United States Department of the Interior

U.S. Geological Survey

MISCELLANEOUS HAWAIIAN XENOLITH LOCALITIES

by

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This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards and stratigraphic nomenclature

INTRODUCTION

During the late 1960s and early 1970s, E. D. Jackson and his coworkers undertook a study of Hawaiian xenoliths. Detailed studies of the xenoliths from Hualalai and Mauna Kea volcanoes on the island of Hawaii are presented elsewhere (Jackson and others, 1981, and Jackson and Clague, 1981), as is some early work work on the xenoliths in the Honolulu Volcanics on Oahu (Jackson and Wright, 1970). The detailed studies of the xenoliths in the Honolulu Volcanics will form the last in this series of reports (Clague, Beeson, Jackson, in prep.). This report presents xenolith count data from Kilauea, Mauna Loa, Kohala, W. Maui, E. Molokai, Kauai, and the Waiainae range on Oahu. Many of these data were summarized by Jackson (1968), but the xenolith counts identified by prefixes 66-, 67-, or 70- were not included in that summary. At localities where xenoliths were numerous, either 50 or 100 xenoliths were measured, described, and their modal mineralogy estimated. Every 10th xenolith and other xenoliths of special interest were collected. The xenoliths were identified as being cumulate rocks, metamorphic (mantle) rocks, or veins. The descriptive details, as well as the xenoliths and the host lavas and their thin sections, are in the Jackson collection at the U.S. National Museum. The interested reader should contact the curator of the Department of Mineral Science for more information.

SAMPLE LOCALITIES

The size, shape, and structure of the xenoliths are tabulated in Table 1 for the 20 counts in this report. Table 2 lists the locations by latitude, longitude, and elevation to enable relocation of the count localities. The modal mineralogy and chemistry of the host lavas are discussed in the following sections.

XENOLITHS

Kilauea, Hawaii: Only two counts were made on Kilauea volcano because xenoliths are not abundant in tholeiitic lavas, and in fact usually are totally absent. The count locations are shown in Fig. 1. Count 66KAPO is in the 1960 Kapoho flow at the lighthouse. The flow is rich in olivine phenocrysts. The xenoliths are open-textured olivine gabbro cumulates that contain vesicles an order of magnitude smaller than those in the host lava. Count 67KII5 is in the 1955 flow on the Kii branch on Highway 137. The xenoliths are extremely abundant, but quite small. The modal mineralogy of the counted xenoliths is shown in Fig. 2a and 2b.

Kohala, Hawaii: These counts were made on Kohala volcano. The locations are shown in Fig. 1. Count 65KOHA is in the upper Kohala trachyte, 5.9 to 6.1 miles from Kawaihai junction. Count 65 WAIM is in the first outcrop uphill from Waimea. The inclusions are mainly dunite with common gabbro and some wehrlite; all are small, reaching a maximum size of 1 inch. The host lava is a dense light-colored non-porphyritic mugearite with inclusions of porphyritic lava. Count 70KIIO is on the roadcut above Malae Point on the new Kawaihai-Mukulona road in the Kiiokalani slice. Analyses of the host lavas from 65KOHA and 65WAIM are presented in Table 3 as samples 65KOH-1 and 65 WAI-1, respectively. The modal mineralogy of the counted xenoliths is shown in Fig. 3a-c.

TABLE 1. Size, Shape and Structure of Xenoliths

Volcano	Count Identification	Area of Count (sq.ft.)	Number of Counts	Angularity % Angular	Angularity % Sub-Angular	Angularity % Rounded	Percent Composition Layering	Percent Foliated	Percent Veins	Arith. Mean Diameter Xeno. (mm)	Median Diameter mm	Median Diameter -ø	1st Quartile mm	1st Quartile -ø	3rd Quartile mm	3rd Quartile -ø	Mean Diam. of Dunite (mm)
Kilauea	66KAPO	500	99	76	18	6	0	0	0	12	8.0	3.00	5.5	2.45	12.6	3.65	8.4
	67KIIS	100	100	65	30	5	2	0	0	7.3	5.7	2.45	3.8	1.94	7.2	2.85	-
Kohala	65KOHA	3060	99	79	19	2	3	9	5	15.2	8.9	3.15	6.3	2.65	16.0	4.00	15.2
	65WAIM	775	100	78	21	1	3	4	0	12.7	9.2	3.20	7.0	2.80	14.9	3.90	12.7
	70KIIO	-	100	38	47	15	0	4	0	18.0	10.6	3.40	6.5	2.70	19.0	4.25	17.5
Mauna Loa	65KUHU	3500	100	4	95	1	0	0	0	20.8	16.6	4.05	13.0	3.70	21.1	4.40	-
	65KAKU	400	100	1	99	0	0	0	0	23.4	17.8	4.15	15.5	3.95	21.1	4.40	-
	65LELE	6	101	23	70	7	0	0	0	7.9	8.3	3.05	3.4	1.75	11.7	3.55	-
	65KAAP	1.024×10^7	100	75	20	5	0	2	0	8.8	5.9	2.55	5.1	2.36	9.2	3.20	9.3
	66HKUA	-	49	51	41	8	0	0	0	10.4	7.9	2.98	5.7	2.50	10.2	3.35	11.4
	67KAOH	2500	50	70	26	4	0	0	0	9.7	6.3	2.65	4.8	2.25	9.9	3.30	-
East Molokai	67PAHO	250000	99	67	23	10	0	3	0	10.1	5.9	2.55	4.8	2.25	10.2	3.35	9.5
	67AUMI	202500	100	72	22	6	0	13	2	15.4	9.2	3.20	5.9	2.55	16.0	4.00	10.1
	*67KAWE	-	40	45	45	10	0	8	0	11.6	8.6	3.10	5.7	2.50	12.6	3.65	10.2
West Maui	65PAPA	345	100	74	25	1	0	0	0	10.2	7.0	2.80	5.3	2.40	9.9	3.30	9.4
	65MANU	360	100	88	12	0	1	0	0	12.7	8.9	3.15	7.2	2.85	10.2	3.35	8.9
	65OPUN	350	100	70	30	0	0	0	0	15.2	11.3	3.50	8.6	3.10	14.9	3.90	14.5
Kauai	65GROV	15	100	76	24	0	-	20	-	20.3	16.6	4.05	8.0	3.00	25.1	4.65	11.7
	65KAHI	125	101	70	28	2	-	2	-	22.9	17.2	4.10	9.5	3.25	25.1	4.65	16.3
Waiainae Oahu	65NANA	440	100	77	23	0	0	0	3	10.2	7.8	2.95	5.5	2.45	9.68	3.40	10.2

*ankaramite, stream boulder

TABLE 2.

Locations of Xenolith Counts

	Latitude	Longitude	Elevation
Kilauea			
66KAPO	19°30.71' 19°31.15'	154°50.26' 154°48.85'	115' 45'
67K115	19°29.19'	154°50.12'	60'
Kohala			
65KOHA	20°04.47'	155°45.90'	3520'
65WAIM	20°22.06'	155°42.44'	2510'
70K110	20°06.84'	155°52.83'	200'
Mauna Loa			
65KUHU	19°10.08'	155°45.59'	5030'
65KAKU	19°10.62'	155°45.68'	5280'
65LELE	19°44.28'	155°00.72'	0'
65KAAP	19°15.87'	155°52.75'	1280'
66HKUA	19°20.61'	155°52.56'	1040'
67KAOH	19°19.54'	155°52.54'	1100'
E. Molokai			
67PAHO	21°03.55'	156°54.22'	20'
67AUMI	21°03.59'	156°54.40'	40'
67KAWE	21°04.13'	156°57.05'	∿10'
W. Maui			
65PAPA	20°46.90'	156°32.65'	40'
65MANU	20°46.65'	156°32.02'	0'
65OPUN	20°47.38'	156°33.46'	120'
Kauai			
65GROV	21°58.04'	159°27.13'	400'
65KAHI	22°13.30'	159°25.68'	∿15'
Waiainae Oahu			
65NANA	21°23.25'	158°08.03'	70'

Figure 1.

Location map of the island of Hawaii showing xenolith counts from Kilauea, Kohala, and Mauna Loa volcanoes. Precise locations are given in Table 2.

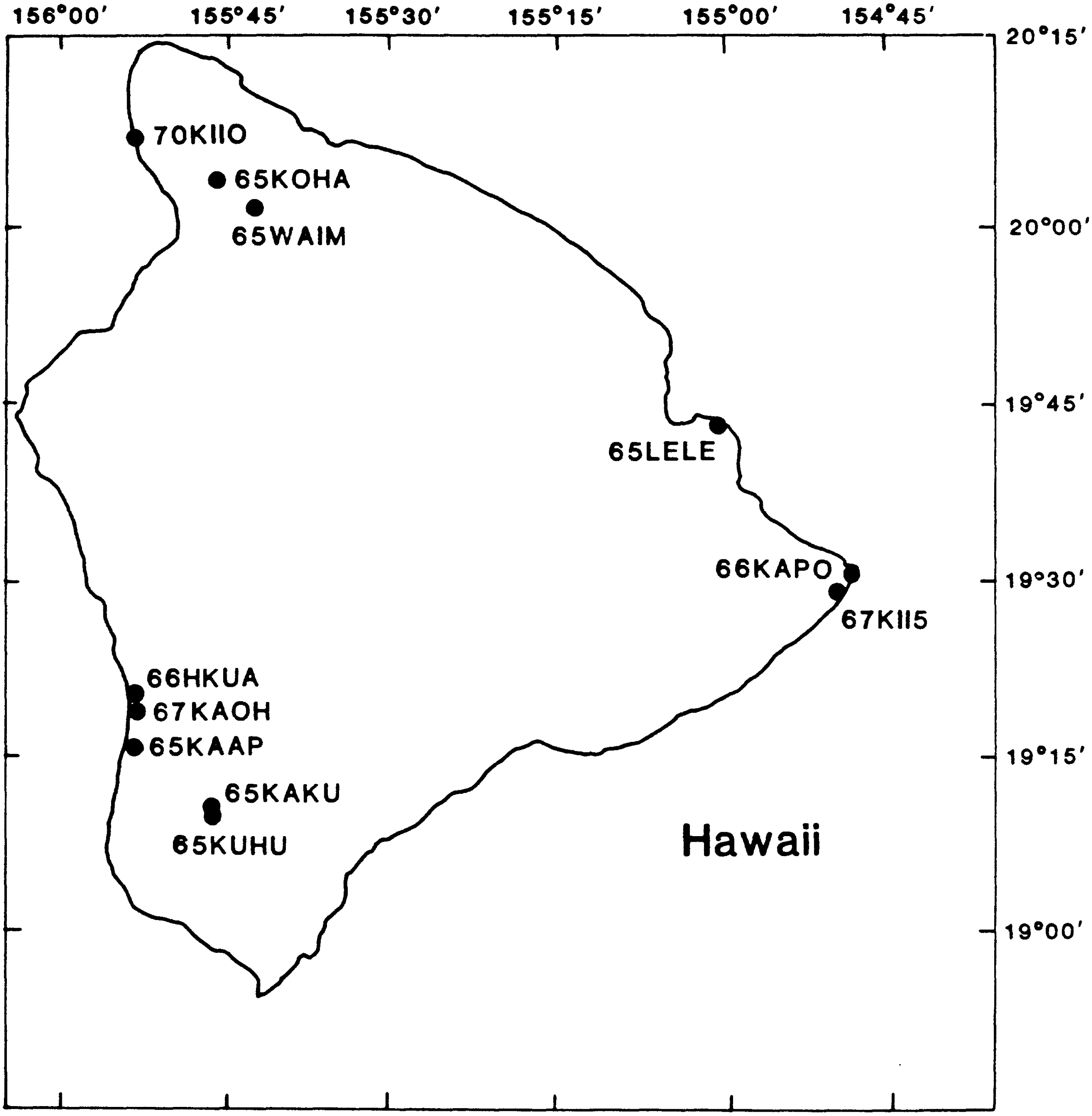


Figure 2.

Modal mineral proportions estimated in the field for xenoliths from Kilauea volcano, Hawaii. Modes displayed on unfolded olivine-clinopyroxene-plagioclase-chromite tetrahedron. Open dot is single sample, filled dot is two samples, open dot with adjacent number is the number of samples indicated. The designation in the lower right (1 OPX 50, PC 50) indicates one xenolith composed of 50% orthopyroxene and 50% plagioclase.

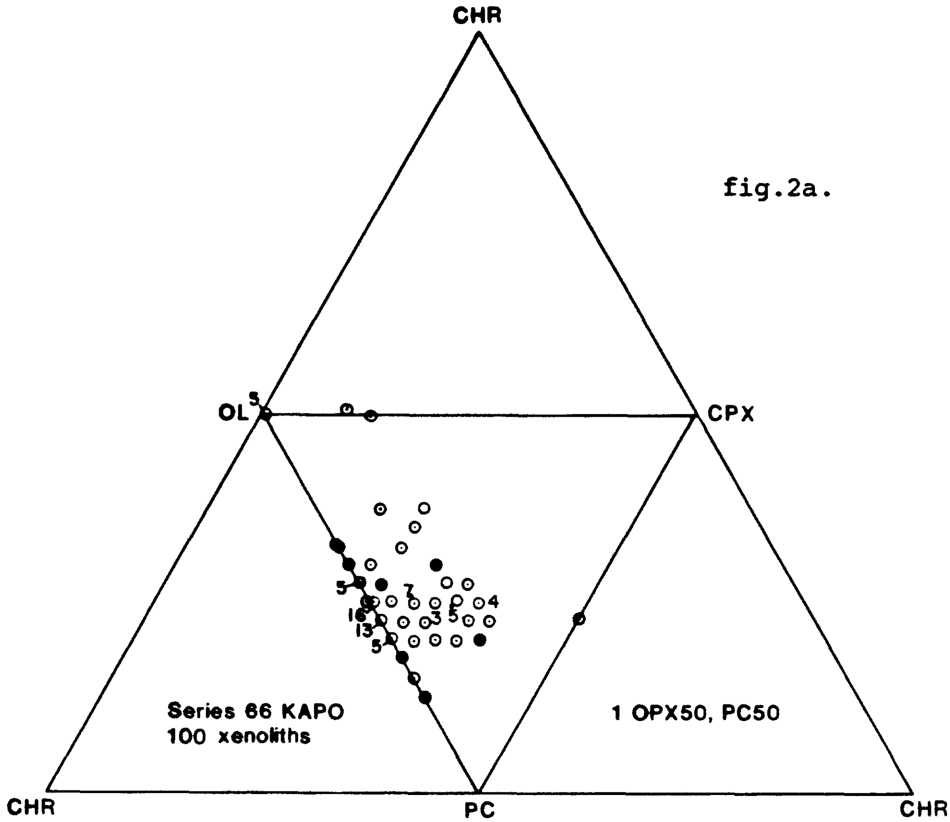

CHR
OL
CPX
CHR
PC
CHR
Series 66 KAPO
100 xenoliths
1 OPX50, PC50

fig.2a.

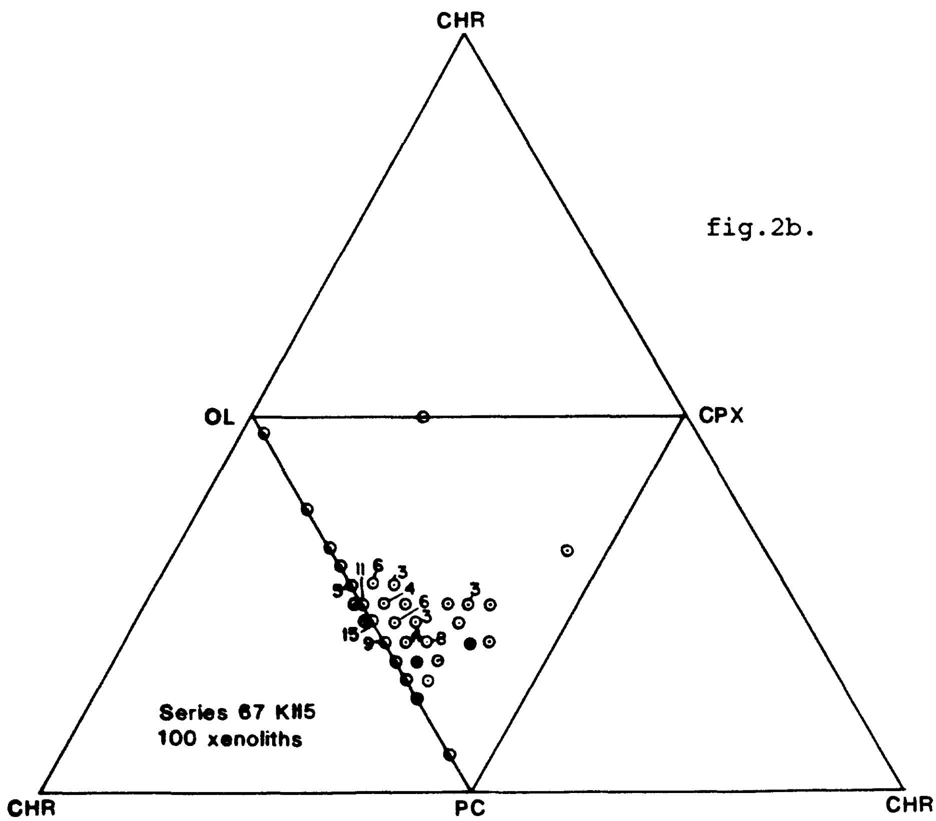

CHR
OL
CPX
CHR
PC
CHR
Series 67 KH5
100 xenoliths

fig.2b.

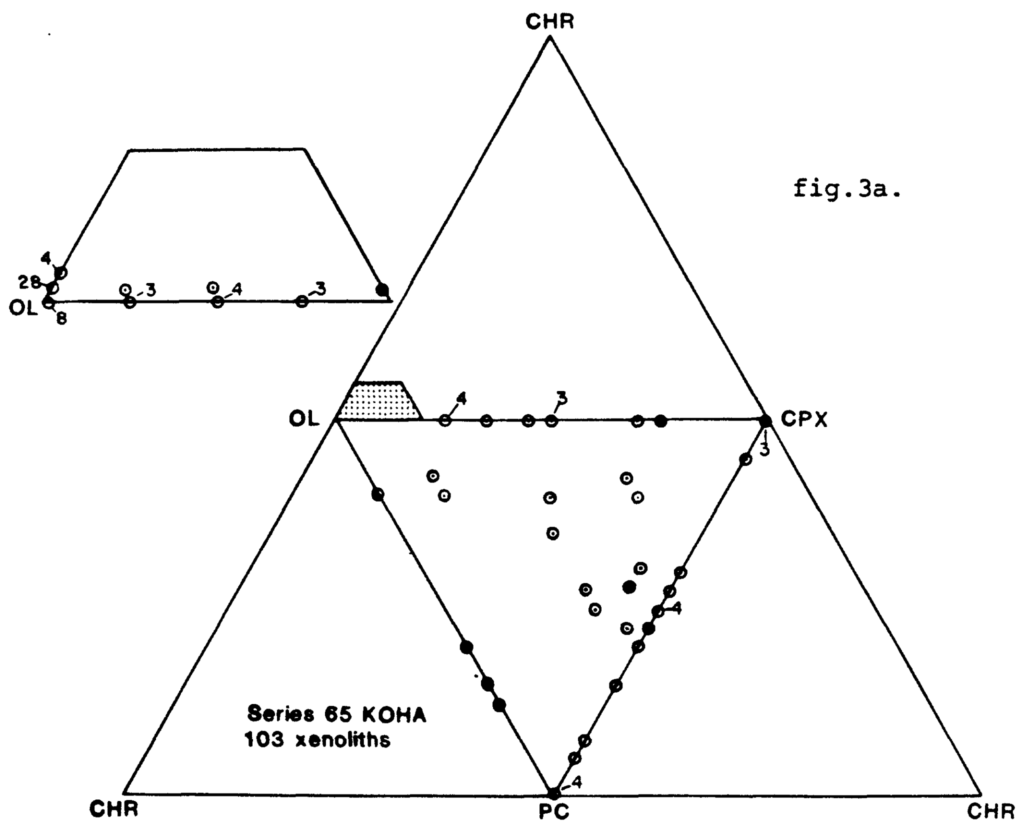
TABLE 3. Major Element Chemistry

	65MAN-1 Mauna Loa Thol.	65KUH-2 Mauna Loa Thol.	65KOH-1 Kohala Trachyte	65WAI-1 Kohala Mugearite	65PAP-1 W. Maui Alkalic Bas.	65PAP-2 W. Maui Alkalic Bas.	65OPU-1 W. Maui Hawaiite	65MNI-1 W. Maui Hawaiite	65KAH-2 Kauai Nephelinite	65NAN-1 Oahu Hawaiite
SiO_2	50.26	51.34	58.37	51.79	45.38	45.09	45.36	45.16	38.40	47.30
Al_2O_3	12.00	13.13	18.11	17.33	10.80	13.48	9.19	12.57	10.19	14.64
Fe_2O_3	2.30	2.23	4.31	4.98	4.22	7.55	3.38	5.36	4.49	3.59
FeO	8.82	8.80	2.48	4.68	8.84	5.99	9.65	7.83	9.90	8.76
MgO	13.08	9.92	1.29	3.16	16.08	9.69	19.90	12.16	14.30	8.25
CaO	8.87	9.74	2.97	6.01	8.67	10.45	8.50	9.49	12.62	8.68
Na_2O	1.96	1.95	7.01	5.43	1.36	1.93	1.39	2.42	2.24	3.48
K_2O	.34	.37	2.87	2.26	.06	.15	.22	.40	1.05	1.20
H_2O^+	.13	.10	.09	.30	1.08	1.20	.21	.38	1.61	.11
H_2O^-	.02	.03	.13	.15	1.12	1.09	.18	.55	.88	.14
TiO_2	1.65	1.82	1.00	2.11	1.79	2.55	1.54	2.61	3.22	2.90
P_2O_5	.19	.24	.66	1.34	.18	.30	.18	.42	.70	.59
MnO	.17	.17	.24	.21	.19	.19	.18	.18	.21	.17
CO_2	.01	.02	.02	.01	.00	.03	.02	.01	.03	.01
Cl	.01	.01	.01	.02	.03	.04	.01	.15	.03	.01
F	.02	.06	.12	.15	.02	.03	.02	.04	.08	.07
Subtotal	99.83	99.93	99.68	99.93	99.82	99.76	99.93	99.73	99.95	99.90
Less O	.01	.03	.05	.06	.02	.02	.01	.05	.04	.03
Total	99.82	99.90	99.63	99.87	99.80	99.74	99.92	99.68	99.91	99.87

Wet Chemical Analysis by G. O. Riddle

Figure 3.

Modal mineral proportions estimated in the field for xenoliths from Kohala volcano, Hawaii. Modes displayed on an unfolded olivine-clinopyroxene-plagioclase-chromite tetrahedron. Symbols as in Fig. 2.



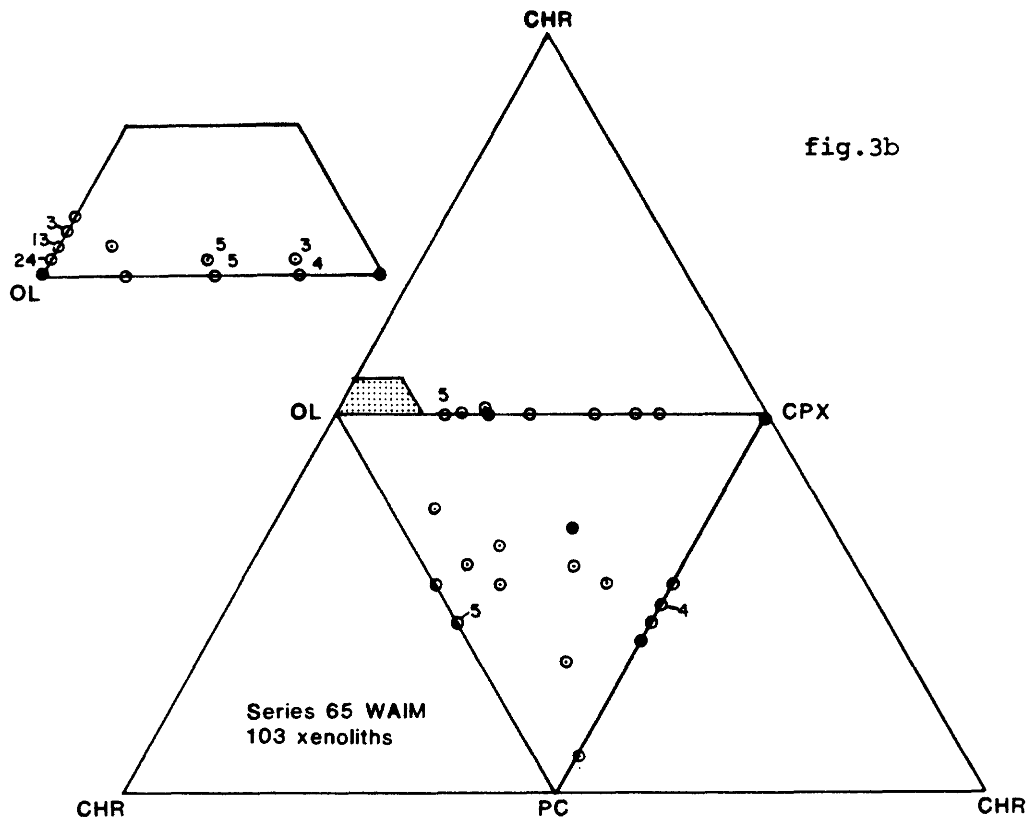

CHR
OL
CPX
CHR
PC
CHR
Series 65 WAIM
103 xenoliths

fig.3b

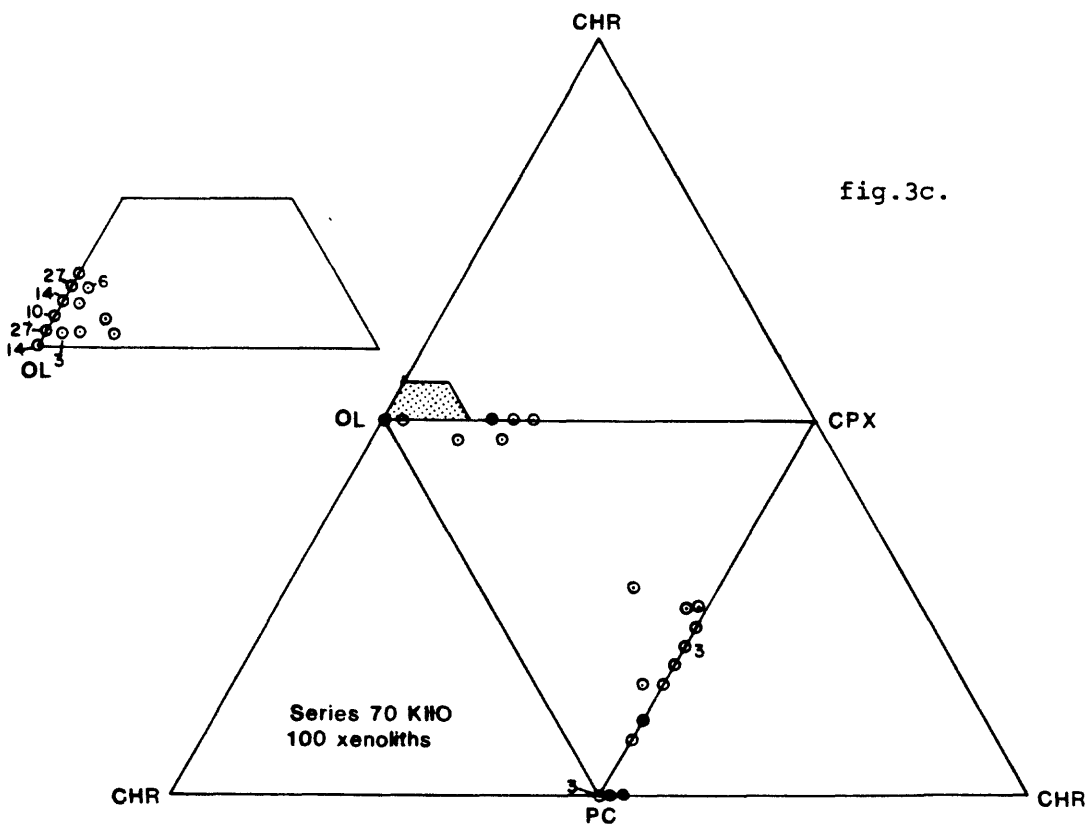

CHR
OL
CPX
CHR
PC
CHR
Series 70 KHO
100 xenoliths

fig.3c.

Mauna Loa, Hawaii: Six counts were made on Mauna Loa volcano. The count locations are shown in Fig. 1. Count 65KUHU contains cumulate olivine gabbro and troctolite xenoliths and is from a vesicular altered olivine plus minor plagioclase physic tholeiitic flow that contains some denser layers. The composition of the host flow is presented in Table 3 as sample 65KUH-2. Count 65KAKU is in the saddle between two cinder cones, each at about 5400 ft. elevation, 0.75 miles southwest of Ohohia where a flow issued from the mouth of the eastern cinder-spatter cone. The olivine gabbro xenoliths occur as discrete cobbles in black cinder only. Count 65LELE is between Waiuli and Leleiwi Points on the outskirts of Hilo. The olivine gabbro xenoliths are present in basaltic beach boulders. The xenoliths appear to have grown in place rather than having been broken fragments. Count 65KAAP is from the Kaapuna branch of the 1950 flows and contains mainly olivine gabbro, troctolite, and olivine norite xenoliths. Count 66HKUA has only rare inclusions, mostly diabasic or porous feldspar-rich xenoliths. Count 67KAOH is from the Kaoha branch of the 1950 flow on the west side of the highway. The other Mauna Loa sample, 65MAN-1, does not contain xenoliths; it is located at the sea south of Kawaihai, where Hualalai and Mauna Loa flows are interbedded. The modal mineralogy of the counted xenoliths is shown in Figure 4a-f.

East Molokai: Count 67PAHO is from an outcrop at the east end of Pahoa inlet. Abundant xenoliths of dunite and plagioclase-rich gabbro are present in dense black basalt flow. Count 67AUMI is from an outcrop at the west end of Pahoa inlet where the abundant dunite and gabbro xenoliths are fairly large and occur in a dense sheeted basalt flow. Count 67KAWE is from a single large stream boulder in Kawelo gulch. It contains abundant xenoliths of gabbro and some of dunite. The locations of these three counts are shown in Fig. 5 and the modal mineralogy is shown in Fig. 6a-c.

West Maui: Count 65PAPA is from a roadcut 220' northwest of Papawai Point. The roadcut consists of about 10 2- to 10-foot-thick flows with up to 6" ochre colored soil horizons between flows. The count is a composite of these flows. The xenoliths are mostly wehrlite and dunite. Count 65MANU is from Manuohuli Point where a light-colored olivine (25-30%) and plagioclase (3-5%) phyric flow is exposed as a sea cliff. The xenoliths are mainly gabbro with rare dunite and wehrlite. 65OPUN is from a 15-foot thick aa flow 600' southeast of the southeast end of tunnel. Most inclusions are dunite or are clinopyroxene-rich gabbro. The locations of these three counts are shown in Fig. 7 and the modal mineralogy is shown in Fig. 8. Chemical analyses of the host lava flows are presented in Table 3. Samples 65PAP-1 and 65PAP-2 are two of the flows that contain xenoliths included in count 65PAPA. Sample 65OPU-1 is the host flow for the xenoliths in count 65OPUN and 65MNI-1 is the host flow for count 65MANU.

Kauai: The two counts from Kauai are both from the post-erosional alkali Koloa Volcanics. Count 65GROV is from Grove Farm quarry at the east side of the waterfall. Many of the xenoliths are schistose or gneissic lherzolite. Count 65KAHI is from the seacliffs between Pukamai and Kilihiwai Points. The abundant lherzolite inclusions are present in beach boulders; the seacliff has the same xenoliths but is inaccessible. The locations of these counts are shown in Fig. 9 and the modal mineralogy is presented in Fig. 10. An analysis of the host nephelinite flow for count 65KAHI is given as sample 65KAH-2 in Table 3.

Figure 4.

Modal mineral proportions estimated in the field for xenoliths from Mauna Loa volcano, Hawaii. Modes displayed on an unfolded olivine-clinopyroxene-plagioclase-chromite tetrahedron. Symbols as in Fig. 2.

fig.4a.

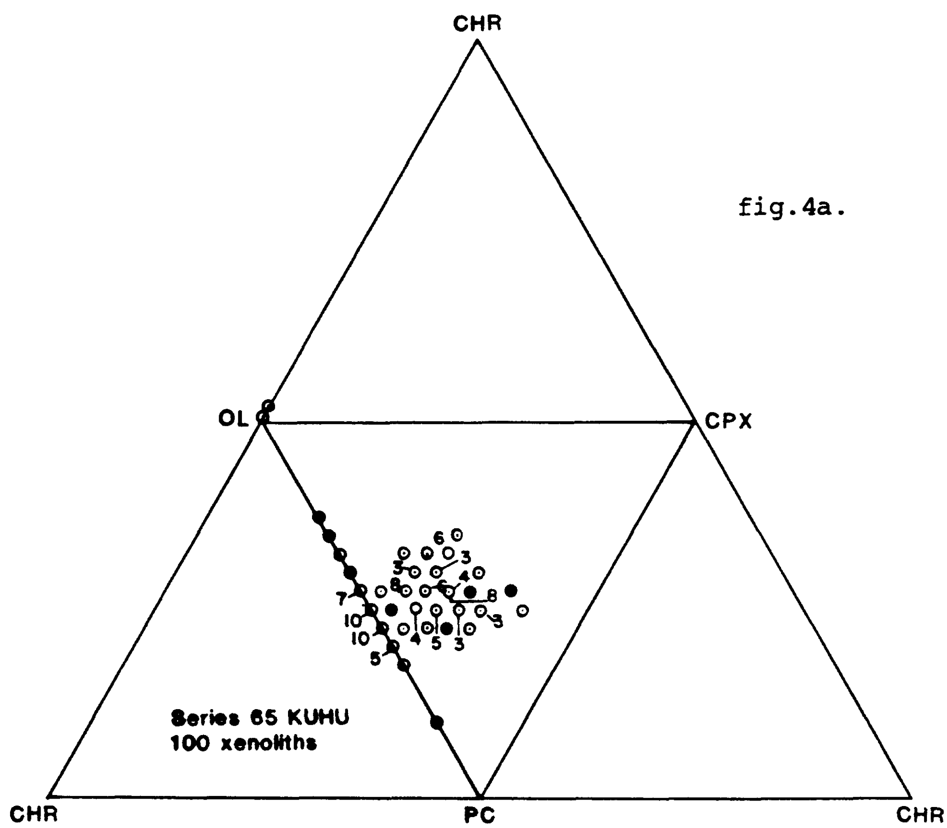


fig.4b.

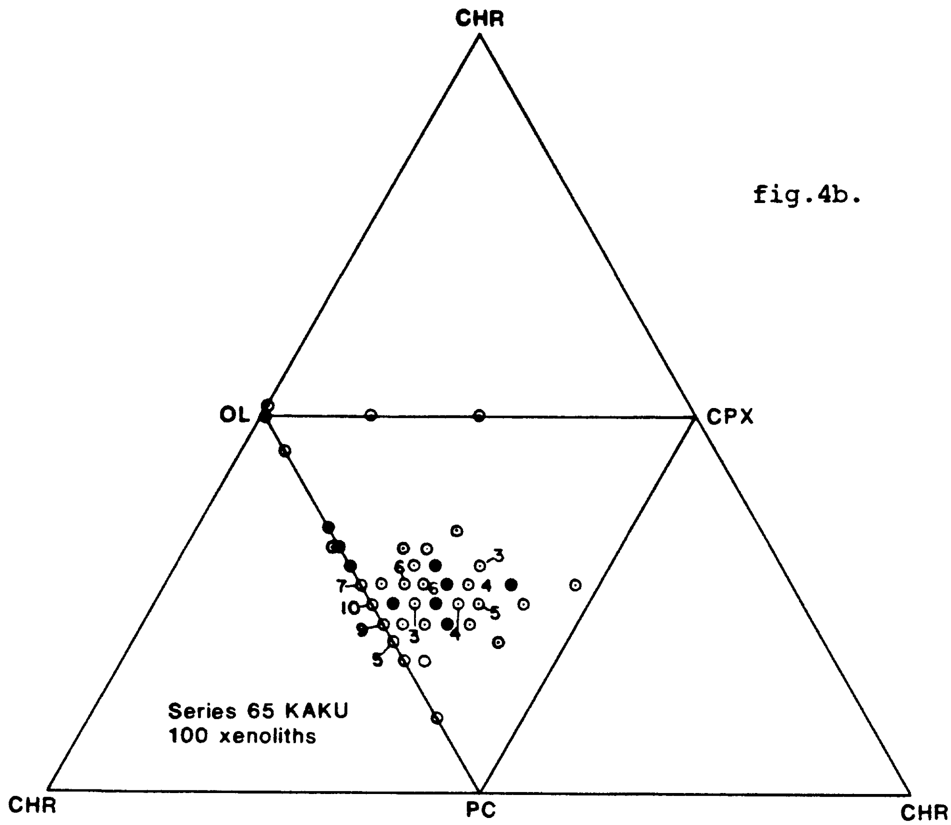

CHR
OL
CPX
Series 65 KAKU
100 xenoliths
CHR
PC
CHR

fig.4c.

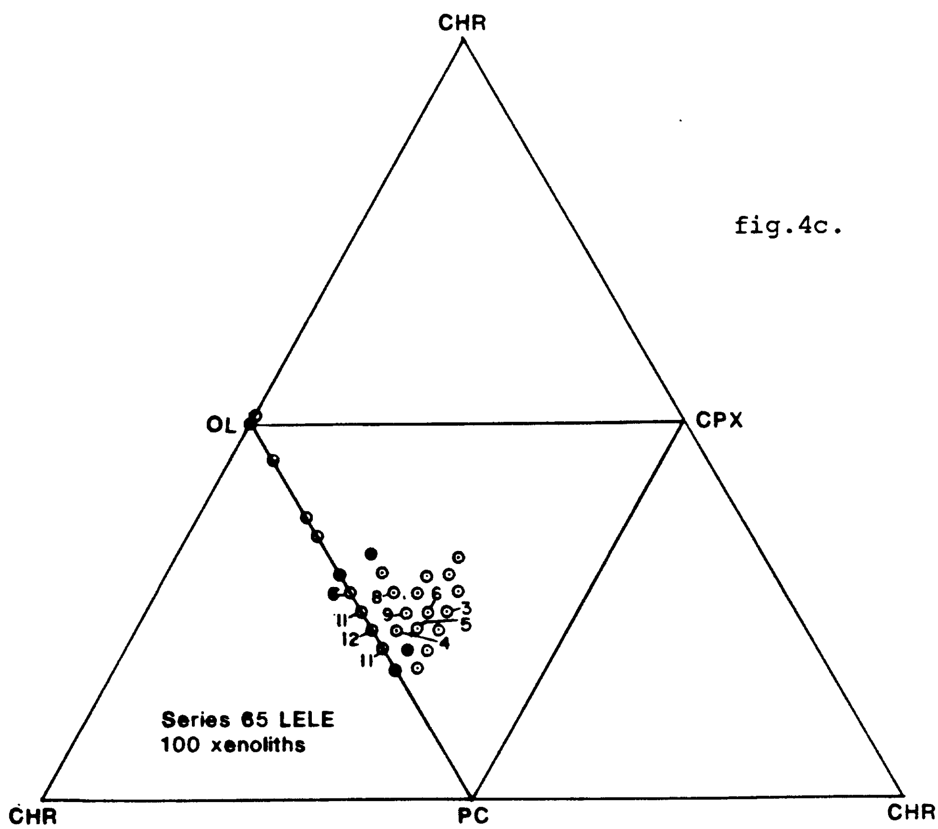
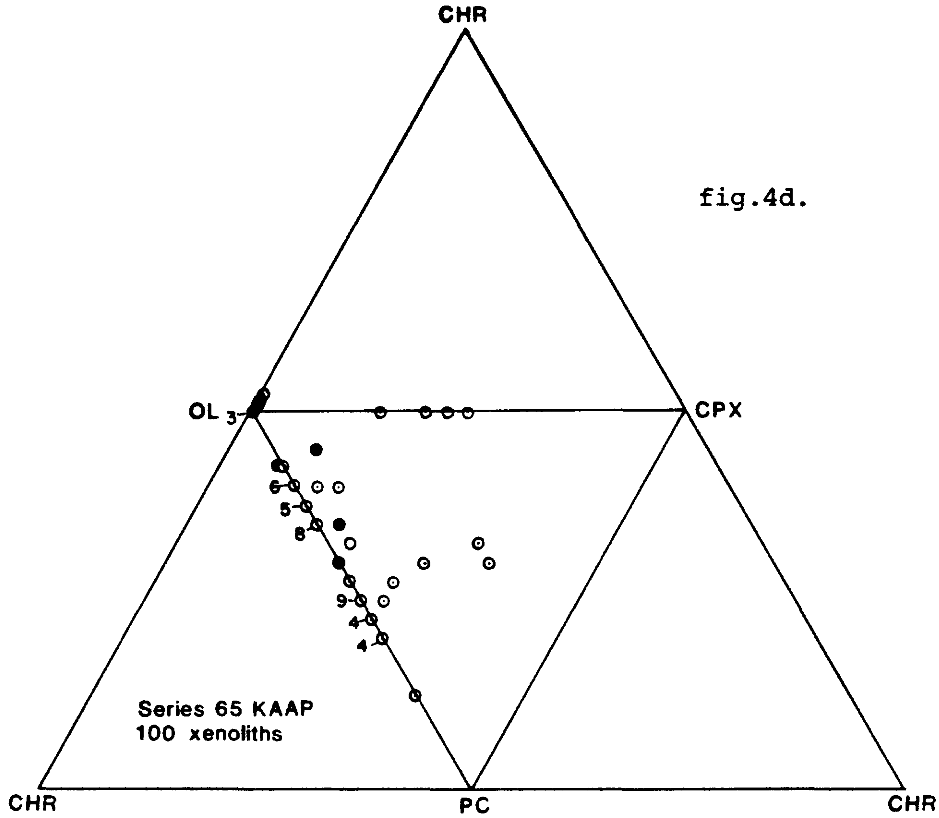
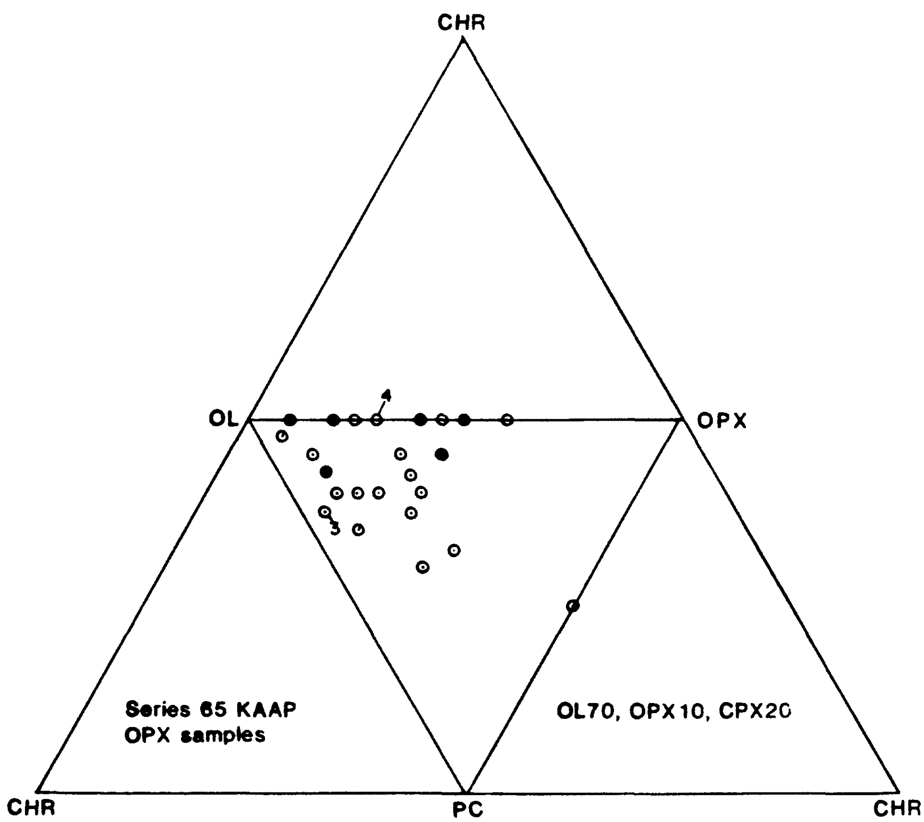

CHR
OL
CPX
Series 65 LELE
100 xenoliths
CHR
PC
CHR

fig.4d.


CHR
OL
CPX
3
6
5
8
9
4
4
Series 65 KAAP
100 xenoliths
CHR
PC
CHR


CHR
4
OL
OPX
3
Series 65 KAAP
OPX samples
OL70, OPX10, CPX20
CHR
PC
CHR

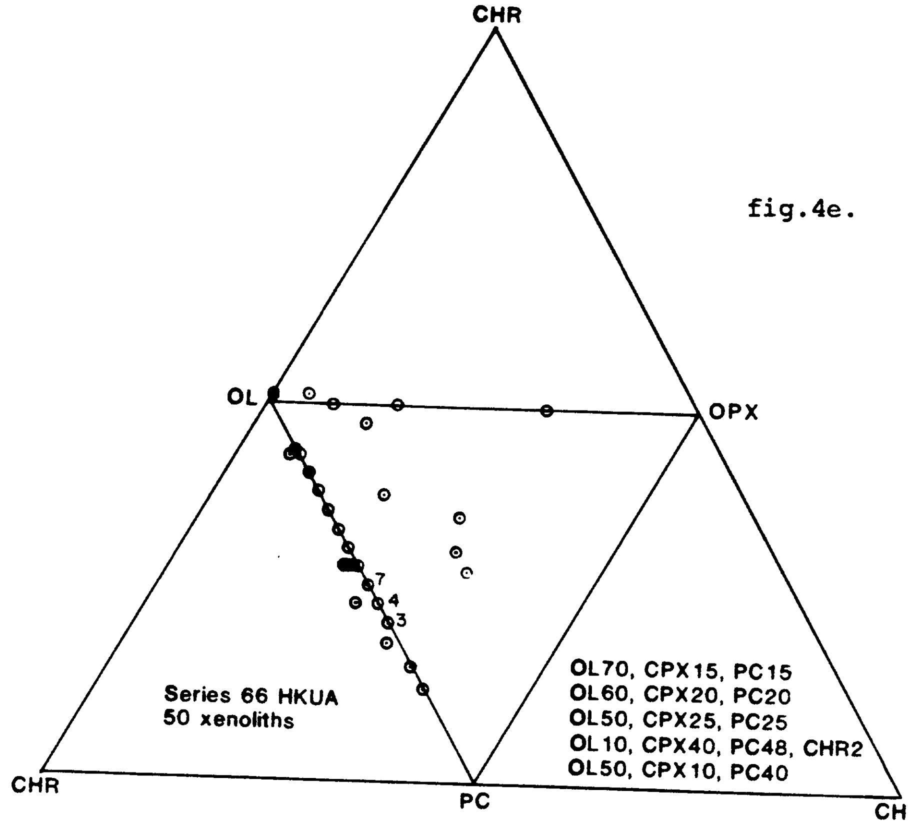

CHR
OL
OPX
7
4
3
Series 66 HKUA
50 xenoliths
OL70, CPX15, PC15
OL60, CPX20, PC20
OL50, CPX25, PC25
OL10, CPX40, PC48, CHR2
OL50, CPX10, PC40
CHR
PC
CHR

fig.4e.

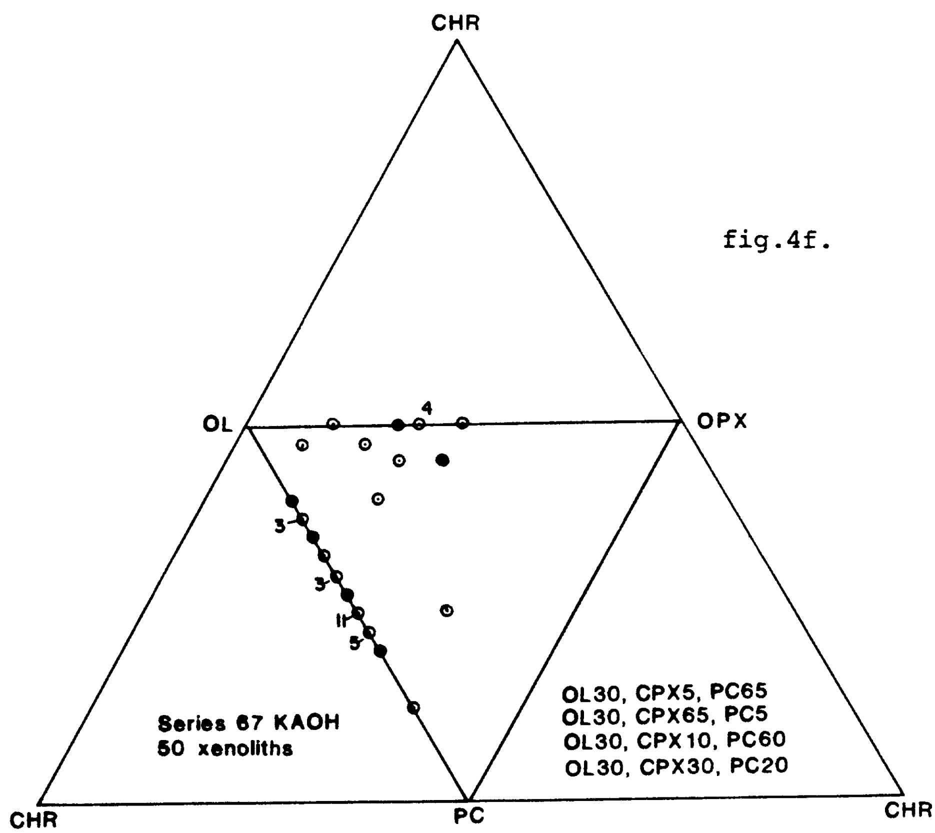

CHR
OL
4
OPX
3
3
11
5
Series 67 KAOH
50 xenoliths
OL30, CPX5, PC65
OL30, CPX65, PC5
OL30, CPX10, PC60
OL30, CPX30, PC20
CHR
PC
CHR

fig.4f.

Figure 5.

Location map of the island of Molokai showing xenolith counts from East Molokai volcano. Precise locations are given in Table 2.

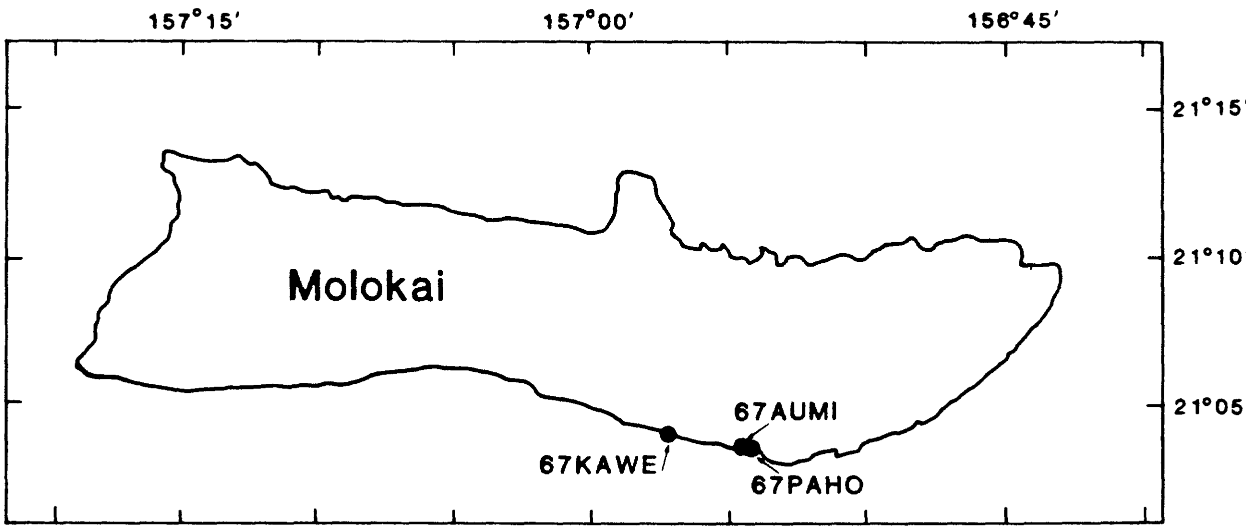
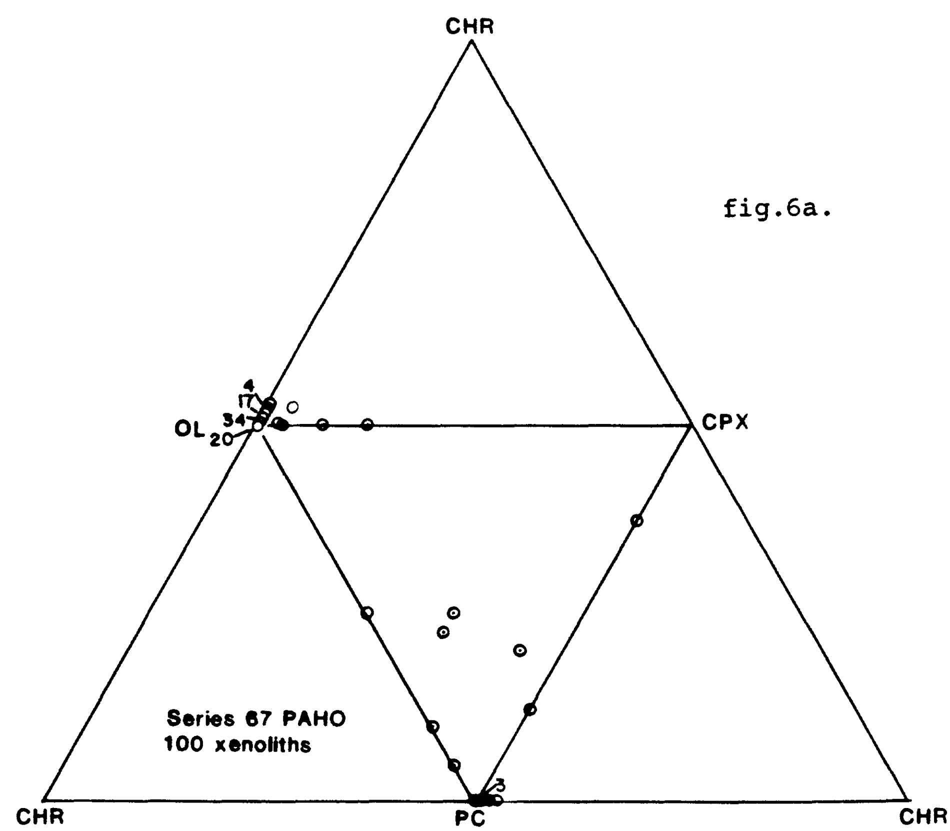


Figure 6.

Modal mineral proportions estimated in the field for xenoliths from East Molokai volcano. Modes displayed on an unfolded olivine-clinopyroxene-plagioclase-chromite tetrahedron. Symbols as in Fig. 2.



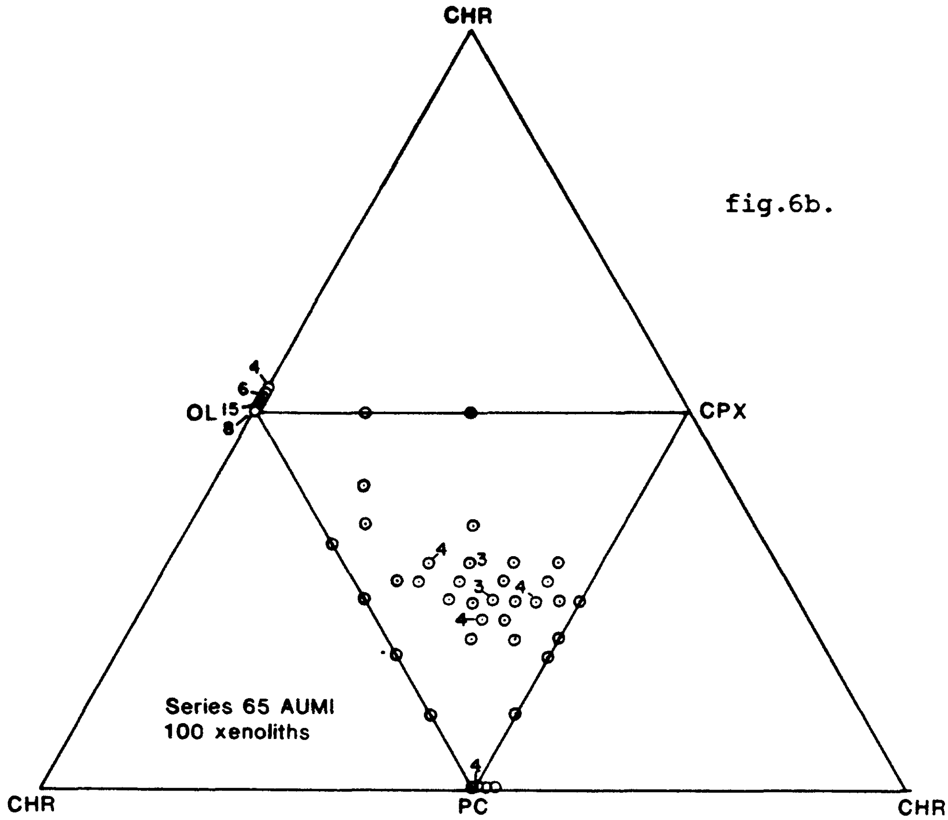

CHR
CPX
OL
15
8
6
4
4
3
3
4
4
4
Series 65 AUMI
100 xenoliths
CHR
PC
CHR

fig.6b.

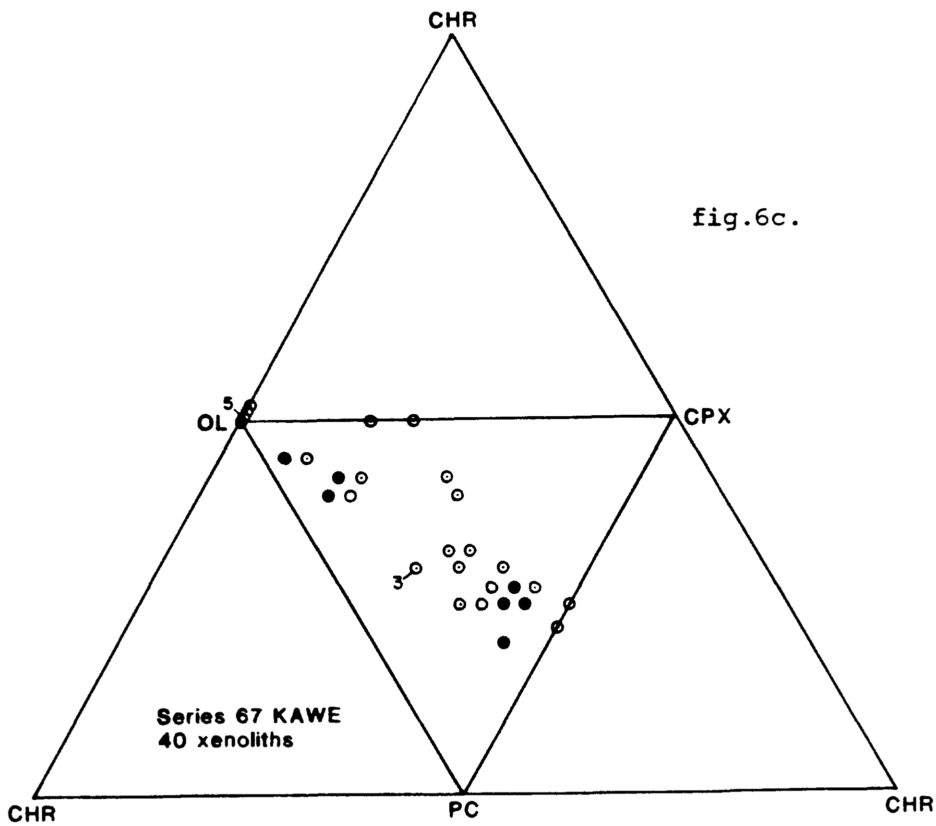

CHR
5
OL
CPX
3
Series 67 KAWE
40 xenoliths
CHR
PC
CHR

fig.6c.

Figure 7.

Location map of the island of Maui showing xenolith counts from West Maui volcano. Precise locations are given in Table 2.

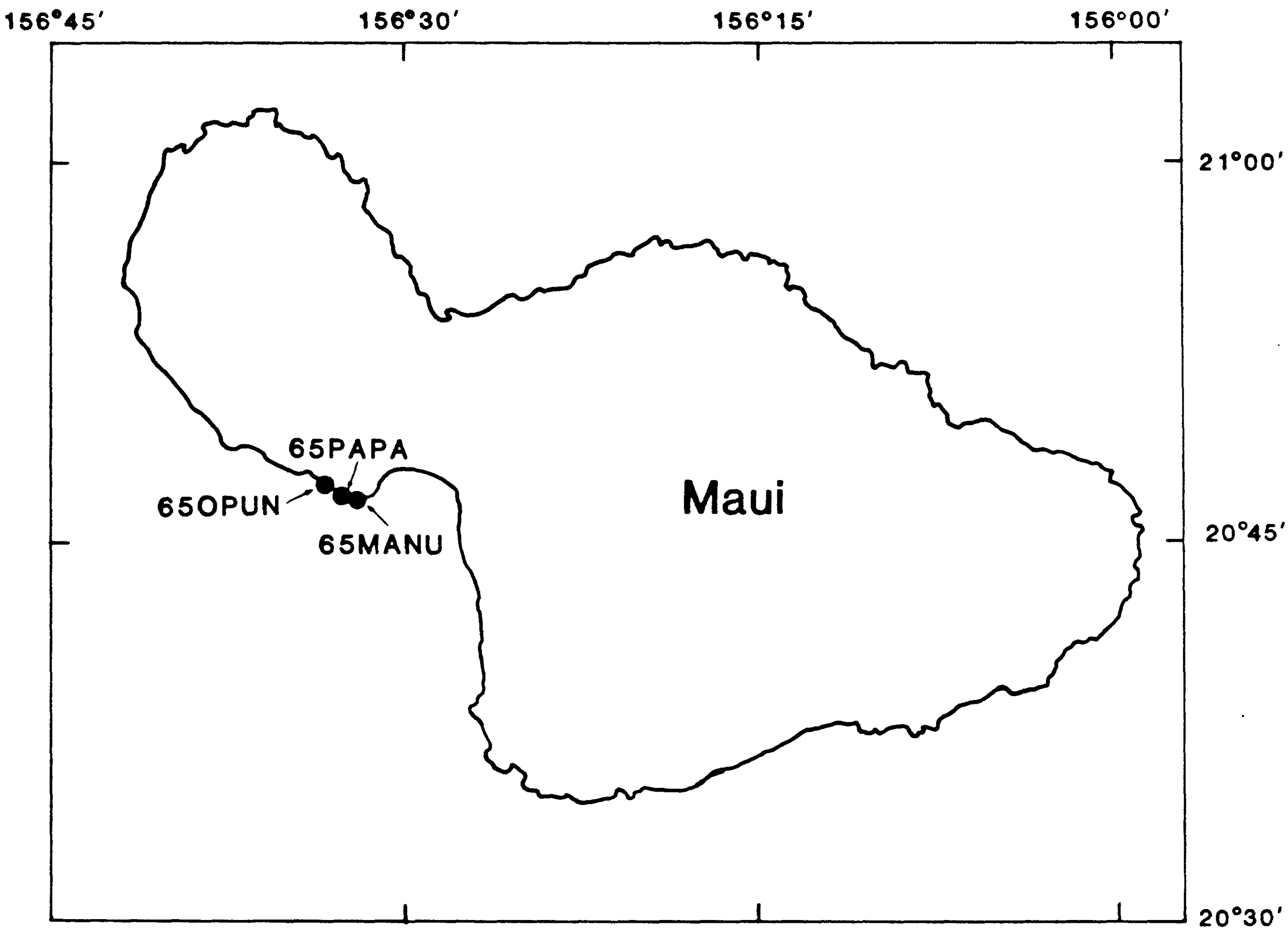
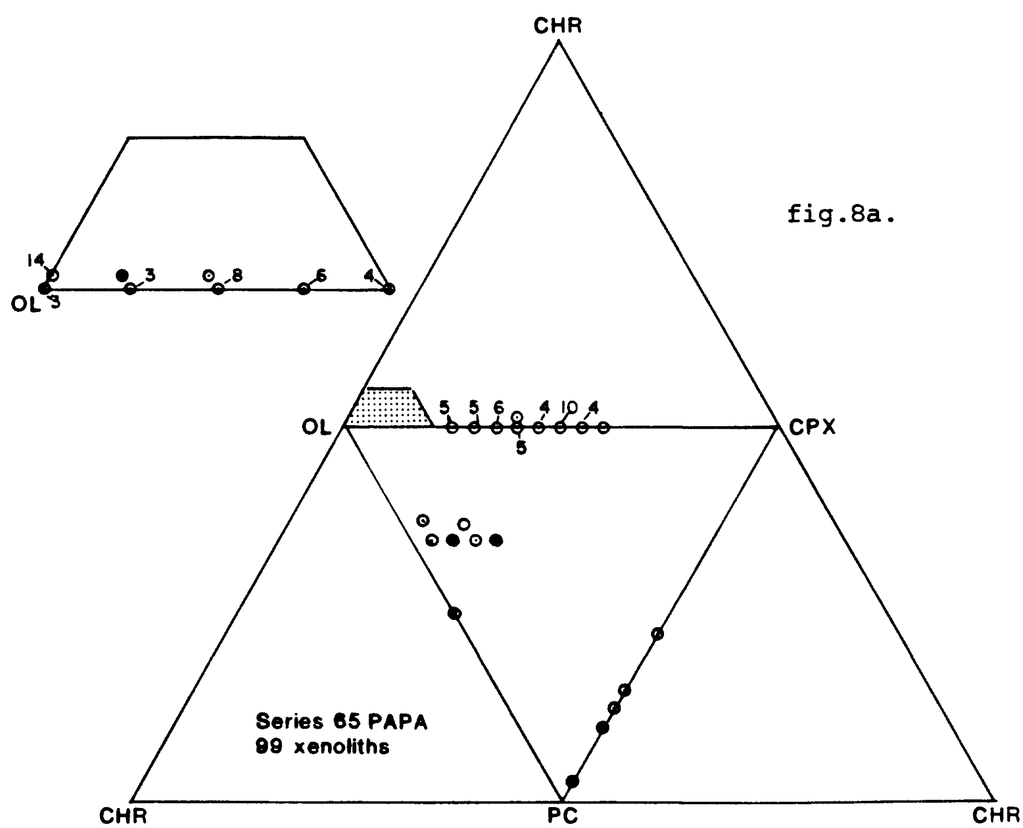


Figure 8.

Modal mineral proportions estimated in the field for xenoliths from West Maui volcano. Modes displayed on an unfolded olivine-clinopyroxene-plagioclase-chromite tetrahedron.
Symbols as in Fig. 2.



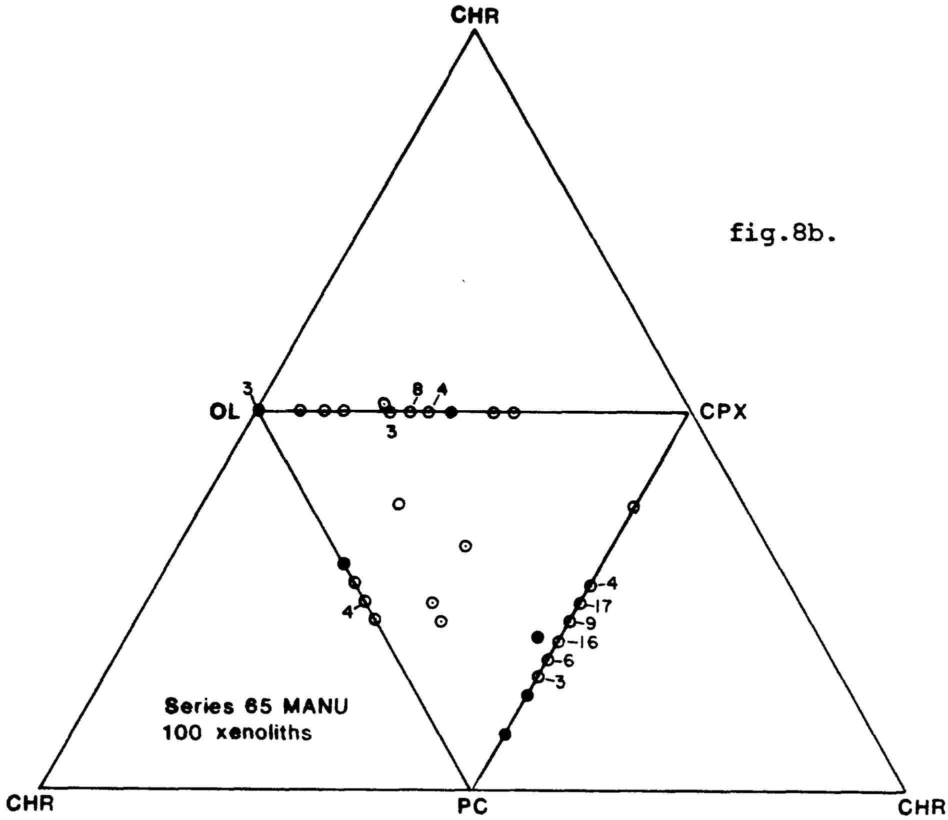

CHR
OL
CPX
CHR
PC
CHR
3
8
4
3
4
-4
-17
-9
-16
-6
-3
Series 65 MANU
100 xenoliths

fig.8b.

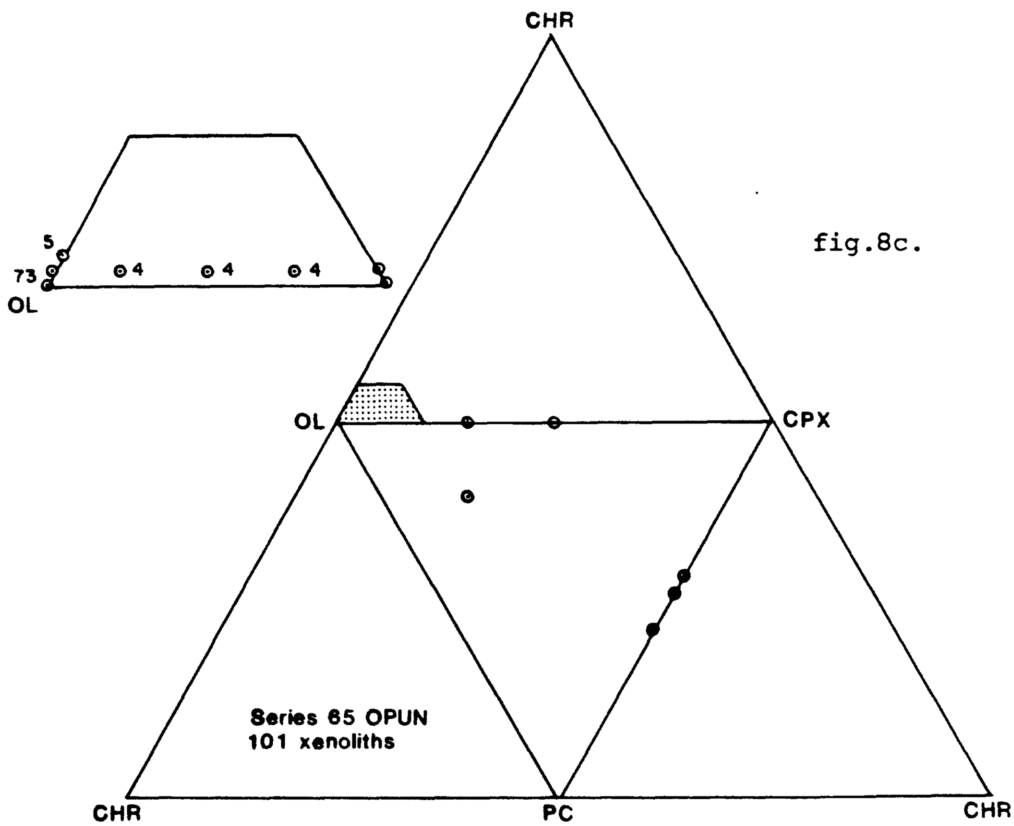

CHR
5
73
OL
4
4
4
OL
CPX
CHR
PC
CHR
Series 65 OPUN
101 xenoliths

fig.8c.

Figure 9.

Location map of the island of Kauai showing xenolith counts from the Koloa Volcanics. Precise locations are given in Table 2.

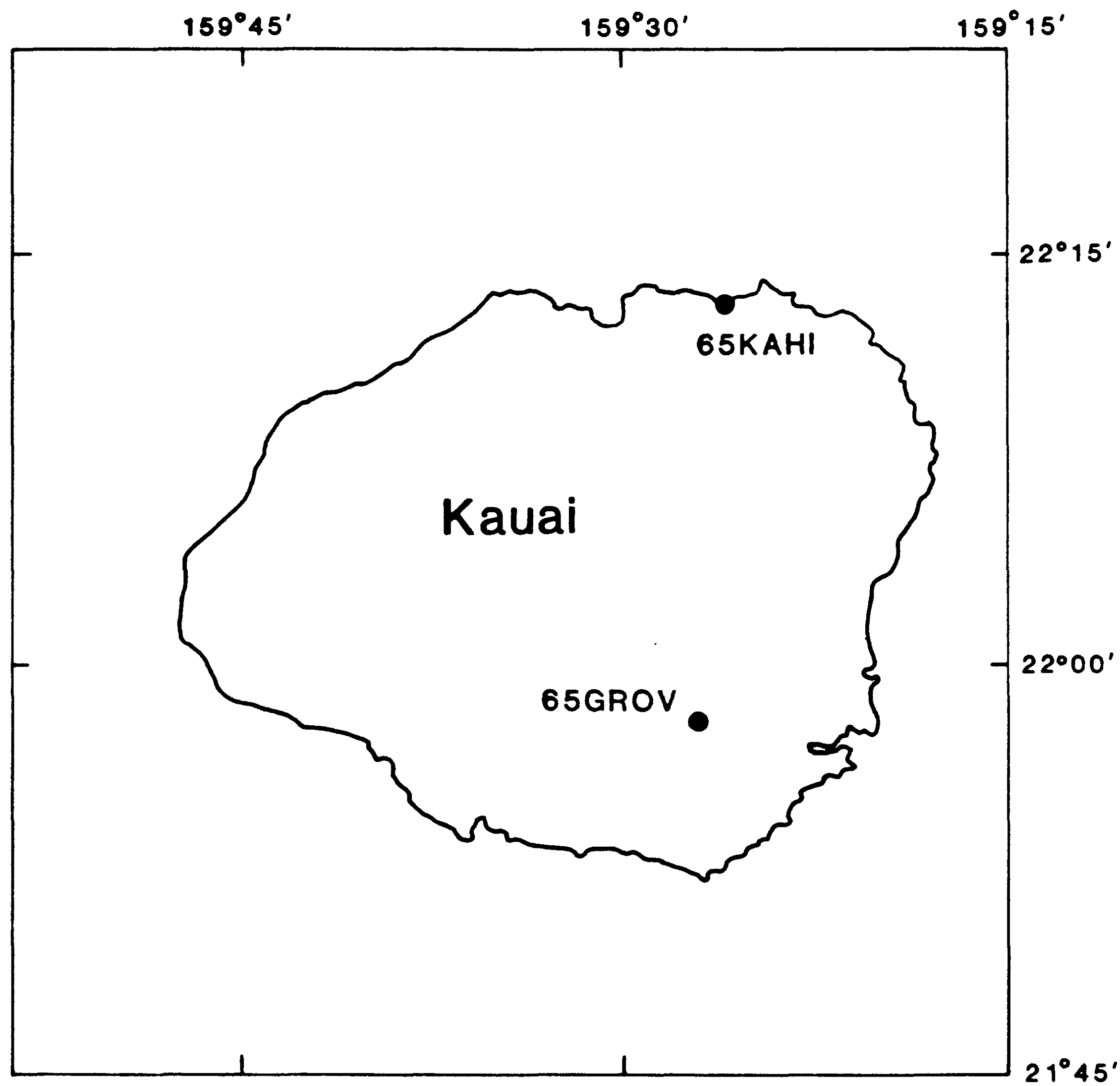
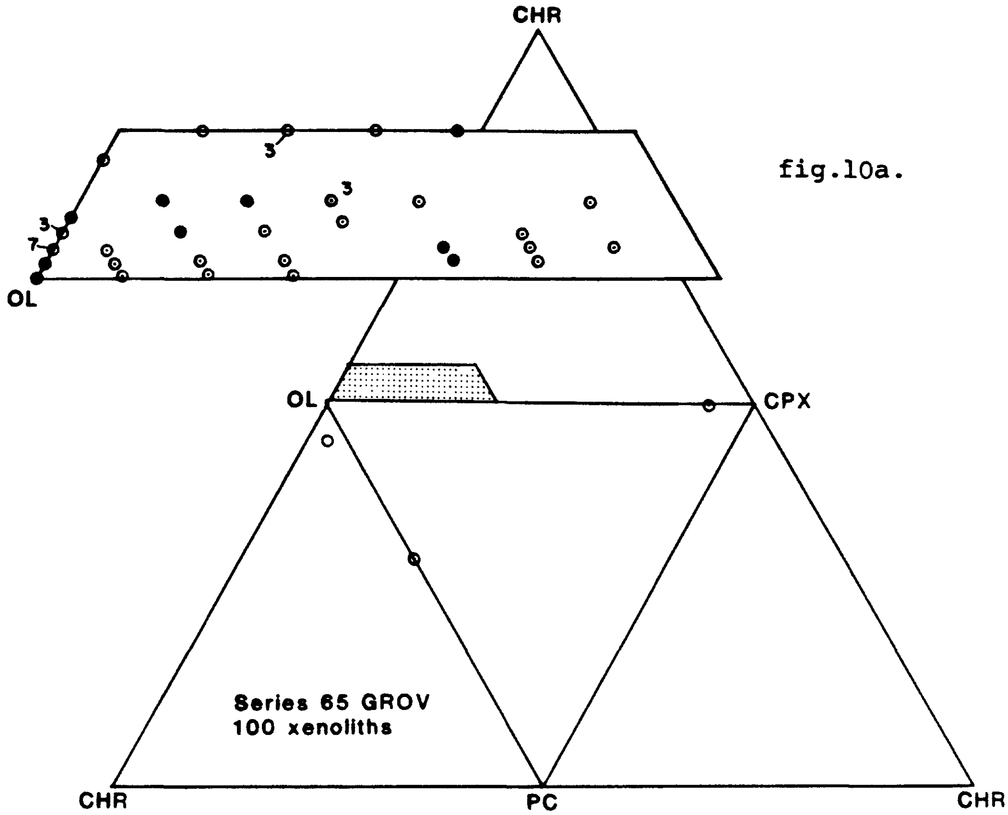


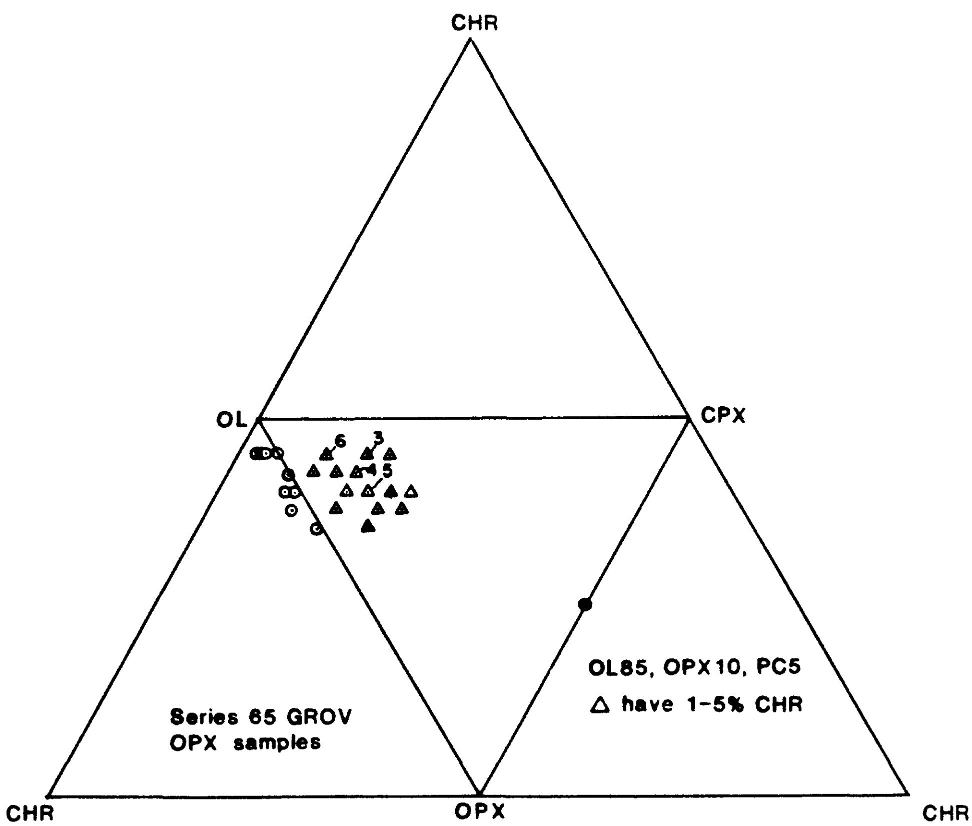
Figure 10.

Modal mineral proportions of xenoliths from the Koloa Volcanics, Kauai. Modes for each count displayed on unfolded olivine-clinopyroxene-plagioclase-chromite tetrahedron and, for ortho-pyroxene-bearing xenoliths, on an unfolded olivine-clinopyroxene-orthopyroxene-chromite tetrahedron. Symbols as in Fig. 2.



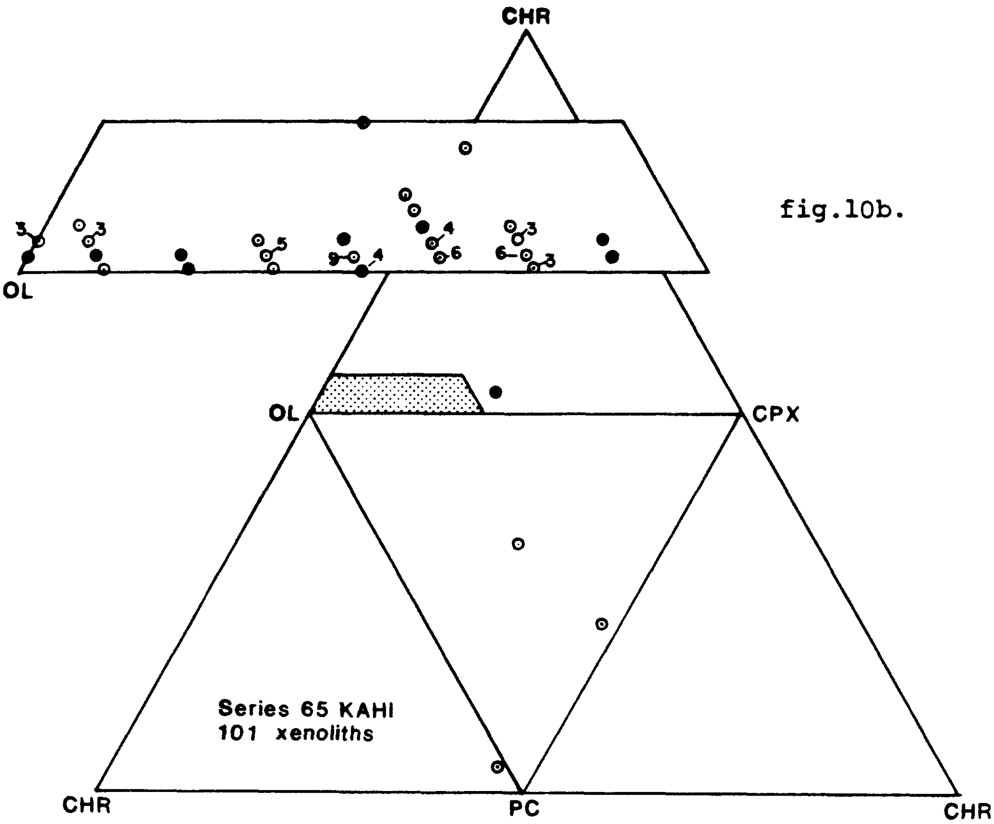
CHR
3
3
3
7
OL
OL
CPX
Series 65 GROV
100 xenoliths
CHR
PC
CHR

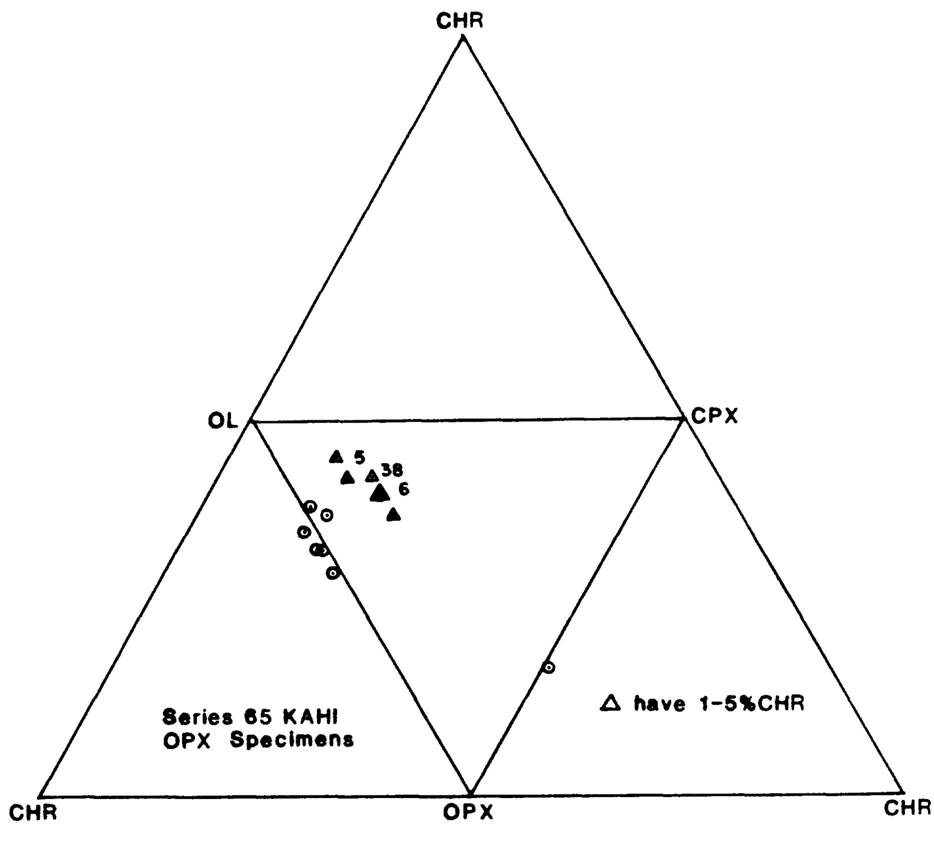
fig.10a.



CHR
OL
CPX
6
3
4
5
OL85, OPX10, PC5
△ have 1-5% CHR
Series 65 GROV
OPX samples
CHR
OPX
CHR

fig.10b.


CHR
OL
CPX
Series 65 KAHI
101 xenoliths
CHR
PC
CHR


CHR
OL
CPX
Series 65 KAHI
OPX Specimens
△ have 1-5%CHR
CHR
OPX
CHR

Oahu: The single xenolith count from Waiainae volcano, 65NANA, is from Nanakuli quarry where the xenoliths occur in a dense hawaiite flow. The xenoliths are mainly dunite and wehrlite, but some gabbroic inclusions are also present. The location is shown in Fig. 11 and the modal mineralogy in Fig. 12. An analysis of the host hawaiite is presented in Table 2 as sample 65NAN-1.

ACKNOWLEDGMENTS

Rick Murnane compiled most of the data in this report from E. D. Jackson's field notes.

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Figure 11.

Location map of the island of Oahu showing xenolith counts from the upper member of Waiainae volcano. Precise location is given in Table 2.

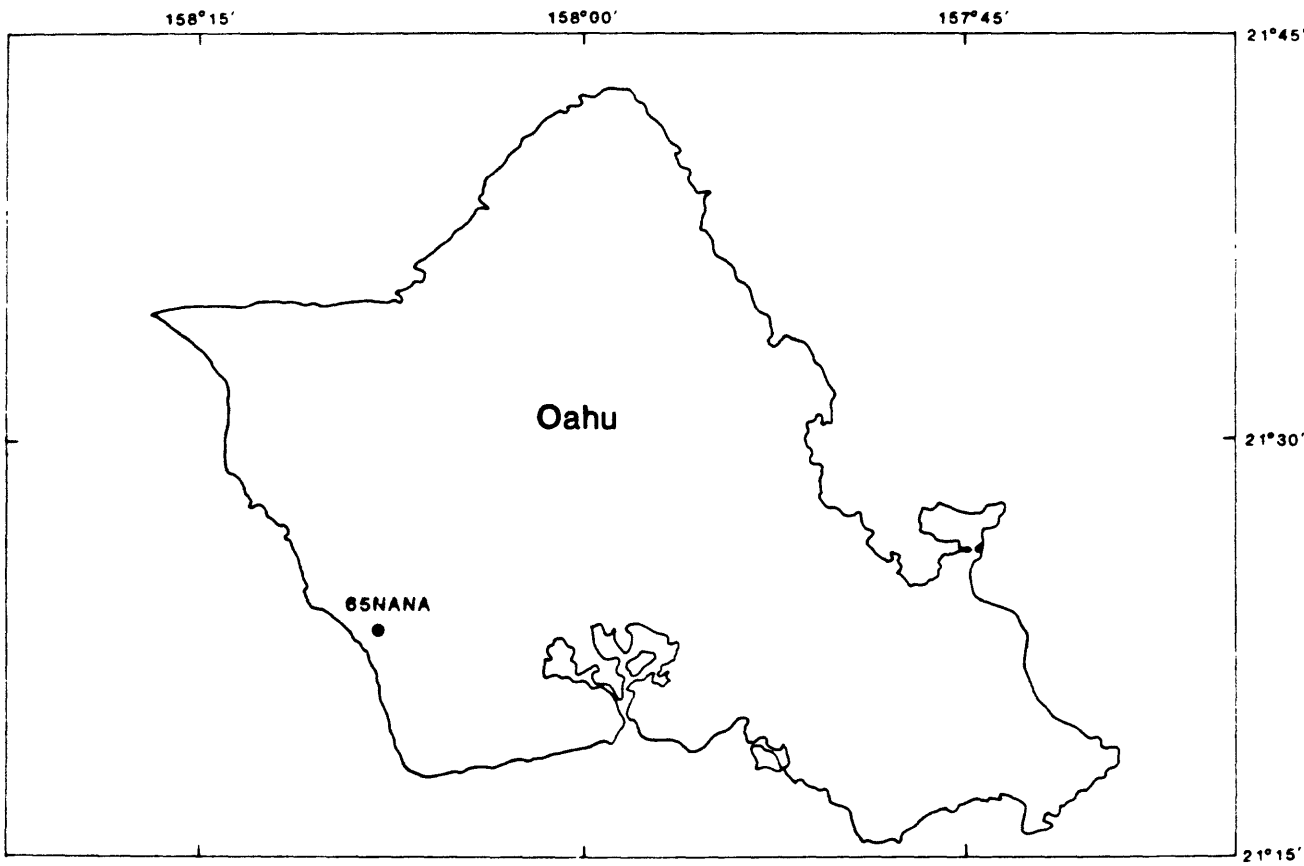

Figure 12.

Modal mineral proportions estimated in the field for xenoliths from the upper member of Waiainae volcano, Oahu. Modes displayed on an unfolded olivine-clinopyroxene-plagioclase-chromite tetrahedron. Symbols as in Fig. 2.