.11	0.16
Subtotal	100.20	100.05
Less O=Cl,F	.02	.01
Total	100.18	100.04
Type of sample	sheared leopard rock	lowest core recovered
Contains glass?	yes	yes
Temperature before quench	high	high

Table 11. Analysis of Core from Kilauea Iki Drill Hole KI81-2

	1
Field no.	KI81-2-88.6
Lab. no.	W-232725
Job no.	BR98
Analyst	JWM
SiO2	57.07
Al2O3	12.86
Fe2O3	2.44
FeO	9.41
MgO	2.37
CaO	6.08
Na2O	3.55
K2O	1.90
H2O+	0.11
H2O-	.07
TiO2	2.59
P2O5	0.96
MnO	0.18
CO2	< .01
Cl	.028
F	0.11
S	-
Cr2O3	< .01
Subtotal	99.73
Less O=Cl,F	.05
Total	99.68
Type of sample	vein-in-vein
Contains glass?	no
Temperature before quench	low