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XENOLITHS IN THE ALKALIC BASALT FLOWS FROM HUALALAI VOLCANO, HAWAII

By

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Introduction

Hualalai volcano is the third oldest volcano on the island of Hawaii. It was last active in 1800-1801 when the voluminous Kaupulehu and smaller Huehue alkalic basalt flows erupted from the northwest rift (Fig. 1). The Kaupulehu flow is well known for the abundant xenoliths it contains (Richter and Murata, 1961; Jackson, 1968), but a number of prehistoric alkalic basalt flows also contain xenoliths. Richter and Murata (1961) briefly describe the remarkable occurrence of the xenoliths in discrete gravel or cobble beds at about 3100 ft. in the Kaupulehu flow. Jackson and Clague (1981) present a detailed plane-table map of the xenolith beds area, Jackson (1968) has summarized the textures and mineralogy of the xenoliths from this location as well as other Hawaiian alkalic basalt flows, and Clague et al., (in press) discuss the compositions of some flows containing xenoliths on Hualalai volcano. This report presents size, shape, structure, density, and modal mineralogy of many xenoliths from the Kaupulehu flow and several prehistoric flows. In addition, whole rock chemistry, including some trace element chemistry, is included for a number of xenoliths representing the major rock types found in the Kaupulehu flow.

At locations where xenoliths were found in abundance, the first 100 to 300 xenoliths observed were measured, described, and hand specimen field modes determined. The size, shape, and structure of the xenoliths in each count are tabulated in Table 1 and the count locations are shown in Figure 2, a simplified version of a detailed plane-table map of the xenolith beds area (Jackson and Clague, 1981). All the counts except 65KEAH, 65KAIL, and 65HUEH are from the Kaupulehu flow. Count 65TR is from the vent area of the Kaupulehu flow at about 5400 ft, 65AAMA and 65MALA are along Highway 19 at about 2000 ft., and 65KIHO, 65LUAH, 65JACK, and 65KAUP are from exposures at the beach. All the remaining counts are from the nodule beds located at about 3100 ft. The nodule beds have been subdivided into northern (N), central (C) and southern (S) source areas and the beds are numbered from top (1) to bottom. Count 65-115 is from bed C-2, 65-114 from bed C-3, 65-100 from bed C-4, 65-7 from bed N-1, and 65-93 from bed N-3. All the rest are from bed C-1.

Size Distribution

The xenoliths in the Kaupulehu flow are variable in size at any location, but tend to be moderately sorted in some locations. The largest xenoliths (median 46.9 mm diameter) are found in the xenolith beds area and near Highway 19 (median 34.4 mm diameter); near the beach the median xenolith size is only 14 mm. The three prehistoric flows contain xenoliths comparable in size to those found in the Kaupulehu flow near the beach. The limited southern bed (S-1) has fairly well sorted large xenoliths, although no count was made in this area. The top central bed (C-1) is well sorted at counts 65-109, 65-61, 65-60 and 65-41 but is particularly poorly sorted at 65-124, 65-68, and 65-86. The single counts in the lower C beds suggest that the C-4 bed is the best sorted and the C-2 bed is moderately sorted. The N-1 and N-3 beds are also moderately sorted.

It is surprising that the xenoliths at Highway 19 are similar in size to those in the nodule beds. This may be due in part to a bias in the 65AAMA and 65MALA counts such that larger xenoliths were preferentially counted since they are, for the most part, totally enclosed in basalt and the smaller xenoliths are more difficult to see. The counts near the beach are mainly in wave-cut surfaces and should not suffer from this possible bias.

Rock Types and Modal Mineralogy

Hand sample modes for the 2843 xenoliths counted are shown in Figure 3 (parts a to w) broken down by individual counts. The most abundant xenoliths (∿ 60%) have metamorphic textures and are composed of olivine ± chrome spinel ± clinopyroxene. Thus, dunite and wehrlite are the most common xenoliths. There are also about 5% dikes, sills and veins present. The remaining 35% are cumulates ranging from dunite and wehrlite, through troctolite, clinopyroxene gabbro, and olivine-clinopyroxene gabbro, to anorthosite. Orthopyroxene-bearing xenoliths are present as both websterite and 2-pyroxene gabbros, but are quite rare (only 18 counted out of 2843 xenoliths). Jackson (1968) presented composite diagrams for the metamorphic and cumulate xenoliths and briefly described the textures of these rocks.

The analyzed dunite samples in Table 3 (65KAP-16, 66KAP-11, 70KAP-1, 70KAP-2 and 66KAP-1) all have metamorphic textures and consist of large kink-banded olivine surrounded by small clear recrystallized olivine. The wehrlite samples fall into three groups: those that have metamorphic textures (65KAP-17, 65-115-153B, and 66KAP-2), those that have kink-banded olivine, but undeformed clinopyroxene (63KAP-10, 65-114-63), and those that are olivine cumulates with intercumulus clinopyroxene (63KAP-16, 65KAP-1, 65WALT-1A, 66KAP-3 and 68KAP-1C). The websterite samples are all orthopyroxene cumulates with intercumulus clinopyroxene and, rarely, small amounts of plagioclase (68KAP-2, 63KAP-9, 67KAP-1, 65KAP-12, 65-7-158, 66KAP-4, 65-25-100, and 65-115-112). Samples 65-60-75 and 65-115-55 have cumulate olivine in addition to cumulate orthopyroxene. In all the websterite samples the intercumulus clinopyroxene is extensively exsolved. The gabbro samples have cumulus olivine (65KAP-18, 65-114-75B), olivine + orthopyroxene (63KAP-12), olivine + clinopyroxene (63KAP-7B), clinopyroxene (63-KAP-4), orthopyroxene + plagioclase (65-68-46), olivine + plagioclase

(65KAP-14D), olivine + clinopyroxene + plagioclase (63KAP-7A, 65KAP-13, 65-7-133, 65-86-92A, and 65-115-80), or olivine + orthopyroxene + clinopyroxene + plagioclase (63KAP-13, 63KAP-15, 65-7-195). The intercumulus material consists of plagioclase + clinopyroxene.

The counts near the beach have more abundant plagioclase-rich xenoliths than further upslope, but dunite still is the most common rock type present. In count 65KIHO, 4 xenoliths are plagioclase and clinopyroxene-bearing quartzite, apparently cumulates. Quartzite xenoliths are also found in two of the prehistoric flows (65KEAH and 65KAIL).

Major and Trace Element Chemistry

Table 2 presents major element chemistry of 41 xenoliths from the Kaupulehu flow. Modal analyses based on 1000 points are given for some of these samples as well. 01 and 01" stand for deformed and recrystallized olivine, respectively, and cpx in opx and opx in cpx stand for exsolved clinopyroxene in orthopyroxene and exsolved orthopyroxene in clinopyroxene, respectively. The analyzed xenoliths were chosen to represent the range of rock types present and to be representative of the major rock types. Orthopyroxene-bearing xenoliths are represented in the analyzed rocks far in excess of their abundance.

The dunites analyzed have olivine compositions from Fo_{86} to Fo_{88} calculated from the major element chemistry. These olivine compositions are similar to phenocryst olivine in Hawaiian tholeiites (Evans and Moore, 1968) and support Sen and Presnall's (1980) interpretation that metamorphic dunites represent deformed olivine cumulates. Many of the websterites display extensive exsolution of orthopyroxene in clinopyroxene and, to a lesser extent, clinopyroxene in orthopyroxene. The wehrlites have relatively high Fe/Mg ratios, possibly reflecting introduction of fairly ironrich liquids which crystallize as post-deformation dark green to black augite (Jackson, 1968).

Trace element data for most of the samples in Table 2 are presented in Table 3. All the xenoliths are characterized by low abundances of incompatible trace elements (P, K, Zr, Ba, Y) and high but variable abundances of compatible trace elements (Co, Ni, Cr, Sc). Detailed interpretation of the major and trace element chemistry will be presented in a subsequent paper.

Density Data

Densities of a large number of xenoliths were determined in the laboratory. This data is presented in Table 4 with modal data for most of the samples. The densities measured range from 2.62 gm/cm^3 for a plagioclase-rich gabbro to 3.66 for a chromite-rich dunite.

Discussion

This study and the plane-table map of the nodule beds locale (Jackson and Clague, 1981) provide a data base for interpreting the xenoliths in the Kaupulehu flow. Several key questions that need to be addressed include (1) how did the many xenoliths in the flow get carried to the surface and from what depths? (2) Are the cumulate xenoliths fragments of oceanic crustal layer 3 or were they formed in a high-level magma chamber in the tholeiitic shield of Hualalai volcano? (3) Are the metamorphic dunites and wehrlites deformed cumulates and if so, when and how was the undeformed clinopyroxene introduced? (4) What is the origin of the quartz-bearing xenoliths?

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Table 1. Shape, Size, and Structure of Xenoliths

Count Identification	Area of Count (sq.ft)	Number Counts	Angularity %			Percent Comp. Layering	Percent Size Layering	Percent Foliated	Percent Veins	Arith.Mean Diameter (mm) Xeno	Median Diameter		1st Quartile		3rd Quartile		Mean Diameter of Dunite (mm)
			A	S	R						(mm)	-ϕ	(mm)	-ϕ	(mm)	-ϕ	
65-60	6	302	5	66	29	4	0	2	8	53.3	40.8	5.35	30.0	4.90	55.9	5.80	51.1
65-61	3	100	8	80	12	4	0	1	10	45.7	36.7	5.20	27.5	4.75	48.4	5.60	46.2
65-86	6	105	6	73	21	2	0	2	11	68.6	48.5	5.60	34.1	5.10	92.5	6.25	50.3
65-25	4	100	7	71	22	2	1	0	4	55.9	32.1	5.15	24.5	4.55	55.8	5.80	45.5
65-109	10	200	9	72	19	1	0	2	4	45.7	30.9	4.95	32.8	4.50	43.6	5.45	42.2
65-68	4	100	19	66	15	4	0	5	6	45.7	32.1	5.15	16.1	4.15	47.3	5.57	39.9
65-41	3	105	10	73	17	2	0	0	9	45.7	32.1	5.15	25.2	4.60	50.0	5.65	36.3
65-124	3.6	100	11	61	28	3	0	0	5	43.2	28.3	4.80	33.1	4.45	106.8	5.50	39.9
65-115	6	211	10	80	10	3	0	3	5	45.7	30.0	4.90	23.2	4.45	50.0	5.65	40.1
65-114	6	213	5	87	8	1	0	2	6	40.6	29.2	4.85	21.9	4.35	40.8	5.35	40.9
65-100	8	201	4	88	8	2	0	3	7	48.3	32.1	5.05	33.9	4.50	50.2	5.65	45.7
65-7	6	206	5	74	21	5	0	2	6	53.3	36.8	5.20	27.6	4.75	57.8	5.85	53.3
65-93	8	200	4	76	20	1	0	1	10	53.3	42.0	5.40	30.0	4.90	57.8	5.85	53.6
65-TR	450	100	58	42	0	2	0	0	0	17.8	10.8	3.55	7.5	2.90	20.0	4.20	16.8
65-AAMA	1500	100	33	57	10	2	0	0	0	45.7	21.9	4.35	8.59	3.15	38.0	5.25	31.8
65-MALA	1500	100	20	62	18	5	0	0	3	63.5	46.9	5.55	32.1	5.05	79.9	6.15	68.6
65-KIHO	500	100	36	62	2	0	0	0	0	17.8	9.18	3.40	7.50	2.90	18.00	4.10	13.0
65-LUAH	290	100	31	51	18	2	0	2	1	15.2	9.45	3.35	7.27	2.85	17.9	4.10	15.5
65-KAUP	425	100	63	35	2	0	0	2	0	10.2	7.78	2.95	4.15	2.05	9.00	3.25	8.9
65-JACK	205	100	71	28	1	0	0	4	2	12.7	9.00	3.25	7.35	2.85	13.5	3.80	11.7
65-KEAH	1600	100	56	40	4	1	0	0	2	17.8	11.8	3.65	8.01	3.01	20.0	4.20	17.5
65-KAIL	1250	100	68	32	0	0	0	2	0	12.7	8.29	3.20	7.25	2.85	12.8	3.75	11.4
65-HUEH	200	100	75	25	0	1	0	7	0	20.3	16.0	4.00	10.8	3.55	23.2	4.45	18.3

Table 2. Major Element Chemistry and Modal Percentages of Selected Samples

Sample:	63-KAP-10	65-KAP-16	66-KAP-11	70-KAP-1	70-KAP-2	63-KAP-12	68-KAP-2	63-KAP-9	67-KAP-1	65-KAP-17	63-KAP-16	63-KAP-7A
Rock Type:	Wehrlite	Dunite	Dunite	Dunite	Dunite	2 px Gabbro	Websterite	Websterite	Websterite	Wehrlite	Wehrlite	Cpx Gabbro
SiO_2	41.55	39.92	39.44	40.11	40.31	45.80	53.21	53.52	52.91	43.55	42.91	44.63
Al_2O_3	1.67	0.73	0.77	0.55	0.73	5.75	3.49	3.75	4.02	2.81	3.71	15.74
Fe_2O_3	1.00	0.87	0.99	0.67	0.94	1.17	1.56	1.48	1.91	1.42	1.23	1.31
FeO	12.51	11.46	12.62	11.32	11.64	10.70	6.90	7.43	7.02	10.69	9.99	8.33
MgO	39.10	46.06	45.22	46.77	45.07	29.46	25.72	26.46	24.59	32.06	37.05	19.83
CaO	3.26	0.07	0.08	<0.01	0.64	5.58	7.82	6.26	7.82	8.52	3.78	8.24
Na_2O	0.18	0.03	0.01	<0.01	0.03	0.68	0.23	0.22	0.39	0.21	0.37	1.46
K_2O	0.01	<0.01	<0.01	<0.01	0.01	0.03	<0.01	<0.01	0.04	0.02	0.03	0.07
H_2O+	0.03	0.03	0.01	0.02	0.04	<0.01	0.01	0.04	0.07	<0.01	<0.01	<0.01
H_2O-	0.02	0.02	0.02	0.03	<0.01	0.02	0.01	0.02	0.03	0.04	0.04	0.05
NiO	0.20	0.20	0.20	0.20	0.23	0.15	0.10	0.07	0.08	0.11	0.15	0.08
Cr_2O_3	0.11	0.38	0.42	0.32	0.20	0.20	0.61	0.41	0.61	0.23	0.41	0.03
TiO_2	0.21	0.06	0.07	0.04	0.08	0.24	0.29	0.31	0.39	0.35	0.14	0.15
P_2O_5	0.01	<0.01	<0.01	<0.01	0.01	0.01	<0.01	<0.01	0.02	<0.01	0.02	0.01
MnO	0.18	0.16	0.18	0.16	0.17	0.17	0.17	0.17	0.17	0.17	0.16	0.12
CO_2	<0.01	<0.01	0.01	0.01	0.01	0.01	0.01	0.01	<0.01	<0.01	0.01	<0.01
Total S	0.02	0.02	<0.01	0.01	0.04	0.02	0.02	0.01	0.01	0.01	0.01	0.01
Subtotal	100.06	100.01	100.04	100.21	100.15	99.99	100.15	100.16	100.08	100.19	100.01	100.06
Less O	0.01	0.01	-	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Total	100.05	100.00	100.04	100.20	100.13	99.98	100.14	100.15	100.07	100.18	100.00	100.05
Analysis Code	1	1	1	1	1	1	1	1	1	1	1	1
Modal Percent												
01	69	79	60	90	87	31	3	<1	<1	43	58	22
01"	22	18	36	9	10	15	1	-	-	12	15	8
cpx	8	1	1	<1	2	9	29	27	26	45	10	6
cpx in opx	-	-	-	-	-	1	4	2	3	-	-	-
opx	<1	-	-	-	-	19	53	65	63	-	<1	1
opx in cpx	-	-	-	-	-	3	9	4	5	-	<1	-
plag	<1	-	-	-	-	22	-	-	2	-	15	63
ch spinel	<1	2	3	<1	1	<1	<1	2	-	-	2	-
Fe oxides	-	-	-	-	-	-	<1	-	<1	-	-	-

	Sample:	63-KAP-7B	63-KAP-4	65-KAP-1	65-KAP-13	65-KAP-18	65-WALT-1A	65-7-133	65-7-185	65-86-92A	65-114-63	65-114-75B	65-115-80
	Rock Type:	Feld.Wehr.	Clino.*	Wehrlite	Gabbro	Gabbro	Wehrlite	Gabbro	Cpx Gabbro	Gabbro	Wehrlite	Ol. Gabbro	Gabbro
	SiO_2	44.19	49.38	45.07	49.42	43.25	45.42	47.75	48.89	46.64	43.60	41.24	47.60
	Al_2O_3	6.76	5.55	1.20	16.22	9.88	2.57	21.78	9.05	22.28	4.04	4.60	21.23
	Fe_2O_3	2.39	1.99	0.77	0.92	1.11	1.60	0.70	2.38	1.06	1.62	0.73	1.11
	FeO	10.27	5.20	9.13	3.35	11.38	9.90	2.87	5.00	3.56	10.87	12.45	4.13
	MgO	25.81	16.79	41.12	11.71	25.90	31.93	10.00	14.35	9.04	29.53	36.37	9.79
	CaO	9.12	18.90	1.70	16.15	6.81	7.54	14.95	18.24	15.52	9.17	3.55	13.84
	Na_2O	0.63	0.48	0.09	1.43	0.95	0.24	1.48	0.80	1.34	0.28	0.36	1.79
	K_2O	0.03	0.02	<0.01	0.03	0.05	0.01	0.03	0.03	0.08	0.02	0.04	0.11
	H_2O+	0.03	0.03	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	H_2O-	0.02	0.01	0.04	0.04	0.02	0.05	0.05	0.04	0.01	0.02	0.01	0.02
	NiO	0.09	0.07	0.28	0.04	0.12	0.26	0.05	0.04	0.06	0.02	0.02	0.04
	Cr_2O_3	0.10	0.57	0.18	0.20	0.26	0.32	0.22	0.19	0.15	0.29	0.12	0.05
	TiO_2	0.41	0.77	0.23	0.28	0.21	0.17	0.18	0.86	0.28	0.36	0.11	0.32
	P_2O_5	0.02	0.01	0.02	0.03	0.03	0.01	0.02	0.01	0.01	0.01	0.01	0.01
	MnO	0.17	0.13	0.15	0.09	0.16	0.17	0.06	0.13	0.07	0.18	0.18	0.07
	CO_2	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	Total S	0.01	0.04	0.01	0.01	0.01	0.03	0.01	0.03	0.02	0.02	0.01	0.01
	Subtotal	100.06	99.95	100.00	99.93	100.15	100.13	100.16	100.05	100.13	100.04	100.91	100.13
	Less O	0.01	0.02	0.01	0.01	0.01	0.02	0.01	0.02	0.01	0.01	0.01	0.01
	Total	100.05	99.93	99.99	99.92	100.14	100.11	100.15	100.03	100.12	100.03	100.90	100.12
	Analysis Code:	1	1	1	1	1	1	1	1	1	1	1	1
Modal Percent	Ol	25	5	52	1	46	43	10	1	6	26	66	6
	Ol"	23	2	29	2	15	17	5	2	3	11	12	13
	cpx	36	89	14	23	12	27	16	89	37	56	6	3
	cpx in opx	-	-	-	-	-	-	1	-	-	-	-	-
	opx	-	-	-	-	-	1	2	-	-	-	-	-
	opx in cpx	-	1	1	1	-	8	<1	-	-	-	-	-
	plag	16	1	4	73	27	3	66	8	53	6	16	78
	chr spinel	-	2	<1	-	-	-	-	-	-	<1	1	-
	Fe-oxides	1	-	-	-	-	-	-	-	-	-	-	-

* Olivine-bearing clinopyroxenite

Sample	65-115-153B	65-KAP-14D	66-KAP-2	66-KAP-3	63-KAP-13	63-KAP-15	65-KAP-12	65-68-46	65-60-75	65-7-158	66-KAP-4
Rock Type:	Wehrlite	Gabbro	Wehrlite	Wehrlite	2 px Gabbro	2 px Gabbro	Websterite	2 px Gabbro	Ol. Webst.	Websterite	Websterite
SiO_2	48.07	46.87	42.51	49.54	48.39	51.88	53.39	50.52	50.98	53.41	53.38
Al_2O_3	4.12	22.68	1.74	4.64	20.29	15.74	3.57	9.11	5.51	3.68	3.39
Fe_2O_3	1.65	0.66	0.90	1.65	0.90	3.91	1.04	2.33	1.80	1.04	1.39
FeO	6.30	2.53	11.59	5.74	2.88	2.70	7.29	6.87	8.05	7.16	6.83
MgO	22.21	8.15	36.88	19.80	9.77	10.40	25.57	13.11	25.07	25.53	25.04
CaO	16.00	17.62	5.66	17.06	16.23	12.25	7.76	15.51	7.12	7.81	8.41
Na_2O	0.40	0.34	0.13	0.44	1.11	2.08	0.23	1.37	0.50	0.24	0.31
K_2O	0.02	0.01	0.01	<0.01	0.02	0.11	0.02	0.08	0.05	0.02	0.02
H_2O+	0.01	0.02	<0.01	0.02	0.10	0.08	0.05	0.03	0.00	0.00	0.00
H_2O-	0.04	0.04	0.06	0.06	0.01	0.06	0.00	0.01	0.02	0.04	0.03
NiO	0.12	0.03	0.22	0.08	0.03	0.03	0.09	0.02	0.11	0.08	0.08
Cr_2O_3	0.64	0.67	0.19	0.47	0.25	0.09	0.69	0.14	0.39	0.63	0.70
TiO_2	0.61	0.08	0.18	0.52	0.16	0.50	0.30	0.90	0.30	0.27	0.27
P_2O_5	0.01	0.01	<0.01	<0.01	0.02	0.02	0.01	0.04	0.02	0.02	0.01
MnO	0.14	0.06	0.18	0.13	0.08	0.13	0.17	0.21	0.18	0.17	0.18
CO_2	0.01	0.01	0.01	0.01	0.02	0.00	0.01	0.01	0.02	0.02	0.01
Total S	0.06	0.02	0.03	0.04	0.01	0.00	0.02	0.00	0.01	0.01	-
Subtotal	100.41	99.80	100.29	100.20	100.27	99.98	100.21	100.26	100.13	100.13	100.05
Less O	0.03	0.01	0.02	0.02	0.01	0.00	0.01	0.00	0.01	0.01	0.00
Total	100.38	99.79	100.27	100.18	100.26	99.98	100.20	100.26	100.12	100.12	100.05
Analysis Code	1	1	1	1	2	2	2	2	2	2	2
Modal Percent: Ol	12	1	-	10	3	-	-	-	4	-	-
Ol"	9	<1	-	2	2	-	-	<1	5	-	-
cpx	79	27	-	88	31	16	33	69	25	29	42
cpx in opx	-	-	-	-	-	<1	2	<1	1	5	2
opx	-	3	-	-	2	13	59	3	47	56	50
opx in cpx	-	2	-	-	1	<1	4	3	8	8	6
plag	-	66	-	-	60	70	1	25	6	1	-
chr spinel	-	-	-	-	-	-	1	-	2	1	<1
Fe oxides	-	-	-	-	<1	-	<1	-	1	-	<1

	Sample	65-25-100	65-115-55	65-115-112	68-KAP-1C	65-7-195	66-KAP-1
	Rock Type	Websterite	Orth.pyroxen.	Websterite	Wehrlite	2 px Gabbro	Dunite
	SiO_2	53.91	51.80	52.83	42.64	47.1	39.33
	Al_2O_3	2.78	3.21	3.36	1.81	7.0	0.85
	Fe_2O_3	1.31	0.99	1.71	1.08	1.5	1.05
	FeO	7.24	7.27	7.60	11.49	9.9	12.96
	MgO	25.75	30.22	23.37	36.35	24.9	44.90
	CaO	7.07	3.81	9.15	4.40	7.6	0.18
	Na_2O	0.19	0.22	0.32	∿ .13	0.87	0.04
	K_2O	0.02	0.03	0.02	0.04	0.04	0.01
	H_2O+	<0.05	<0.05	<0.05	<0.05	0.25	0.00
	H_2O-	<0.05	<0.05	<0.05	<0.05	0.00	0.00
	NiO	0.09	0.15	0.08	0.24	-	0.29
	Cr_2O_3	0.63	0.77	0.60	0.32	-	0.38
	TiO_2	0.28	0.17	0.47	0.17	0.57	0.05
	P_2O_5	<.007	0.01	<.007	0.01	0.07	0.01
	MnO	0.175	0.167	0.185	0.175	0.17	0.19
	CO_2	0.04	0.04	0.04	0.10	0.01	0.01
	Total S	0.008	0.001	0.012	0.023	-	-
	Subtotal						100.25
	Less O						.00
	Total	99.50	98.86	99.75	98.96	98.98	100.25
	Analysis Code	3	3	3	3	4	5
Modal Percent	Ol	-	1	-	31	22	74
	Ol"	-	10	1	10	4	24
	cpx	23	6	39	48	35	1
	cpx in opx	4	5	1	-	1	-
	opx	69	70	51	7	24	-
	opx in cpx	3	-	7	4	4	-
	plag	-	4	<1	-	10	-
	chr spinel	1	4	1	<1	-	1
	Fe oxides	-	-	-	<1	-	-

	Analysts		Method
1.	E. Engleman	Major Elements	Conven. rock anal.
	C. Heropoulus	Cr, Ni	Emission Spec.
2.	E. Engleman	Major Elements	Conven. rock anal.
	R. L. Rahill	Cr_2O_3	Colorimetrically
	R. L. Rahill	NiO	AA
3.	L. Espo	Major Elements	XRF
	J. H. Tillman	FeO, H_2O+, H_2O-, CO_2, Cr_2O_3, NiO	Partial chem. anal.
4.	P. Elmore	Major Elements	Rapid rock analysis
5.	E. L. Munson	Major Elements	Conven. rock anal.

Note: All modal analyses done by W. B. Friesen

Table 3. Trace Element Composition of Selected Samples

Sample Rock type	63-KAP-10	65-KAP-16	66-KAP-11	70-KAP-1	70-KAP-2	63-KAP-12	68-KAP-2	63-KAP-9	67-KAP-1	65-KAP-17	63-KAP-16	63-KAP-7A
Sc	20	<2	7	<2	9	25	52	46	50	47	25	12
V	100	41	54	30	57	130	220	210	240	170	120	43
Co	210	210	220	220	210	160	120	110	100	180	200	130
Cu	155	10	20	23	55	46	89	66	52	24	17	34
Zn	105	114	123	99	127	89	51	41	58	68	114	47
Sr	<5	<5	<5	<5	<5	69	<5	<5	25	10	24	400
Zr	29	14	19	18	24	26	20	33	36	38	20	36
Ba	10	5	4	6	7	27	9	13	21	14	10	26
Ga	10	8	9	8	8	11	12	12	13	11	13	15
Y	<5	11	<5	12	11	<5	<5	<5	<5	<5	∼5	<5
Analysis Code	1	1	1	1	1	1	1	1	1	1	1	1

Sample Rock type	63-KAP-7B	63-KAP-4	65-KAP-1	65-KAP-13	65-KAP-18	65-WALT-1A	65-7-133	65-7-185	65-86-92A	65-114-63	65-114-75B	65-115-80
Sc	39	120	18	70	16	33	33	130	35	42	12	28
V	250	430	96	430	81	190	180	440	160	240	44	150
Co	160	80	170	61	170	180	61	86	62	170	180	64
Cu	120	200	34	23	43	410	45	100	120	110	18	54
Zn	74	39	89	36	75	67	31	37	36	71	77	36
Sr	150	49	<5	80	280	<5	89	141	480	44	102	540
Zr	38	52	32	14	38	25	<5	36	∼5	42	37	8
Ba	15	23	∼2	13	30	10	5	33	26	17	20	37
Ga	12	14	8	16	13	11	18	17	18	11	9	18
Y	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Analysis Code	1	1	1	1	1	1	1	1	1	1	1	1

Table 3. Continued

Sample Rock type	65-115-153B	65-KAP-140	66-KAP-2	66-KAP-3	63-KAP-13	63-KAP-15	65-KAP-12	65-68-46	65-60-75	65-7-158	66-KAP-4	66-KAP-1
Sc	100	35	31	110	38	38	34	100	32	25	44	6
V	290	180	100	300	150	110	130	310	150	170	160	37
Co	110	47	200	94	54	60	97	85	120	110	120	190
Cu	34	40	74	200	34	45	75	26	70	55	48	12
Zn	40	33	76	37	<5	<5	15	7	31	22	23	81
Sr	29	17	<5	36	59	365	<9	78	32	<9	<9	<9
Zr	37	<5	32	26	16	24	28	43	30	25	29	23
Ba	21	<2	10	16	<2	<2	<2	<2	<2	<2	<2	7
Ga	12	15	8	11	17	25	11	22	15	12	12	<4
Y	<5	<5	∿6	<5	18	<9	<9	24	10	<9	<9	<9
Analysis Code	1	1	1	1	2	2	2	2	2	2	2	2

Sample Rock type	65-25-100	65-115-55	65-115-112	68-KAP-1C
Sc	30	23	33	17
V	122	80	165	67
Co	70	85	76	180
Cu	40	28	42	160
Zn				
Sr				
Zr				
Ba	7	6	11	7
Ga	<4	<4	<4	<4
Analysis Code	3	3	3	3

Note: Nb, Li, Cs, Rb all below detection limits.
B below detection limits also but not measured in 65-25-100, 65-115-55, 65-115-112, 68-KAP-1C, or 65-7-195.

Analysis code =
1 - B. King: Ba, Sr, Zn, Zr, Y - XRF
C. Heropoulus: Co, Cu, Ga, Sc, V - Emission Spec.
2 = B. King: Ba, Sr, Zn, Zr, Y - XRF
R. E. Mays - Co, Cu, Ga, Sc, V - Emission Spec.
3 - R. E. Mays: Ba, Co, Cu, Ga, Sc, V - Emission Spec.

Emission spec. reported to two significant figures. Accuracy is I15%.
Near detection limits only one significant digit intended.

Table 4 . Field Modes and Density of Selected Samples

	Modal %						
Sample ID	Ol	Ol"	opx	cpx	pc	chr	Density*
63-KAP-1	40			45	15	15	3.20
-2							3.17
-3	30			60	10	<5	2.90
-4	35			50	15	<5	3.19
-5	60			40		<5	3.33
-6							3.34
-7							2.95
-8	50			45		5	3.23
-10	95					5	3.20
-11	40			30	30		3.05
-12							3.12
-13	15			25	60		2.94
-14	70			20	5	5	3.38
-15			30	30	40		2.86
-16	65			20	15	<5	3.18
65-HU-5							3.32
65-KIH-1							2.62
65-KAI-1	10				90		2.83
65-KAP-1							3.34
-2							3.03
-3							3.36
-4							3.06
-5							3.16
-6							3.36
-7							3.34
-8							3.22
-10							3.26
-16							3.30
-17							3.18

	Modal %						
Sample ID	Ol	Ol"	opx	cpx	pc	chr	Density*
65-KAP-18							3.09
-19							3.37
-23							2.82
66-KAP-1							3.41
-2							3.32
-3							3.26
-4							3.28
-5							3.29
65-60-10	30			69		1	3.22
-17	70			13	14	3	3.20
-20	62			36		2	3.12
-32	3		5	26	66		2.67
-35a	40	40		5	14	1	3.20
-35b	35	10			55		3.20
-37	45	30			25	<1	2.99
-40	35	35		27		3	3.22
-45	20	10		70			3.13
-50	25	10		65			3.16
-51	25	20			55		2.71
-52	60	39				1	3.22
-59	40	40		20			3.30
-60a	85	14				1	3.21
-60b	25			75		<1	3.21
-60c	70	30				<1	3.21
-61	65	35				<1	3.24
-66a	60	40				<1	3.20
-66b	25			75		<1	3.20
-70	40	60				<1	3.32
-73			60	35	5	<1	3.28
-75	5		55	25	15		3.07

* $(\frac{gm}{cm^3})$

Table 4. Continued

Sample ID	Modal %						Density*
	01	01"	opx	cpx	pc	chr	
65-60-80a	60	40					3.29
-80b	40	20		40			3.29
-98a	60	40				<1	3.30
-98b							3.30
-100	48	47		2		3	3.33
-102		50		50		<1	3.14
-120	55	2		43		<1	3.08
-130	45	45		10		<1	3.20
-131	70	25		4		1	3.24
-135	70			5	25		3.10
-160	60	40				<1	3.24
-174				100			3.09
-186	50	20		30			3.24
-190	70	20		10			3.22
-196		50		50			3.02
-200	65	25		10		<1	3.24
-209	30	60		10			3.18
-210	60	30		10			3.21
-225		50		50			3.17
-240	65	34				1	3.34
-250	90	10				<1	3.26
-260		45		55			3.08
-272	80	19				1	3.21
-280	40	45		15			3.14
-290	19	80				1	3.23
-291	99					1	3.32
-300	65			35			3.24
65-61-10	40			60	50		3.02
-26	15			35			2.76
-39	48	50				2	3.14
65-61-40	55	40		4		1	3.30
-50	50			50			3.23
-60	55	35		5		5	3.20
-70	60	40				4	3.19
-80	50	45		4		1	3.27
-90	85	10		3		2	3.26
-100	5			95			3.12
65-86-10	65	15		19		1	3.15
-17	75			15		10	3.14
-20	50	45		4		1	3.20
-25	50			30	18	2	3.18
-46a				40	60		2.71
-46b	25				75		2.71
-50	35			65			3.14
-80	70	25		4		1	3.35
-92a	20			25	55		2.88
-92b	75			25			2.88
-100	35	60		5		<1	3.23
65-25-7	65	35		5			3.21
-8	60	39				1	3.12
-10	50			20	30		3.09
-20	20			80			3.08
-26	50	45		4		1	3.12
-30	90			7		3	3.19
-40	55			45			3.20
-60	30			70			3.22
-70	75	20		3		2	3.18
-74a	23	75				2	3.34
-74b	60			40			3.34
-80	70	25		3		2	3.20

* $(\frac{gm}{cm^3})$

Table 4. Continued

	Modal %						
Sample ID	01	01"	opx	cpx	pc	chr	Density*
65-25-100	-	-	65	35	-	-	3.18
65-109-20	80	20	-	-	-	< 1	3.27
65-109-27	56	-	-	20	20	4	3.09
65-109-50	80	16	-	-	-	4	3.19
65-109-64	55	30	-	15	-	< 1	3.23
65-109-100	60	30	-	9	-	1	3.26
65-109-110	75	17	-	5	-	3	3.24
65-109-115	90	-	-	5	-	5	3.20
65-109-120A	80	17	-	-	-	3	3.24
65-109-120B	25	-	-	75	-	< 1	3.24
65-109-130	75	-	-	34	-	1	3.19
65-109-133	50	-	-	50	-	< 1	3.18
65-109-140	65	-	-	35	-	< 1	3.16
65-109-143	50	15	-	5	30	-	3.18
65-109-146A	55	-	-	20	25	< 1	3.09
65-109-146B	5	-	-	5	90	-	3.09
65-109-146C	5	-	-	60	35	-	3.09
65-109-150	80	-	-	15	-	5	3.18
65-109-162	60	10	-	25	-	5	3.33
65-109-170	70	-	-	29	-	1	3.22
65-109-200	55	15	-	28	-	2	3.18
65-68-10A	80	15	-	3	-	2	3.28
65-68-10B	70	-	-	29	-	1	3.28
65-68-10C	80	15	-	4	-	1	3.28
65-68-17A		-	-		-	-	3.22
65-68-17B	75	-	-	25	-	-	3.22
65-68-20	65	30	-	4	-	1	3.27
65-68-30	70	-	-	30	-	< 1	3.20
65-68-38A	80	15	-	5	-	< 1	3.27
65-68-38B	40	-	-	60	-	-	3.27

	Modal %						
Sample ID	01	01"	opx	cpx	pc	chr	Density*
65-68-40	-	-	-	45	55	-	2.85
65-68-60	10	-	-	90	-	-	3.37
65-68-70	98	-	-	-	-	2	3.32
65-68-80	98	-	-	-	-	2	3.27
65-68-87	45	-	-	-	55	-	3.24
65-68-90	75	15	-	14	-	1	3.24
65-68-100	98	-	-	-	-	2	3.24
65-41-10	60	25	-	14	-	1	3.30
65-41-14	-	98	-	-	-	2	3.29
65-41-20	43	-	-	55	-	2	3.32
65-41-30	95	-	-	< 1	-	1	3.30
65-41-40	85	5	-	8	-	2	3.32
65-41-41	70	15	-	14	-	1	3.24
65-41-50	50	-	-	50	-	< 1	3.20
65-41-56A	95	-	-	4	-	1	3.21
65-41-56B	15	-	-	85	-	-	3.21
65-41-60	50	46	-	-	-	4	3.26
65-41-64	60	30	-	7	-	3	3.28
65-41-69A	80	15	-	3	-	2	3.26
65-41-69B	5	-	-	95	-	-	3.26
65-41-70	45	20	-	35	-	< 1	3.20
65-41-80	45	-	-	30	25	-	3.07
65-41-90	75	20	-	3	-	2	3.33
65-41-100	55	-	-	45	-	-	3.22
65-124-10	85	-	-	15	-	< 1	3.22
65-124-20	75	-	-	25	-	< 1	3.20
65-124-30	60	-	-	40	-	-	3.21
65-124-40	97	-	-	-	-	3	3.28
65-124-50	70	-	-	30	-	< 1	3.26
65-124-60	85	-	-	14	-	1	3.22

* $(\frac{gm}{cm^3})$

Table 4 . Continued

Sample ID	01	01"	Modal % opx	cpx	pc	chr	Density*
65-124-70	95	-	-	3	-	2	3.29
65-124-80	55	-	-	15	30	< 1	3.13
65-124-90A	5	-	-	95	-	-	3.21
65-124-90B	40	-	-	60	-	-	3.21
65-124-90C	5	-	-	95	-	-	3.21
65-124-100A	40	-	-	60	-	-	3.34
65-124-100B	90	-	-	9	-	1	3.34
65-115-3	60	38	-	-		2	3.30
65-115-6	10	-	-	90	-	-	2.84
65-115-7	5	-	-	95	-	-	3.21
65-115-10	10	-	-	40	50	-	2.73
65-115-20	60	15	-	24	-	1	3.07
65-115-30	55	-	-	45	-	-	3.11
65-115-33	40	60	-	-	-	-	3.28
65-115-42	10	-	-	20	70	-	2.63
65-115-50	55	30	-	11	-	4	3.29
65-115-57A	-	90	-	5	5	-	3.21
65-115-57B	-	50	-	-	50	-	3.21
65-115-60	85	13	-	-	-	2	3.22
65-115-70	-	98	-	-	-	2	3.27
65-115-80	20	-	-	25	55	-	2.83
65-115-90	-	85	-	9	5	1	3.07
65-115-100	98	-	-	-	-	2	3.20
65-115-101	50	-	-	35	15	< 1	3.16
65-115-104	5	-	-	95	-	-	3.18
65-115-110	39	60	-	-	-	1	3.14
65-115-120	60	39	-	-	-	1	3.30
65-115-130	50	-	-	50	-	-	3.16
65-115-131	20	-	-	40	40	-	2.74
65-115-138A	75	12	-	12	-	3	3.26

* $(\frac{gm}{cm^3})$

Sample ID	01	01"	Modal % opx	cpx	pb	chr	Density*
65-115-138B	50	-	-	49	-	1	3.26
65-115-150	60	25	-	13	-	2	3.17
65-115-153A	55	25	-	17	-	3	3.17
65-115-153B	45	-	-	55	-	-	3.17
65-115-170	50	48	-	-	-	2	3.28
65-115-182	50	-	-	50	-	< 1	3.13
65-115-210	60	15	-	22	-	3	3.18
65-114-2	65	34	-	-	-	1	3.32
65-114-10	30	45	-	5	20	-	3.20
65-114-15	20	-	-	40	40	-	2.75
65-114-30	-	25	-	35	40	-	2.85
65-114-36	55	-	-	40	5	-	3.06
65-114-40	60	35	-	-	-	5	3.32
65-114-55	45	30	-	10	15	-	3.23
65-114-63	25	20	-	45	15	-	3.25
65-114-70	50	-	-	25	25	-	3.04
65-114-75A	50	49	-	-	-	1	3.09
65-114-75B	25	30	-	20	25	-	3.09
65-114-90	75	22	-	-	-	3	3.26
65-114-100	60	20	-	17	-	3	3.28
65-114-105	50	30	-	20	-	-	3.31
65-114-130	-	45	-	25	30	-	3.18
65-114-140	60	37	-	-	-	3	3.29
65-114-150	55	-	-	45	-	-	3.18
65-114-160	60	39	-	-	-	1	3.33
65-114-200	96	-	-	-	-	4	3.24
65-114-201A	40	-	-	30	30	-	2.89
65-114-201B	25	-	-	25	50	-	2.89
65-114-203	5	-	-	60	35	-	3.12
65-114-207	55	30	14	-	-	1	3.21

Table 4 . Continued

	Modal %						
Sample ID	01	01"	opx	cpx	pc	chr	Density*
65-100-10	-	40	-	30	30	-	3.12
65-100-30	60	39	-	-	1	-	3.24
65-100-33	-	-	-	100	-	-	3.20
65-100-50	60	39	-	-	-	1	3.30
65-100-70	40	60	-	-	-	< 1	3.22
65-100-80	75	24	-	-	-	1	3.30
65-100-90	75	22	-	-	-	3	3.23
65-100-113	-	35	-	30	35	-	3.12
65-100-130	60	40	-	-	-	< 1	3.18
65-100-136A	60	37	-	-	-	3	3.33
65-100-136B	30	25	-	45	-	-	3.33
65-100-140	40	50	-	10	-	-	3.24
65-100-150	60	39	-	-	-	1	3.28
65-100-151A	98	-	-	-	-	2	3.29
65-100-151B	50	-	-	50	0	0	3.29
65-100-158	80	13	-	-	-	7	3.66
65-100-159	70	-	-	30	-	-	3.22
65-100-160	39	60	-	-	-	1	3.36
65-100-161	-	60	-	10	30	-	3.31
65-100-176	75	-	-	23	-	2	3.26
65-100-180	85	10	-	5	-	< 1	3.26
65-100-190	90	10	-	-	-	< 1	3.26
65-100-198	65	20	-	10	-	5	3.30
65-7-10	65	25	-	8	-	2	3.30
65-7-38A	-	-	-	100	-	-	3.20
65-7-45	65	34	-	-	-	1	3.33
65-7-50	-	95	-	3	-	2	3.08
65-7-60	40	10	-	50	-	-	3.30
65-7-70	40	10	-	50	-	-	3.21
65-MALA-25	20	-	-	80	-	-	3.12
65-MALA-30	95	3	-	-	-	2	3.34
66-KAP-6	-	-	-	-	-	-	3.29
67-TES-4	-	-	-	-	-	-	3.11
65-7-80A	60	38	-	-	-	2	3.23
65-7-80B	45	-	-	55	-	-	3.23
65-7-83A	100	-	-	-	-	< 1	3.18
65-7-83B	95	-	-	-	-	5	3.18
65-7-95	-	20	-	30	50	-	2.78
65-7-120	40	25	-	35	-	-	3.22
65-7-139	-	-	-	100	-	-	3.20
65-7-150	15	-	-	35	50	-	3.08
65-7-158	-	-	55	35	10	-	3.12
65-7-160A	40	60	-	-	-	< 1	3.22
65-7-160B	15	-	-	85	-	-	3.22
65-7-170	97	-	-	-	-	3	3.30
65-7-180	60	25	-	13	-	2	3.29
65-7-185	5	-	-	60	35	-	3.13
65-93-30	50	49	-	-	-	1	3.27
65-93-39	55	-	-	40	4	1	3.32
65-93-50	75	22	-	-	-	3	3.34
65-93-60	96	-	-	-	-	4	3.32
65-93-90	40	60	-	-	-	< 1	3.37
65-93-160A	35	-	-	35	30	-	2.92
65-93-160B	20	-	-	30	50	-	2.92
65-93-180	75	25	-	-	-	< 1	3.24
65-93-190	70	20	-	8	-	2	3.31
65-AAMA-10	65	-	-	15	20	-	3.20
65-AAMA-30A	25	75	-	-	-	-	3.01
65-AAMA-40	30	40	-	30	-	-	3.22
65-AAMA-60	30	35	-	35	-	-	3.30
65-AAMA-72	39	60	-	-	-	1	3.30
65-AAMA-90	50	30	-	20	-	-	3.30

* $(\frac{gm}{cm^3})$

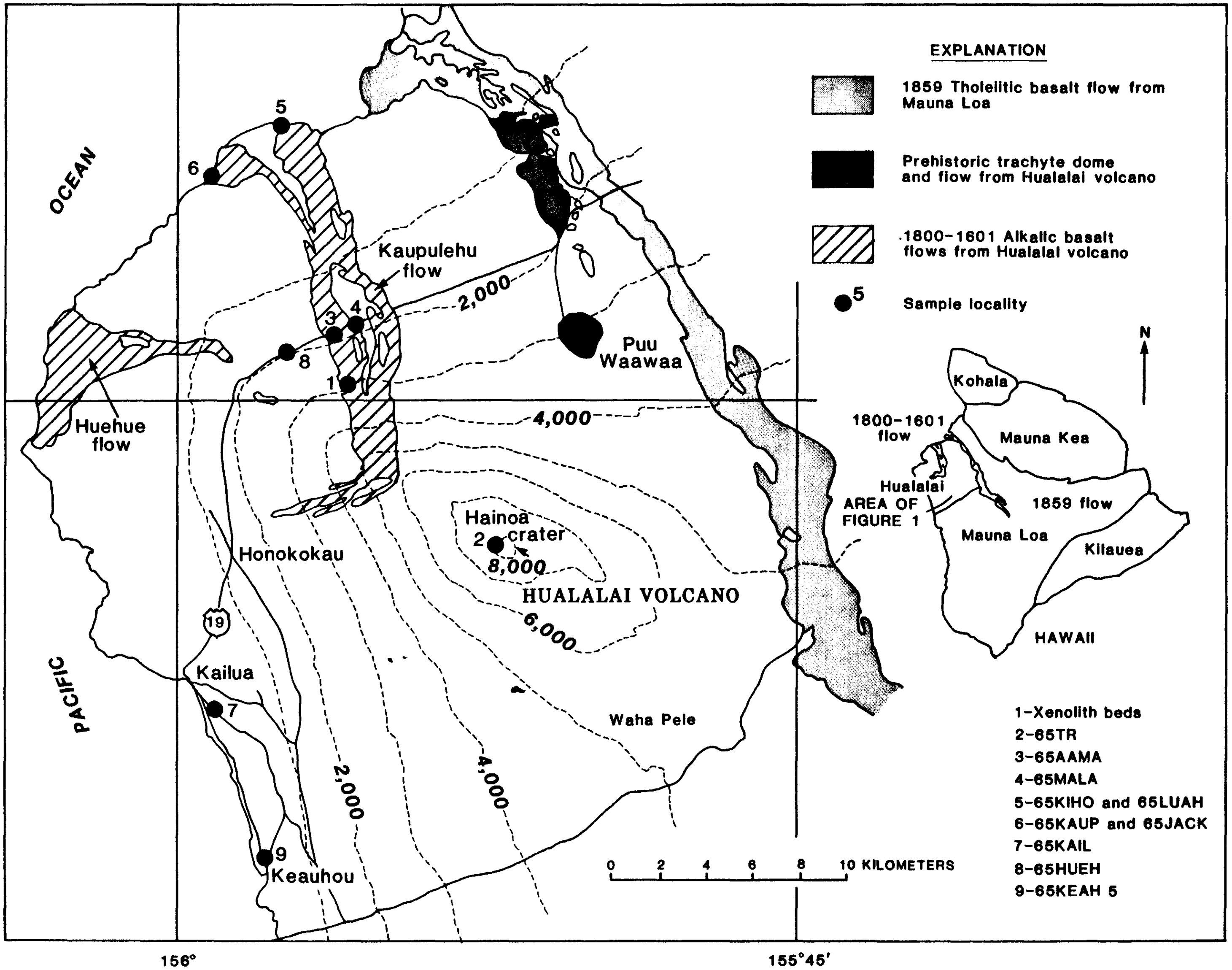


Figure 1. Simplified geologic map of Hualalai volcano showing the locations where xenolith counts were done. The nodule beds locality of the 1801 Kaupulehu flow is shown in Figure 2. The inset shows the location of Hualalai volcano on the island of Hawaii.

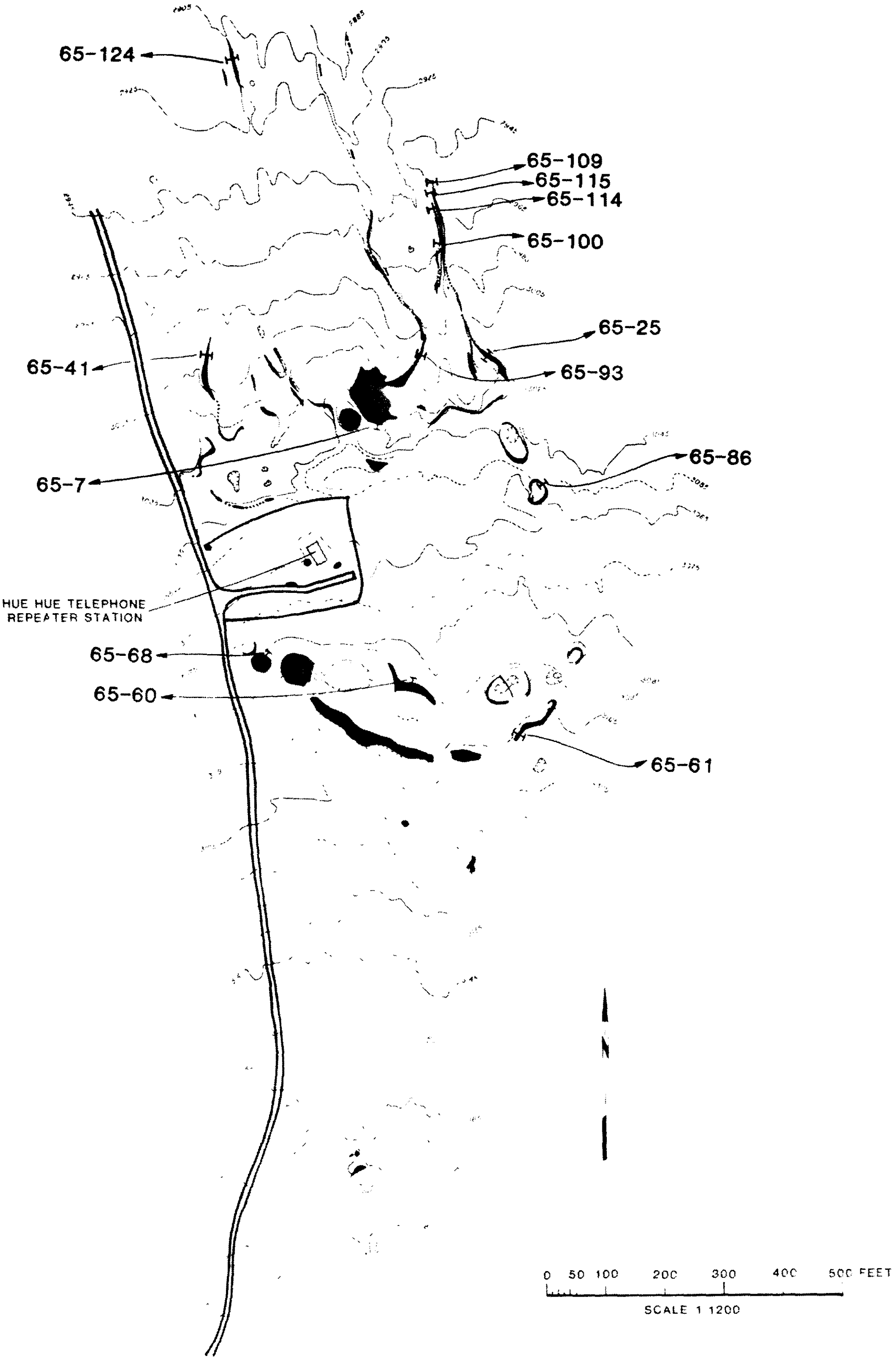


Figure 2. Simplified map of the 1801 Kaupulehu flow nodule beds (after Jackson and Clague, 1981) showing the xenolith beds in black and the locations of the counts (Table 1). The Hue Hue telephone repeater station is located at 19°45'20", 155°55'40"W and the contours are in feet.

Figure 3. (parts a to w). Modal mineralogy plots for each of the xenolith counts. The xenolith count identification and number of xenoliths counted are shown in the lower left corner. The insets are expanded portions of the modal plots shown by the stippled pattern. Xenoliths that contain orthopyroxene (opx) or quartz (qtz) are listed separately. Xenoliths that contain olivine (ol), clinopyroxene (cpx), plagioclase (pc) and chromite (chr) are plotted in the ol-cpx-pc portion of the diagram with a ▲ symbol and the amount of chr is listed in the lower right corner.

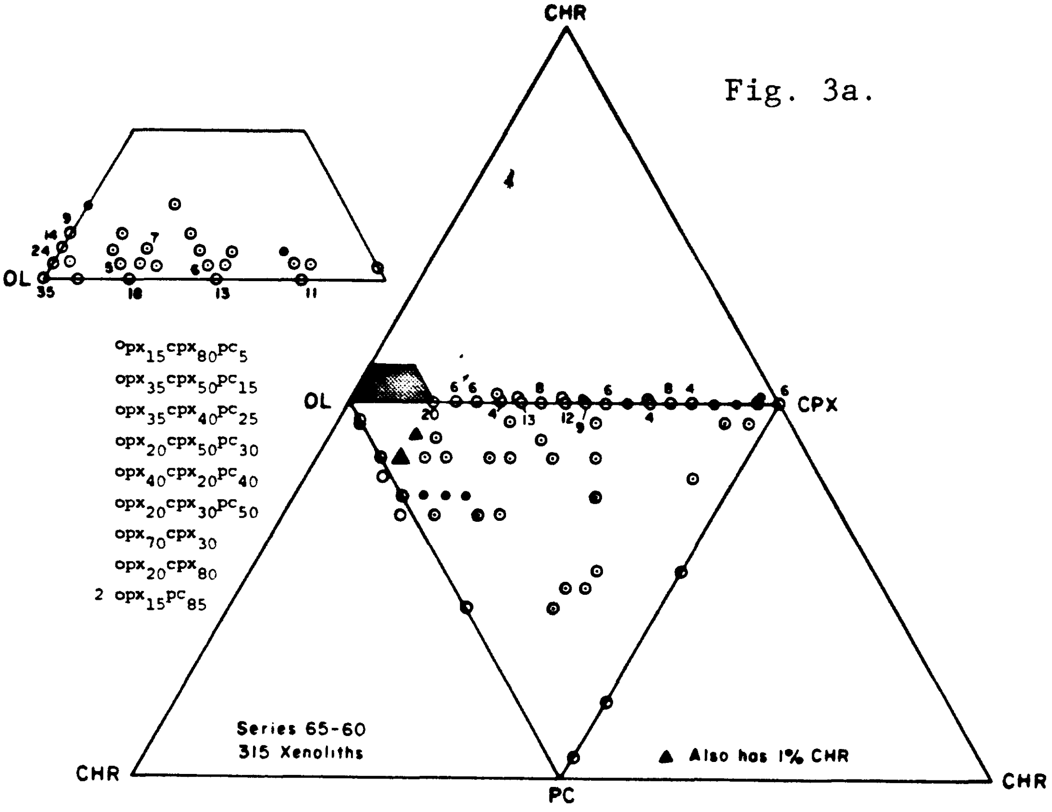


Fig. 3a.

Fig. 3b.

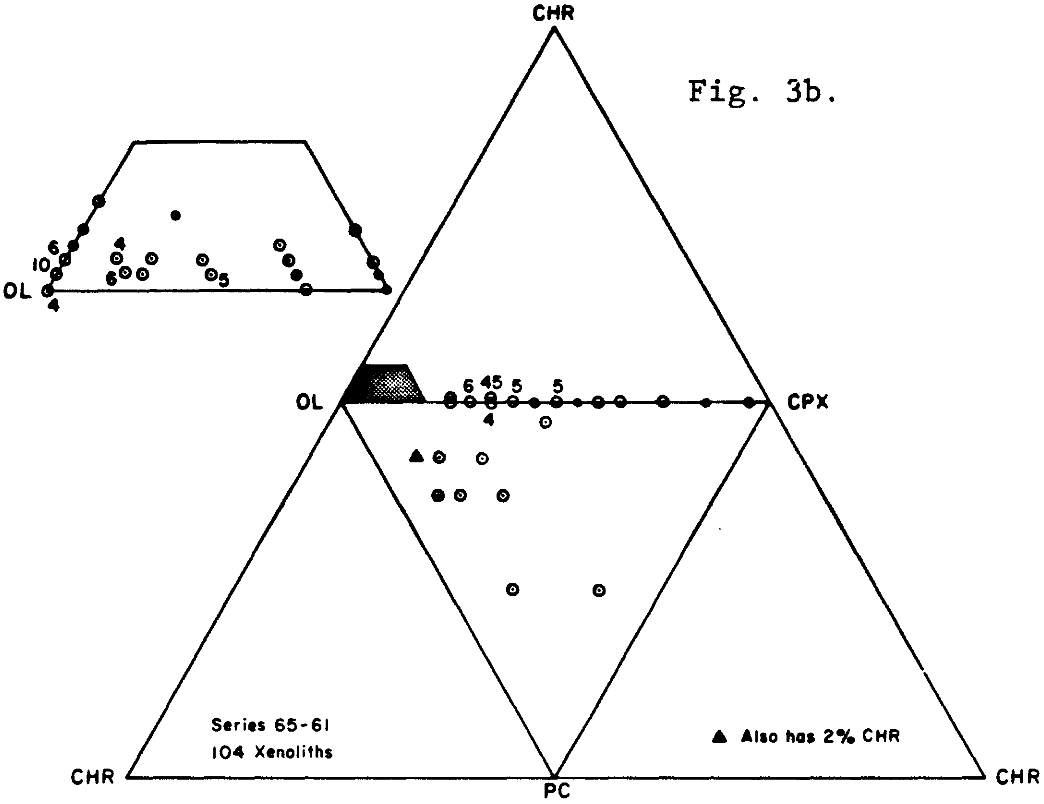
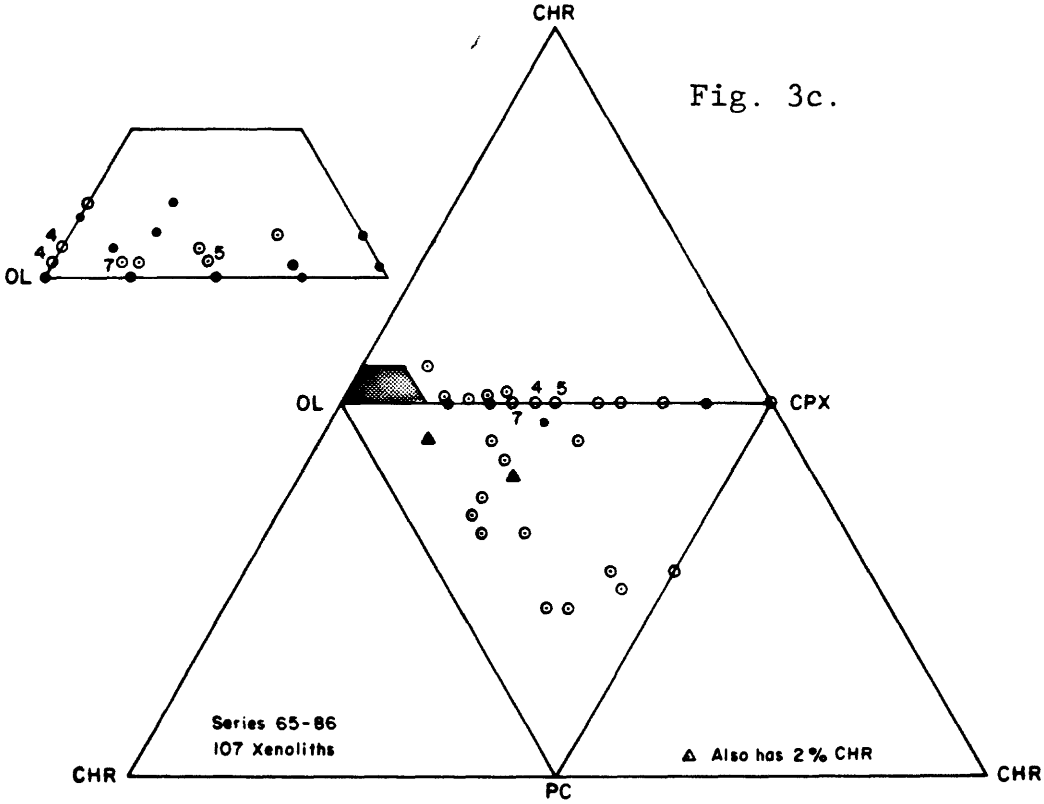

CHR
OL
CPX
CHR
PC
CHR
6
10
OL
4
4
6
5
6 45 5 5
4
Series 65-61
104 Xenoliths
▲ Also has 2% CHR

Fig. 3c.


CHR
OL
CPX
CHR
PC
CHR
4
4
OL
7
5
4 5
7
Series 65-86
107 Xenoliths
△ Also has 2% CHR

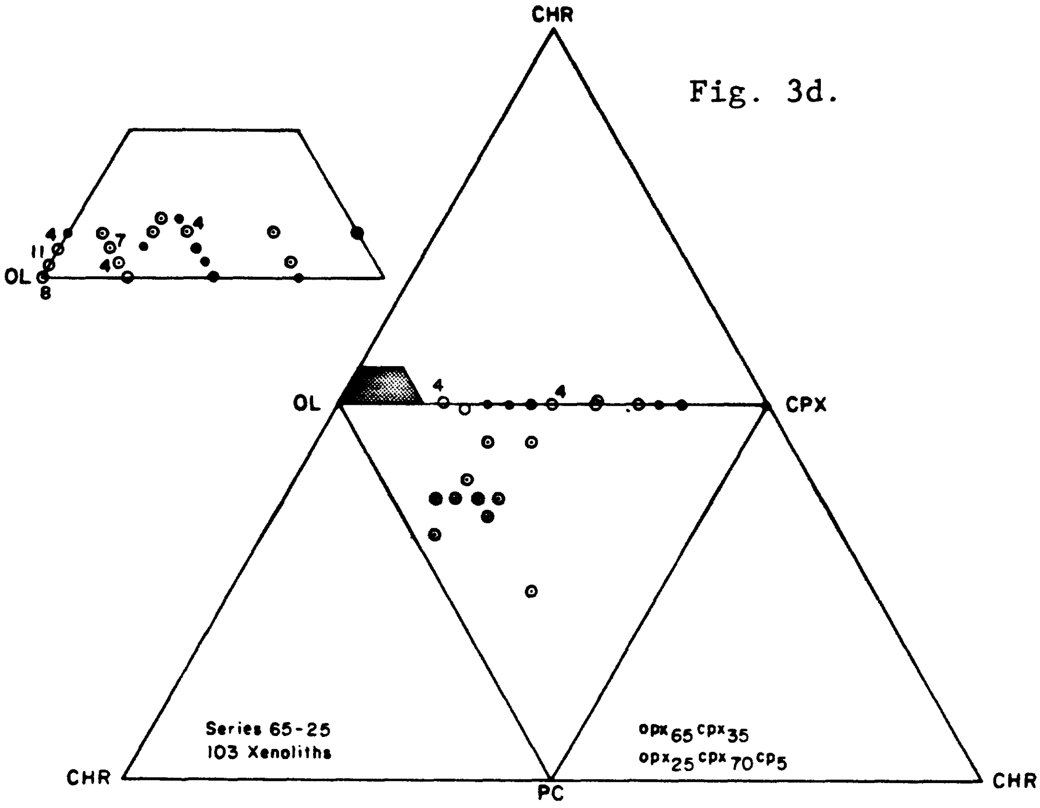


Fig. 3d.

CHR
OL
CPX
CHR
PC
CHR
OL
4
11
8
7
4
4
4
4
Series 65-25
103 Xenoliths
opx$_{65}$cpx$_{35}$
opx$_{25}$cpx$_{70}$cp$_{5}$

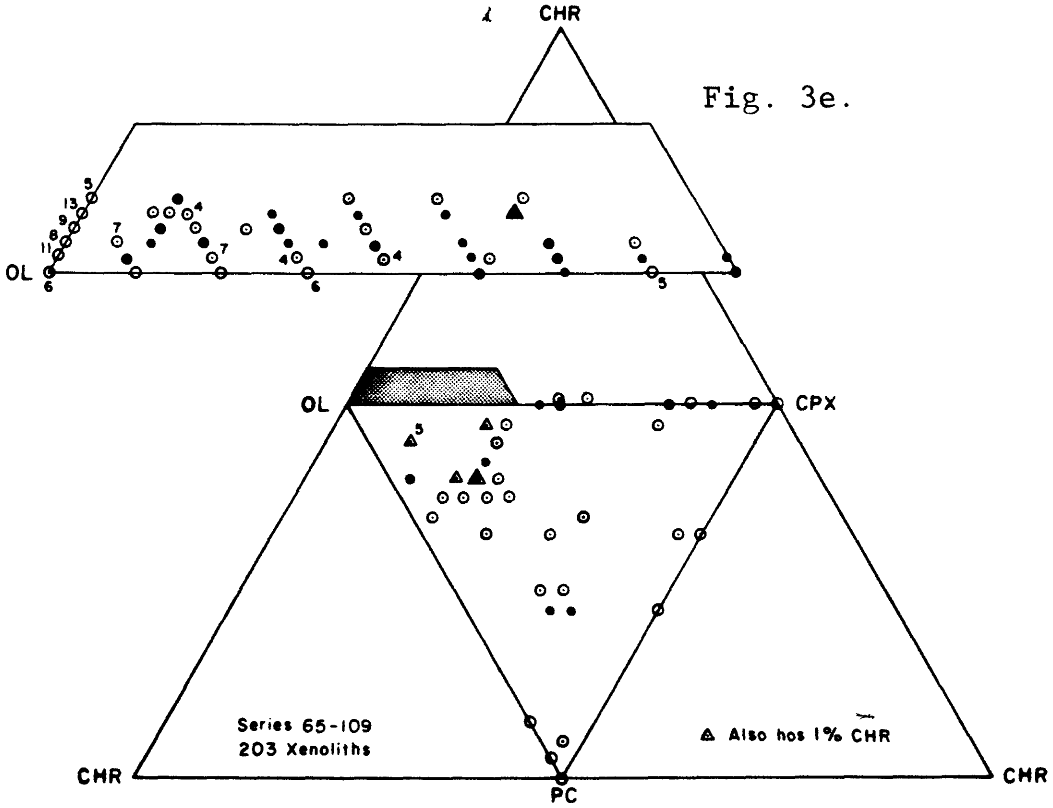


Fig. 3e.

CHR
OL
5
13
9
8
11
6
7
4
7
4
6
4
5
OL
CPX
5
CHR
PC
CHR
Series 65-109
203 Xenoliths
▲ Also has 1% CHR

Fig. 3f.

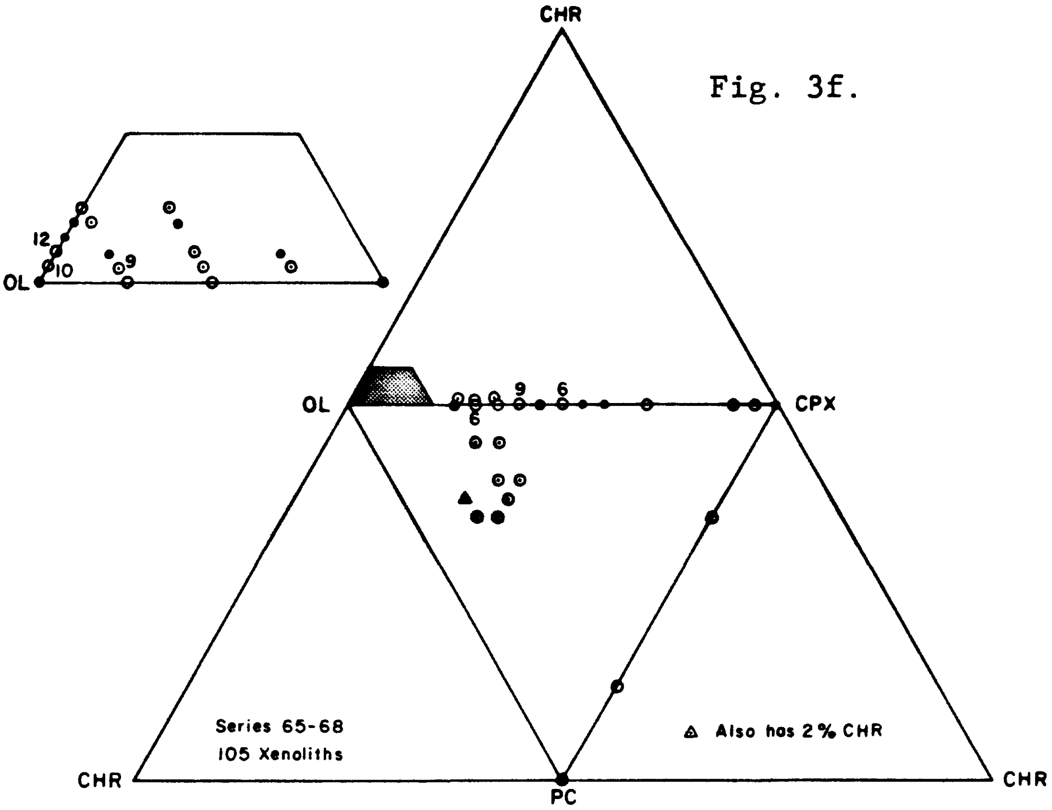
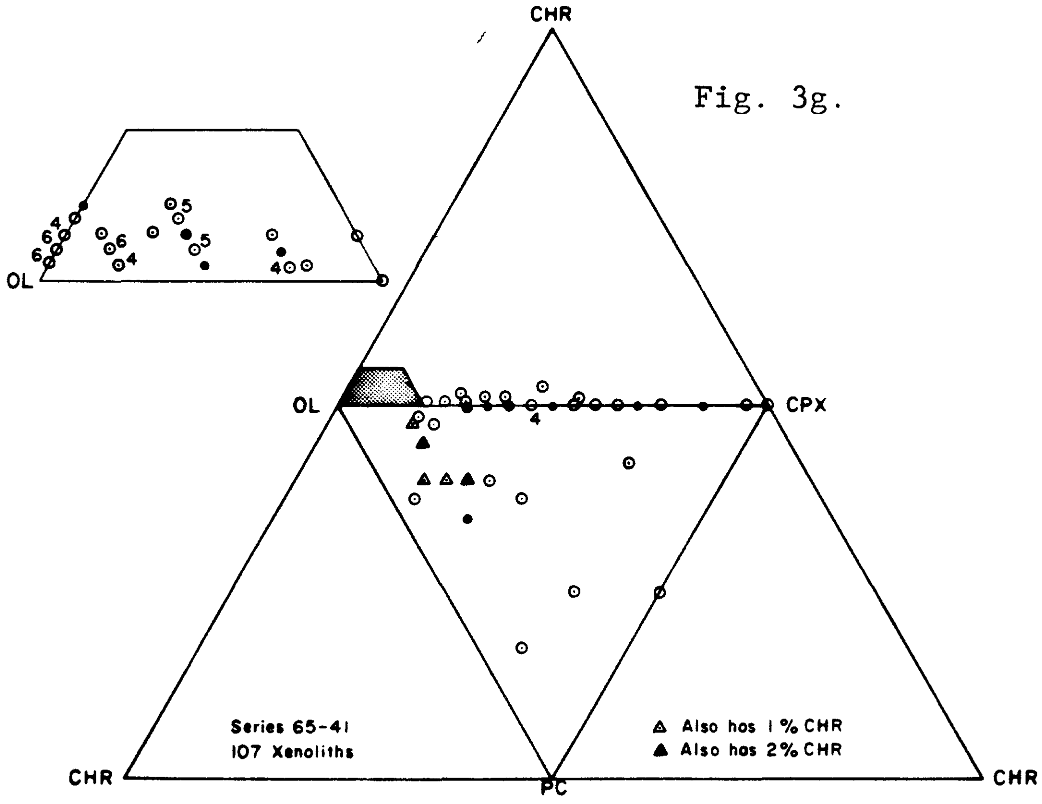

CHR
OL
12
10
9
6
9
6
CPX
CHR
PC
CHR
Series 65-68
105 Xenoliths
△ Also has 2% CHR

Fig. 3g.


CHR
OL
4
6
6
6
4
5
5
4
CPX
4
CHR
PC
CHR
Series 65-41
107 Xenoliths
△ Also has 1% CHR
▲ Also has 2% CHR

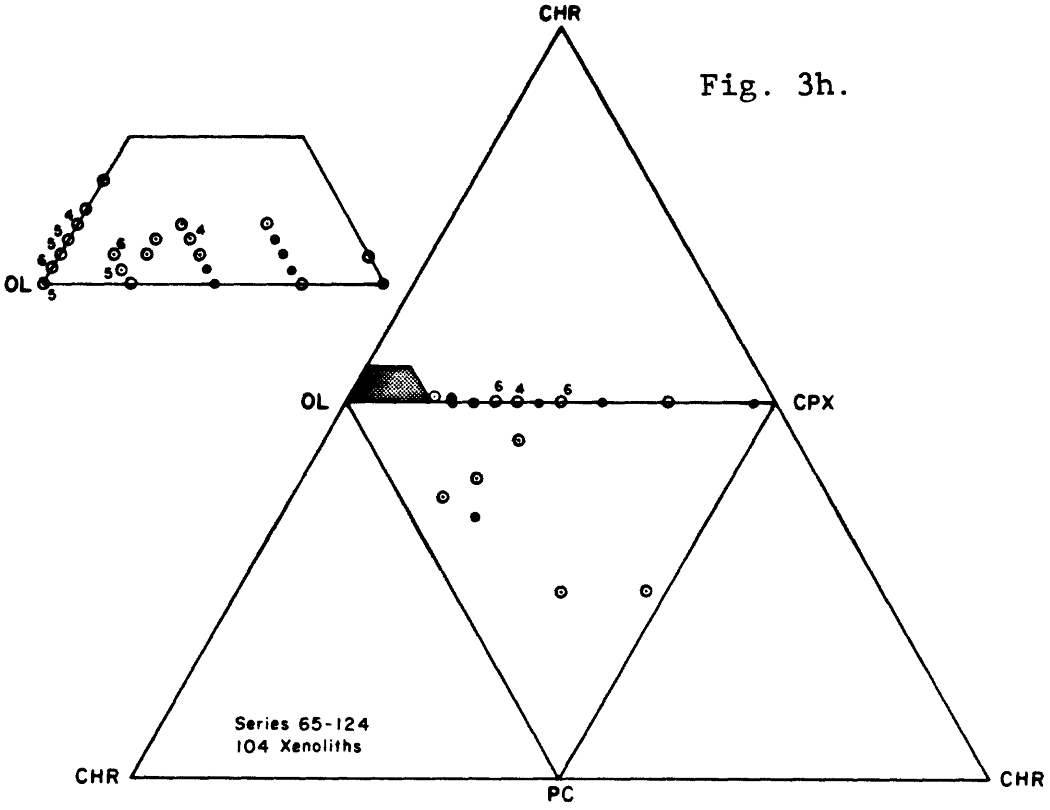

CHR
OL
CPX
CHR
PC
CHR
Series 65-124
104 Xenoliths

Fig. 3h.

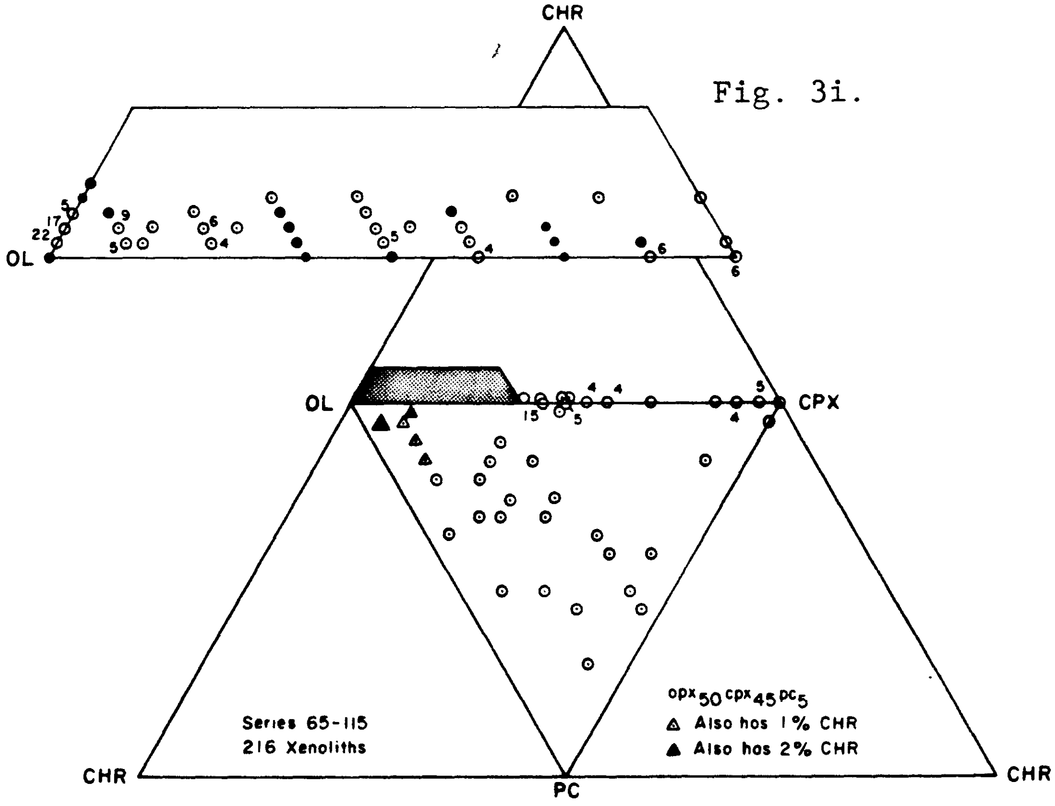
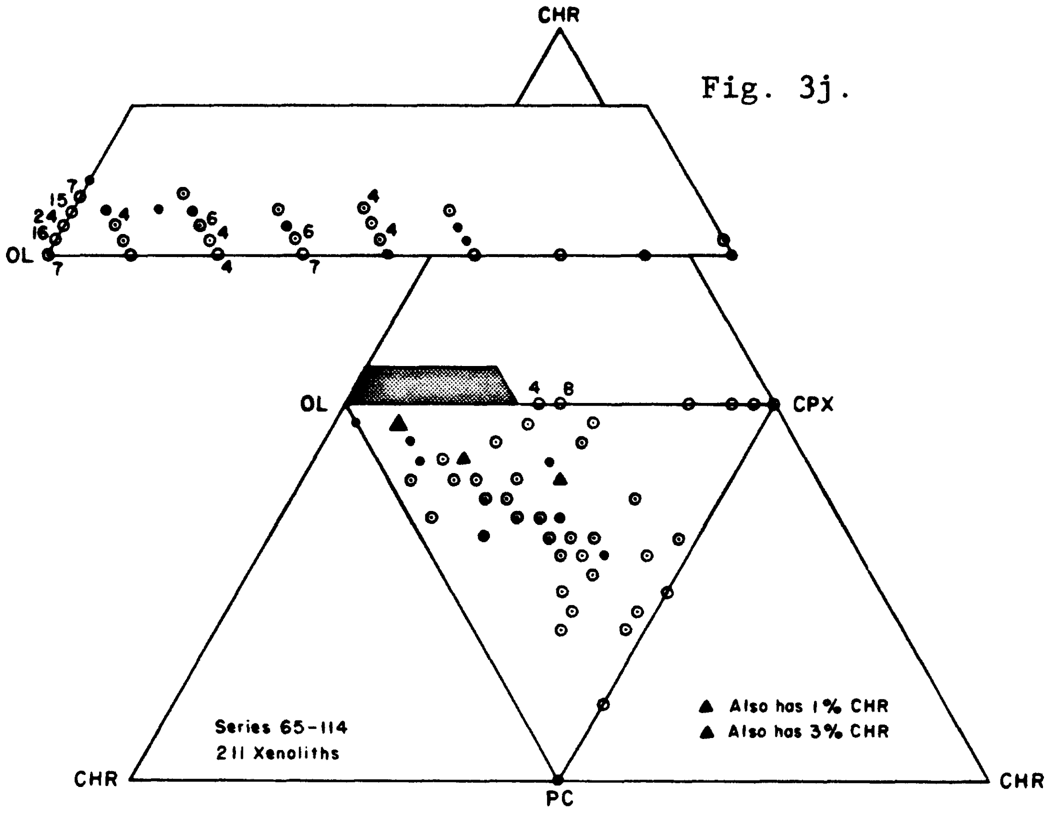
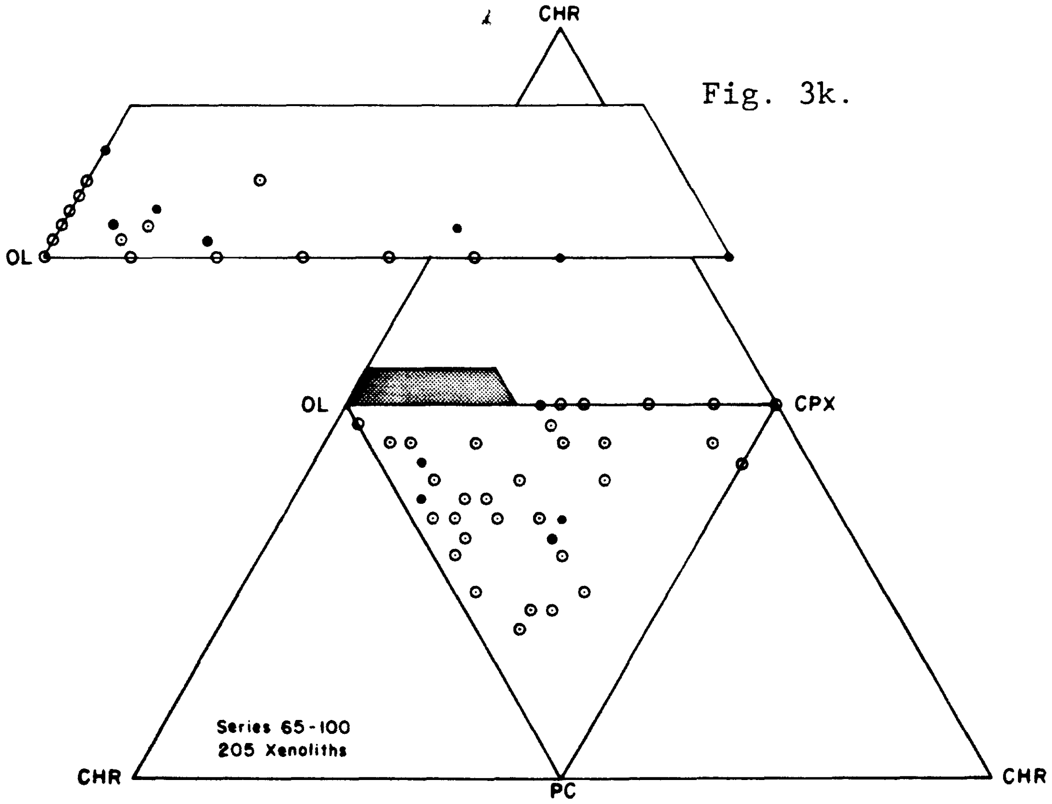

CHR
OL
CPX
CHR
PC
CHR
Series 65-115
216 Xenoliths
opx50 cpx45 pc5
△ Also has 1% CHR
▲ Also has 2% CHR

Fig. 3i.



CHR
OL
7
15
24
16
7
4
6
4
4
7
4
6
4
OL
4
8
CPX
Series 65-114
211 Xenoliths
▲ Also has 1% CHR
▲ Also has 3% CHR
CHR
PC
CHR

Fig. 3j.



CHR
OL
OL
CPX
Series 65-100
205 Xenoliths
CHR
PC
CHR

Fig. 3k.

Fig. 3l.

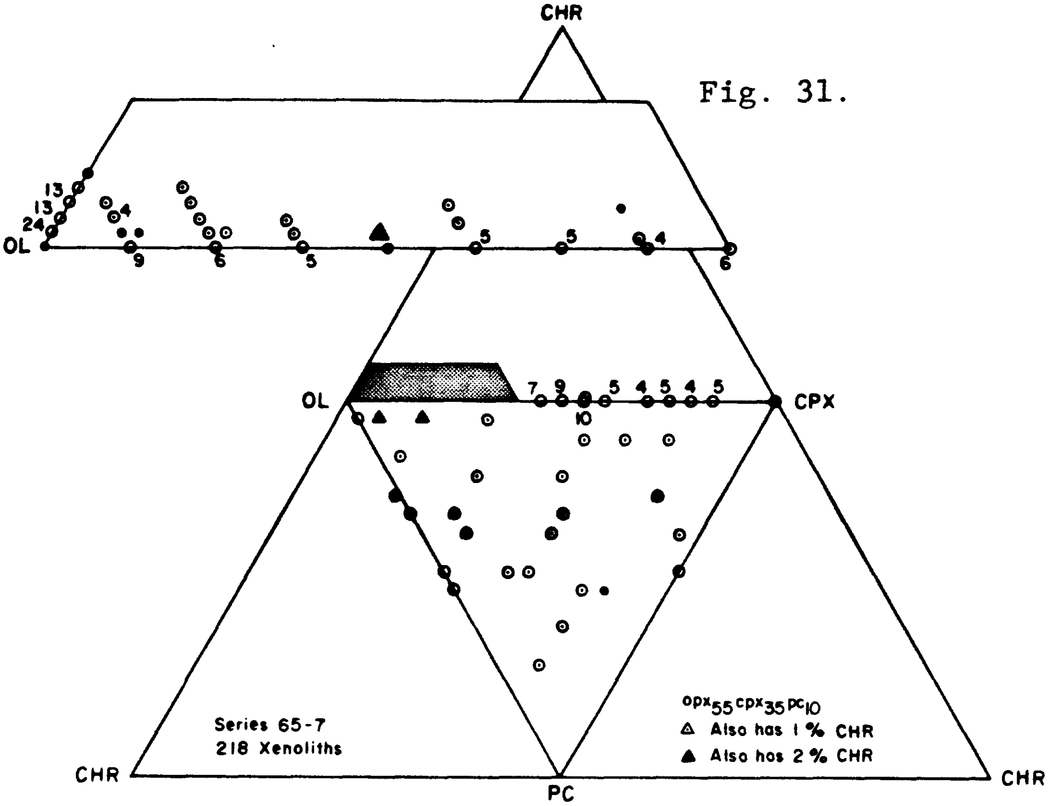
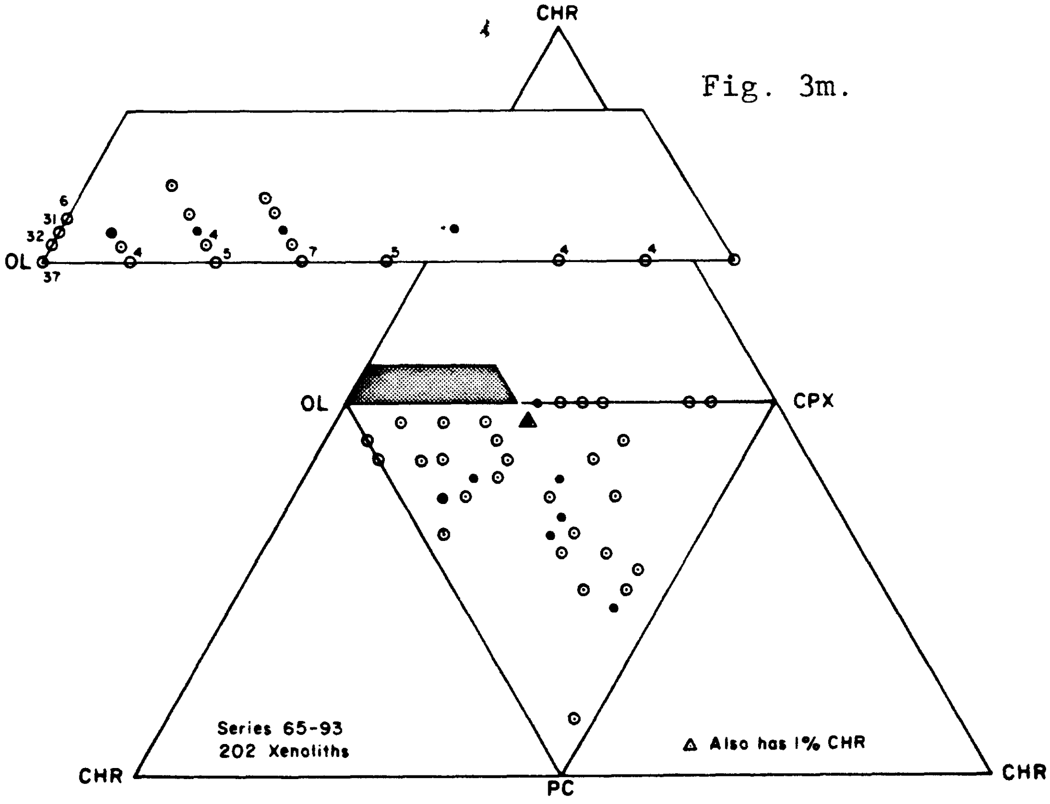

CHR
13
13
24
OL
4
9
6
5
5
5
4
6
7
9
5
4
5
4
5
OL
CPX
10
Series 65-7
218 Xenoliths
$opx_{55}cpx_{35}pc_{10}$
△ Also has 1 % CHR
▲ Also has 2 % CHR
CHR
PC
CHR

Fig. 3m.


CHR
6
31
32
OL
37
4
4
5
7
5
4
4
OL
CPX
Series 65-93
202 Xenoliths
△ Also has 1% CHR
CHR
PC
CHR

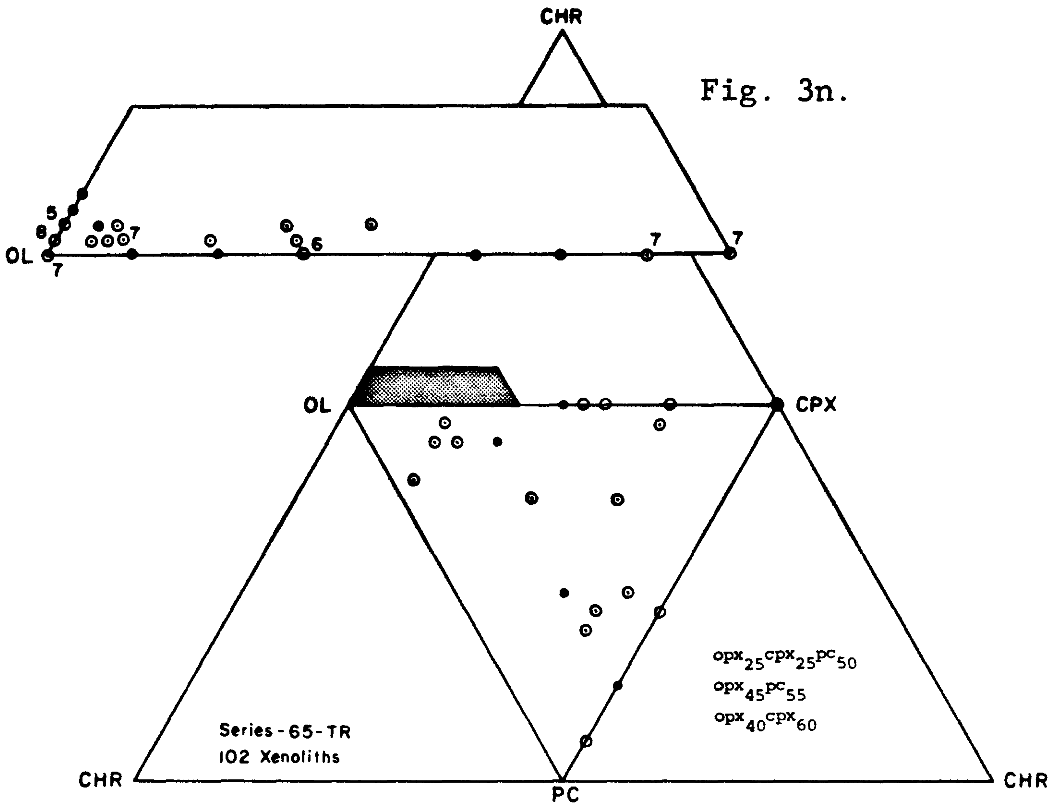


Fig. 3n.

CHR
5
8
7
6
OL
7
7
7
OL
CPX
opx25cpx25pc50
opx45pc55
opx40cpx60
Series-65-TR
102 Xenoliths
CHR
PC
CHR

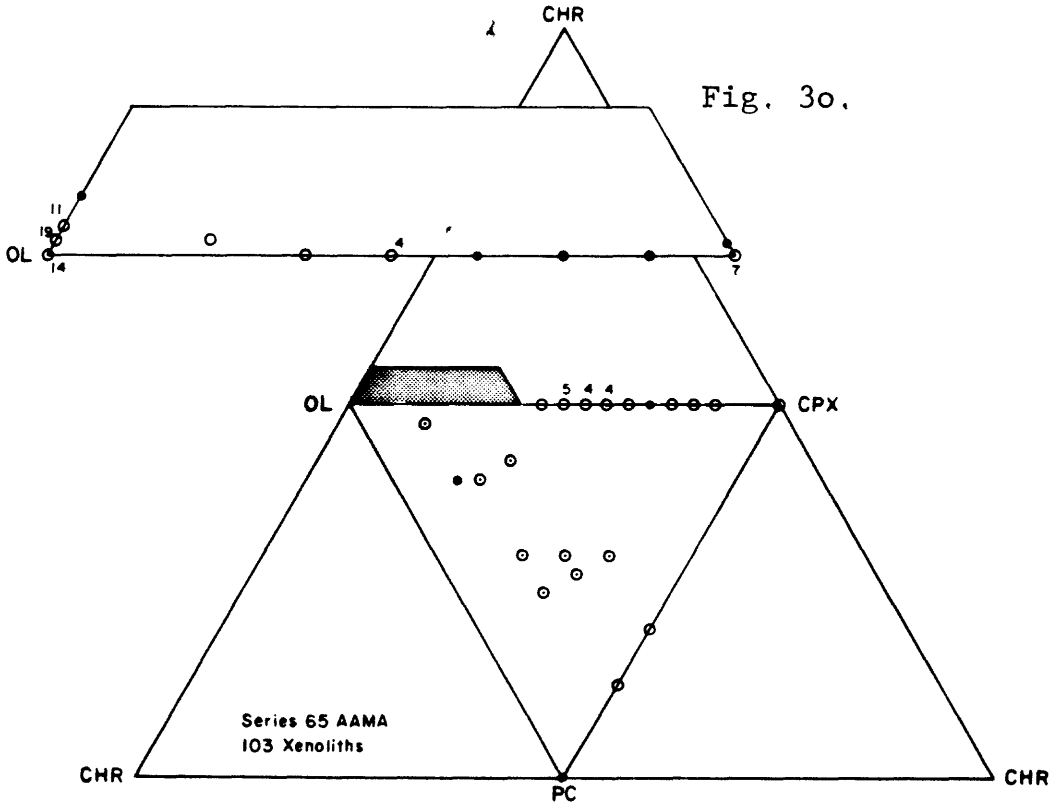


Fig. 3o.

CHR
11
19
OL
14
4
7
5 4 4
OL
CPX
Series 65 AAMA
103 Xenoliths
CHR
PC
CHR

Fig. 3p.

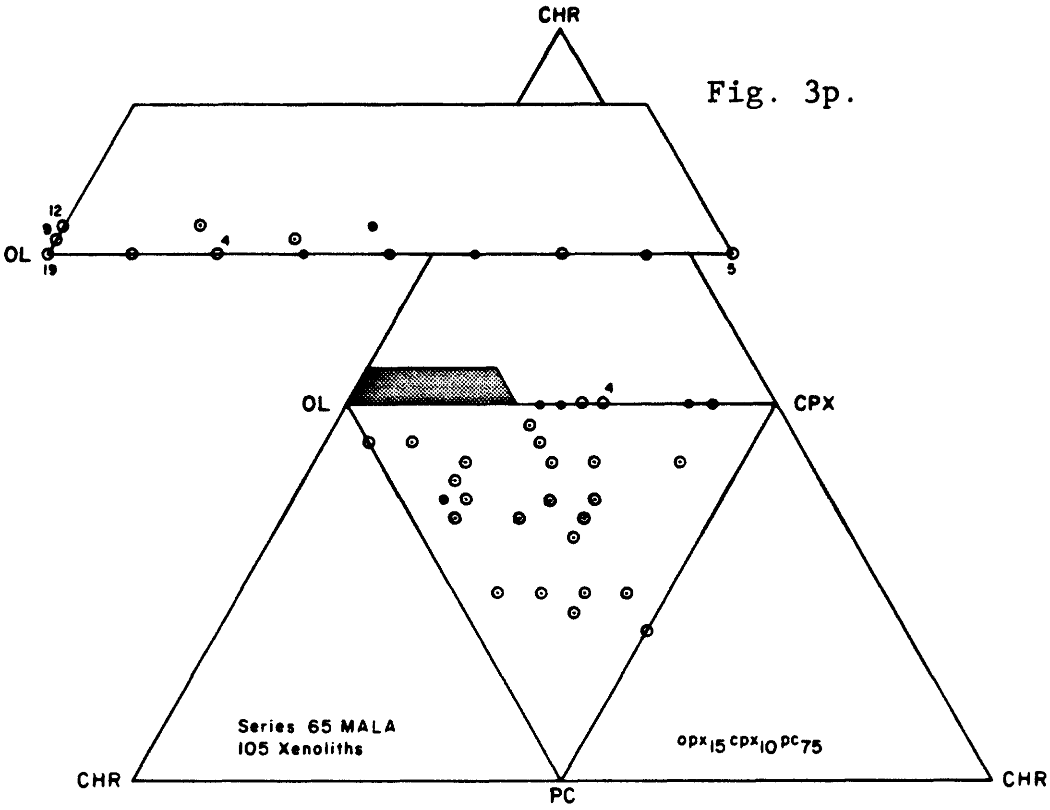
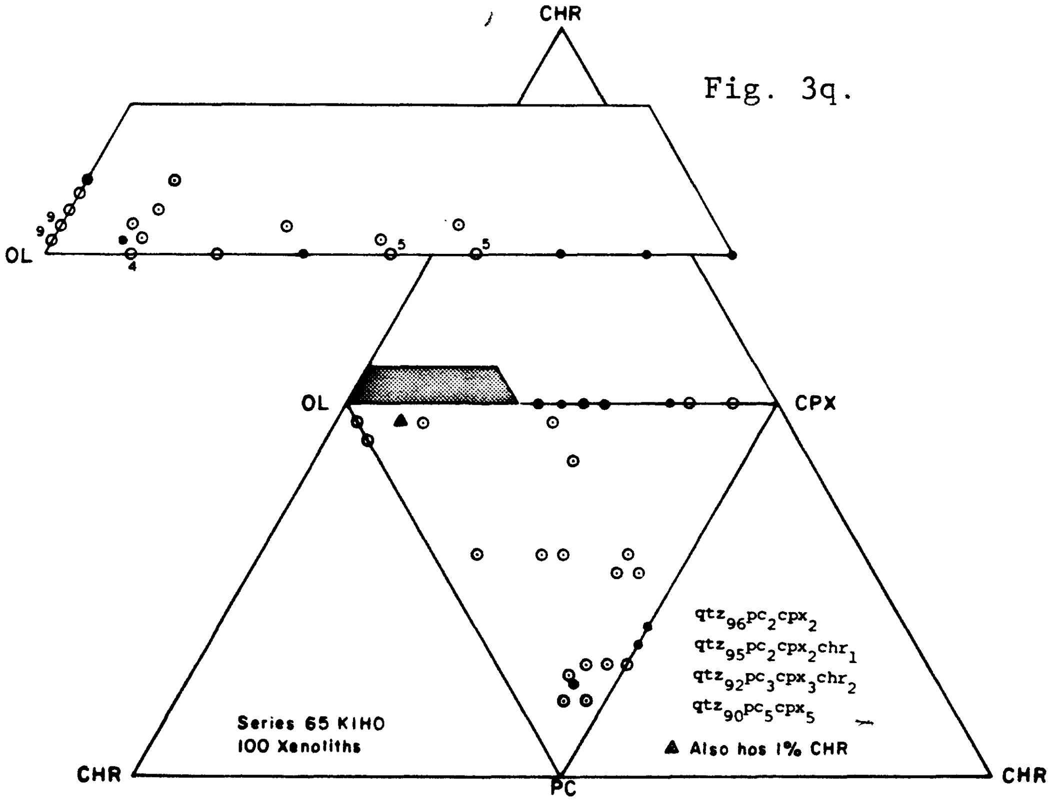

CHR
OL
12
9
19
4
5
OL
4
CPX
Series 65 MALA
105 Xenoliths
$opx_{15}cpx_{10}pc_{75}$
CHR
PC
CHR

Fig. 3q.


CHR
OL
9
9
4
5
5
OL
CPX
$qtz_{96}pc_2cpx_2$
$qtz_{95}pc_2cpx_2chr_1$
$qtz_{92}pc_3cpx_3chr_2$
$qtz_{90}pc_5cpx_5$
▲ Also has 1% CHR
Series 65 KIHO
100 Xenoliths
CHR
PC
CHR

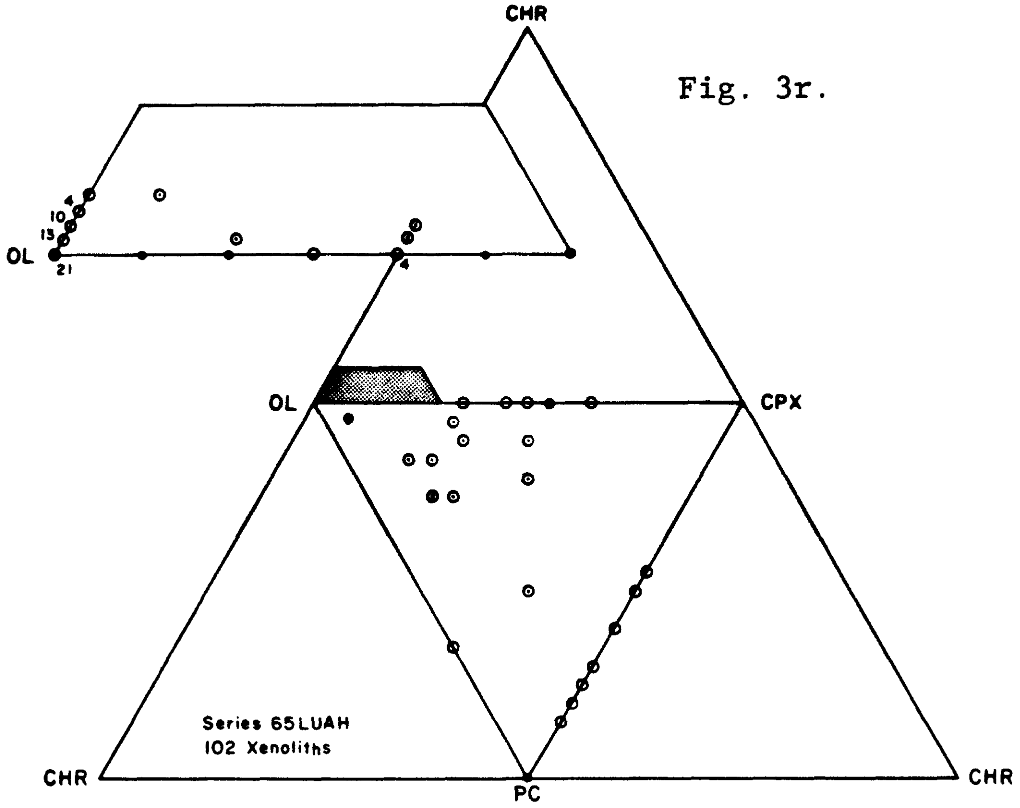


Fig. 3r.

CHR
4
10
13
OL
21
4
OL
CPX
Series 65LUAH
102 Xenoliths
CHR
PC
CHR

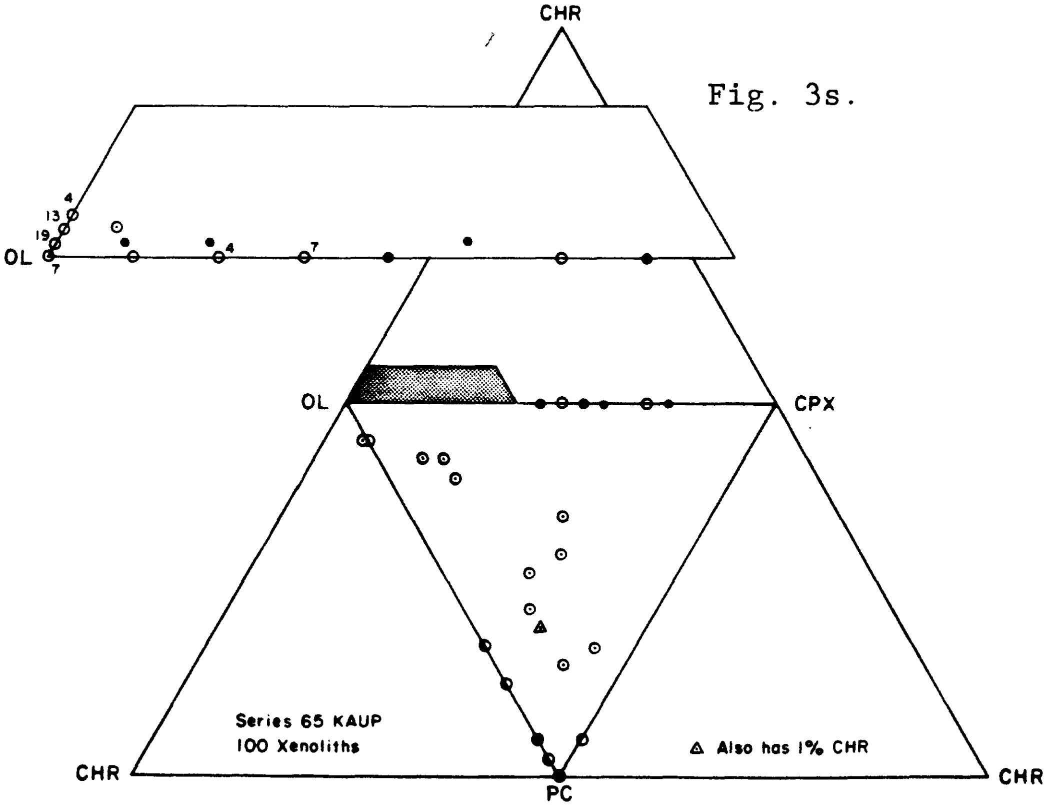


Fig. 3s.

CHR
4
13
19
OL
7
4
7
OL
CPX
Series 65 KAUP
100 Xenoliths
△ Also has 1% CHR
CHR
PC
CHR

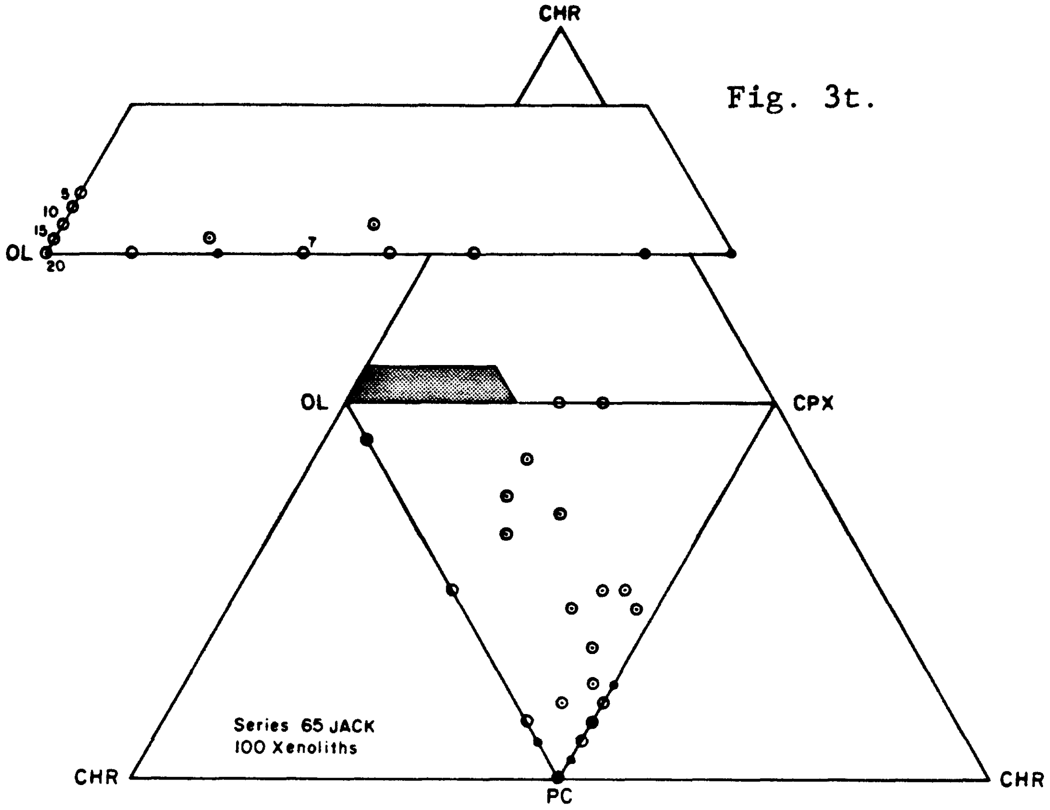

CHR
5
10
15
OL
20
7
OL
CPX
Series 65 JACK
100 Xenoliths
CHR
PC
CHR

Fig. 3t.

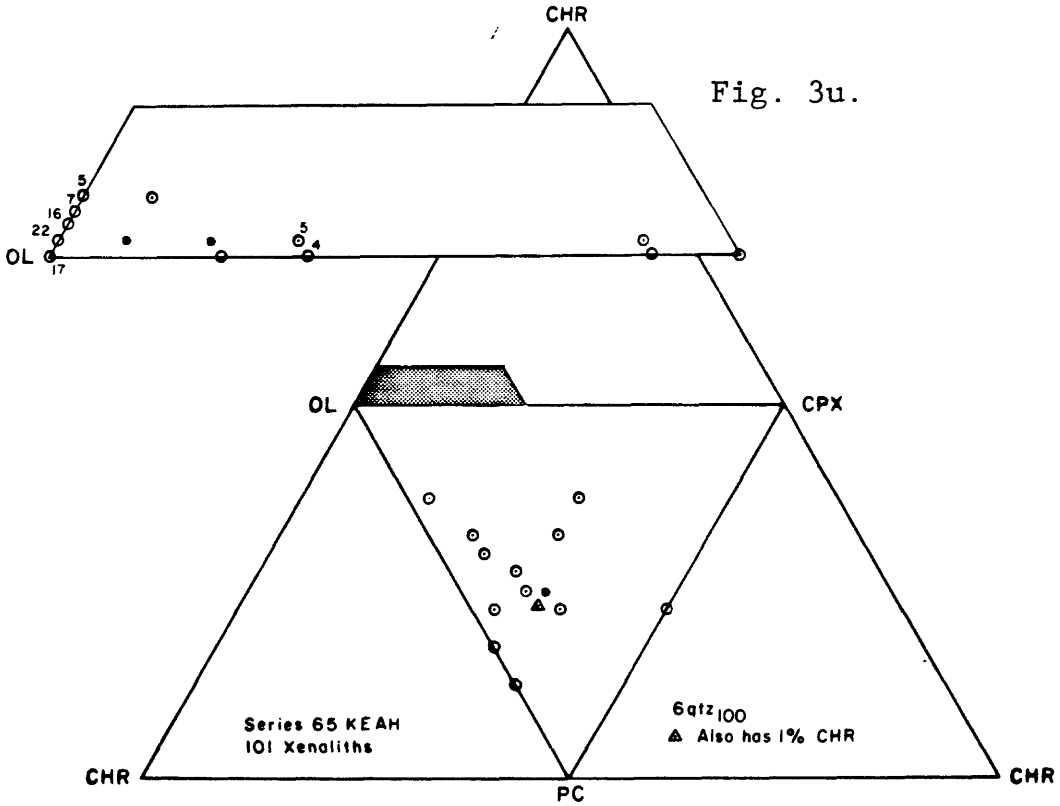

CHR
5
7
16
22
OL
17
5
4
OL
CPX
Series 65 KEAH
101 Xenoliths
6qtz 100
▲ Also has 1% CHR
CHR
PC
CHR

Fig. 3u.

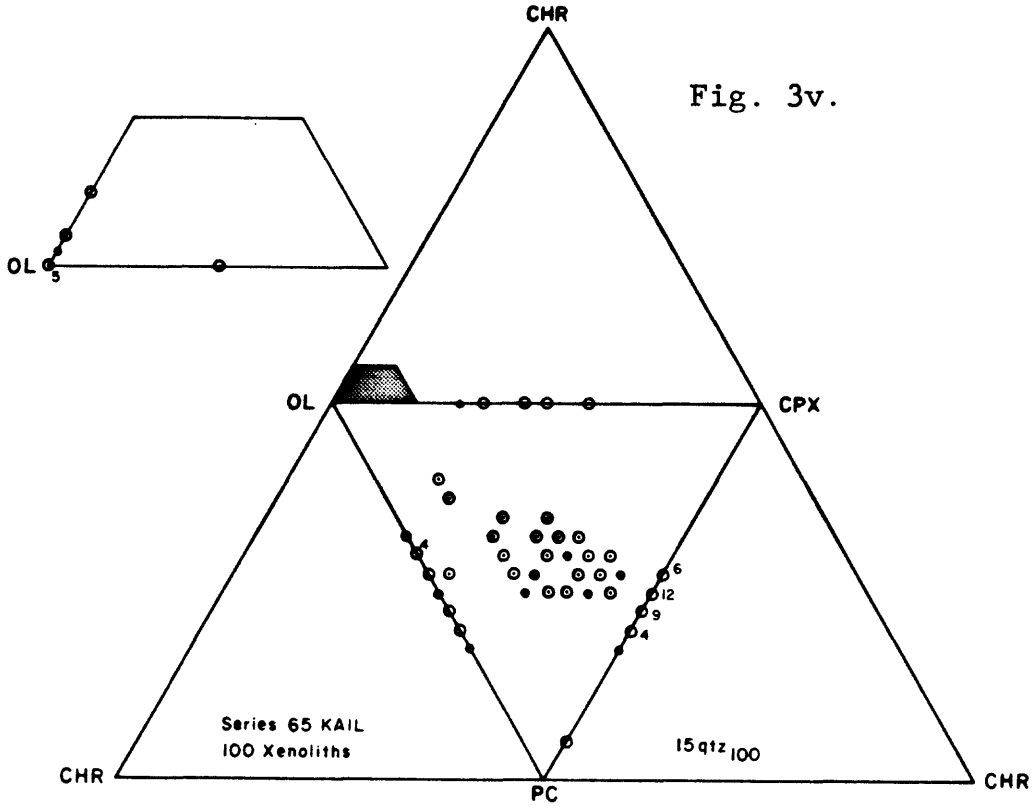

CHR
OL
5
OL
CPX
4
6
12
9
4
Series 65 KAIL
100 Xenoliths
15qtz 100
CHR
PC
CHR

Fig. 3v.

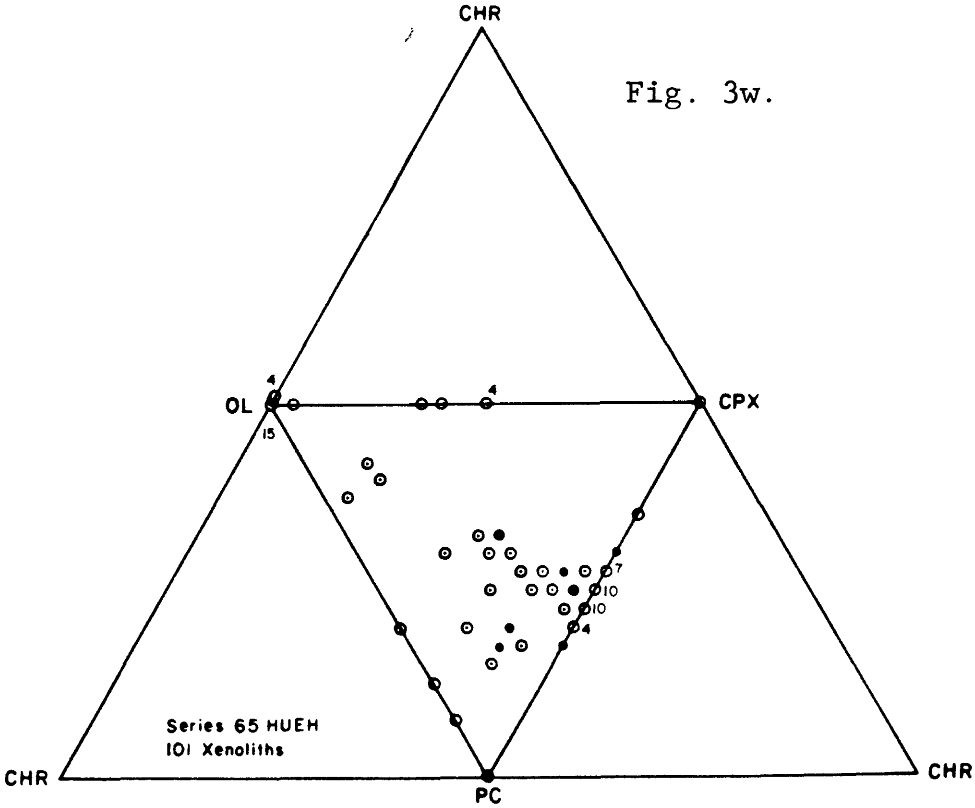

CHR
4
OL
15
4
CPX
7
10
10
4
Series 65 HUEH
101 Xenoliths
CHR
PC
CHR

Fig. 3w.