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THE PETROLOGY OF LAVAS AND PYROCLASTICS FROM SOME NEW GUINEA VOLCANOES

by

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SUMMARY

The report describes the petrography and chemical analyses of samples of lavas and pyroclastics from some of the volcanic islands along the north coast of New Guinea, and from Fergusson and Dobu Islands, immediately east of Papua.

The volcanics from the north coast islands are hypersthene and/or olivine-bearing basalt, basaltic andesite, and andesite. Most of them are characterized by being moderately to strongly porphyritic. The phenocrysts consist of calcic plagioclase and diopsidic augite, together with hypersthene in some, and olivine in others. They are enclosed in a fine-grained groundmass composed of plagioclase, clinopyroxene, and iron oxide; in most, some rock glass is present. Orthopyroxene was observed in a few samples.

The chemical analyses of the north coast rocks are compared with those of samples from Mounts Lamington, Victory, and Yelia. All are found to belong to the calc-alkaline kindred.

The samples collected from Fergusson and Dobu Islands are mostly peralkaline rhyolites and obsidians. They contain a few phenocrysts of anorthoclase and aegirine. In the rhyolites, the groundmass consists of alkali feldspar, quartz, aegirine, riebeckite, and probable cossyrite. The obsidians have a groundmass composed almost entirely of glass. Chemically, the rocks are peralkaline; it is not known to which kindred the lavas belong. However, at Dobu Island, a specimen of andesite was collected and described; in general appearance, this rock is similar to the andesites from the north coast islands, suggesting that the peralkaline volcanics are related to the calc-alkaline rocks.

INTRODUCTION

During 1963, a number of volcanic rock samples were submitted by G.A. Taylor to the laboratory for petrological and chemical investigation. This report summarizes their petrography and discusses the chemical analyses.

The samples were collected from Blup, Blup, Kadovar, Manam, Karkar, Bogabag, and Long Islands, along the north coast of New Guinea, and from Fergusson and Dobu Islands, immediately east of Papua. The general locations are shown in the sketch map in Plate I.

The report should only be regarded as a preliminary petrographic survey of the volcanics, rather a detailed examination. Petrologically speaking, the New Guinea volcanic province is virtually untouched; it could provide an admirable field for petrological research.

BLUP BLUP ISLAND

PETROGRAPHY

One specimen, R.15617 (field number P.1025) from Blup Blup Island was examined. This was collected from a village near the south anchorage, and is an olivine-bearing hypersthene-augite hyaloandesite. The specimen is moderately to strongly porphyritic, the phenocrysts forming 25% of the rock. They range up to 3 mm. in diameter, although their average size is about 1 mm. Some phenocrysts are clustered into monomineralic groups; other clusters are composed of somewhat intergrown plagioclase and pyroxene, and are possibly cognate xenolithic inclusions.

Plagioclase phenocrysts are tabular to sub-tabular, and are slightly altered to clay minerals. The crystals show oscillatory zoning, and commonly have a large calcic core (compositions measured on a universal stage range between An_{78} and An_{81}), surrounded by a fairly narrow margin composed of labradorite. Diopsidic augite phenocrysts are pale green, commonly embayed crystals, with 2E(+) measuring between about 58° on crystal cores to 53° on crystal margins. Hypersthene is prismatic, slightly embayed, and is pleochroic from colourless to pale pink; 2E(-) measures 74°. Olivine phenocrysts are not common in the rock; they form colourless crystals that show embayment and which, in places, are partly replaced by clinopyroxene; where this has taken place, a thin zone of black iron oxide is present between olivine and the pyroxene. A few embayed black iron oxide phenocrysts are present.

The groundmass consists of fine-grained, roughly flow-oriented laths of plagioclase, measuring about 0.03 mm. by 0.005 mm., prismatic to granular pale green clinopyroxene, about 0.004 mm. across, and octahedral black iron oxide crystals that measure about 0.002 mm. in diameter. All the grains are enclosed in a pale brown glass that has a very low refractive index.

A modal analysis of the rock is :-
groundmass: 75%; plagioclase: 18%; diopsidic augite: 4%; Hypersthene: 1%; olivine: trace; black iron oxide: 2%.
A visual estimate of the percentages of minerals and glass in the groundmass is :- plagioclase: 35, clinopyroxene: 5, black iron oxide: less than 1, and glass: 60.

KADOVAR ISLAND

PETROGRAPHY

The three specimens examined consist of hypersthene-augite hyaloandesite. R.15614 (field number P.1026) was collected from the dome summit of Kadovar; R.15615 (P.1027) is from the anchorage on the north side of the island; R.15616 was collected from the east coast.

Texturally and mineralogically, the three specimens are similar to each other. They are very strongly porphyritic, the phenocrysts forming about 60% of the rock in each of the specimens. The phenocrysts range up to about 1.5 mm. diameter. Plagioclase forms tabular phenocrysts showing oscillatory zoning, it has a composition of An_{80} to An_{85}, zoned to labradorite on crystal margins. Diopsidic augite phenocrysts occur as prismatic, very slightly embayed, pale brownish-green crystals. In some places they form clusters of intergrown crystals that sometimes include hypersthene. Diopsidic augite in R. 15614, has 2E(+) of 51°. Hypersthene forms prismatic crystals, pleochroic from pale brownish-green to pale pinkish-brown; the colour deepens towards crystal margins. In R. 15614, hypersthene has 2E(-) of 77° to 80°. Hypersthene phenocrysts are commonly surrounded by a thin rim composed of fine clinopyroxene grains.

The groundmass, in R. 15614, consists of minute plagioclase microlites (0.005 by 0.002 mm. in size), acicular prisms of pyroxene (0.009 by 0.001 mm.), and grains of black iron oxide, 0.005 mm. diameter, all enclosed by an abundant colourless glass matrix. The groundmass in specimens R.15615 and R.15616 has an average grainsize of about 0.01 mm., and less than 20% is composed of colourless glass. The crystals consist of plagioclase laths, clinopyroxene prisms, and octahedral black iron oxide.

A modal analysis of R.15614 is:-
groundmass: 41%, plagioclase: 22%, clinopyroxene: 27%, hypersthene: 6%, and black iron oxide: 4%. A visual estimate of the percentages of minerals in the groundmass of this specimen is :-
plagioclase: 30, pyroxene: 10, black iron oxide: less than 1, and glass:60.

CHEMISTRY

The analysis and C.I.P.W. norm of specimen R.15614 are shown in Table 2; the analysis is plotted on the F.M.A. and Solidification Index diagrams in Plates II, III and IV. Compared with the Blup Blup Island specimen, the analysis has lower Al_2O_3, CaO, and alkalis, and is somewhat richer in total iron and MgO.

CHEMISTRY

A chemical analysis of the specimen described is shown with its C.I.P.W. norm in Table I, and is plotted on the F.M.A. and Solidification diagrams shown on Plates II, III and IV. It will be noticed that in spite of the fact that small amounts of olivine are present in the specimen, the analysis shows the rock to be fairly rich in silica, resulting in 15.3% quartz in the norm. The olivine is an unstable relic; evidence for this are the clinopyroxene reaction rims around olivine crysta crystals.

TABLE I

Analysis		Norm		
SiO_2	58.50		qz	15.30
TiO_2	0.32		or	10.01
Al_2O_3	15.20		ab	20.44
Fe_2O_3	3.40		an	25.58
FeO	4.30	di	wo	4.99
MnO	0.15		en	3.30
MgO	4.60		fs	1.32
CaO	7.70	hy	en	8.20
Na_2O	2.40		fs	3.56
K_2O	1.69		mt	4.87
P_2O_5	0.23		il	0.61
H_2O +	1.48		ap	0.34
H_2O -	0.38		Water	1.86
CO_2	0.01			
Total	100.36			

Specimen R.15617. Olivine-bearing hypersthene-diopside augite hyaloandesite. Collected from a village near the south anchorage of Blup Blup Island.

Analyst: L. Castanelli and R.L. Bruce, A.M.D.L.

TABLE 2

Analysis			Norm	
SiO_2	57.60		qz	15.30
TiO_2	0.31		or	8.34
Al_2O_3	13.50		ab	16.77
Fe_2O_3	4.75		an	23.63
FeO	4.60	di	wo	8.35
MnO	0.16	di	en	5.90
MgO	5.95	di	fs	1.72
CaO	9.00	hy	en	9.00
Na_2O	2.00	hy	fs	2.51
K_2O	1.45		mt	6.96
P_2O_5	0.24		il	0.61
H_2O+	0.33		ap	0.34
H_2O-	0.16		cc	0.05
CO_2	0.02		Water	0.49
Total	100. 07			

Specimen R.15614. Hypersthene-augite hyaloandesite. Collected from the dome summit of Kadovar Island.
Analysts: L. Castanelli and L.R. Bruce, A.M.D.L.

MANAM ISLAND

PETROGRAPHY

This part of the report contains a summary description of the petrography of lava specimens and some ash samples from Manam Island. The specimens examined represent material erupted in early 1957, late 1957 - early 1958, 1960, 1962, and 1964. Some samples of ancient lava flows were also examined. The locations of all the specimens are shown in Tables 3 to 8.

Generally speaking, the ancient and the recent Manam lavas are a rather monotonous series of porphyritic olivine-bearing basalts, basaltic andesites, and andesites. In them, the amount of phenocrystic material present ranges between about 20% and 40%. Phenocrysts commonly range up to about 1 or 2 mm. across, particularly the pyroxenes; the average size of the phenocrysts, however, is about 0.5 mm. The phenocrysts are enclosed by intersertal hyalo-crystalline or holocrystalline groundmasses. In some rocks, slight flow textures can be seen affecting the groundmass; in a few, even the phenocrysts are flow-oriented.

TABLE 3

Ancient Flows, Manam Island

Registered No.	Field No.	Location
R.14717	MO/1	North wall of south-east valley.
R.14718	MO/2	Outside north wall of south-east valley.
R.14774 R.14719 R.14720	MO/3 MO/4 MO/5	Between Waris and Aberia.
R.14721	MO/7	Lower floor of Bokure Channel
R.14722	MO/8	Upper floor of Bokure Channel
R.14753	MO/9	Northern well of north-east valley.
R.14775	MO/10	North-east valley.
R.14776	MO/11	Between Bokure and Kolang.
R.14777	MO/12	Between Borda and Balian
R.14752	MO/13	In channel near Kulugumwa.
R.15639	P.1040	South-west valley.
R.15640	P.1041	South-west valley.
R.15645	P.1046	Upper flow in neck of S.W. Valley.
R.15646	P.1047	Lower flow in neck of S.W. valley.

TABLE 4

Material erupted in January, 1957

Registered No.	Field No.	Location
R.15636	P.1037	Flow, south-east valley.
R.15637	P.1038	Bomb fragment, south-east valley.
R.15638	P.1034	Bomb, south-east valley.
R.15641	P.1042	Nueé boulder, south-west valley.
R.15642	P.1043	Cob boulder, south-west valley.
R.15643	P.1044	Nueé fragment south-west valley.
R.15644	P.1045	Nueé fragment south-west valley.

TABLE 5

Late 1957 - early 1958 eruption, Manam Island

Registered No.	Field No.	Location
R.14722	MK/2	North-east Valley, flow descending 10/1/58
R.14726	MK/3	North-east Valley, flow descending 16/1/58
R.14723	MK/4	North-east Valley cob from surface flow 16/1/58
R.14773	MK/4	North-east Valley cob from surface flow 16/1/58
R.14724	MK/5	North-east Valley 16/1/58, top end beneath surface rubble.
R.14725	MK/6	North-east Valley base of flow of 16/1/58 in valley.
R.14751	MK/7	North-east Valley spinose surface of 16/1/58.
R.14727	MK/8	North-east Upper levee wall distorted.
R.14728	MK/9	North-east Valley; upper levee wall undistorted. top structure
R.14729	MK/10	North-east Valley lower levee wall distorted.
R.14730	MK/11	North-east Valley spinose lava in heated zone.
R.14731	MK/12	North-east Valley conchoidal surface.
R.14732	MW/1	South-east Valley, under nuee deposit, south flank of valley.
R.14733	MW/2	South-east Valley, pre 5/3/58, north flank of valley.
R.14734	MW/3	South-east Valley, pre 5/3/58, north flank of valley below floor.
R.14735	MW/4	South-east Valley, pre 5/3/58, on floor of north flank of valley, about 2000 feet a.s.l.
R.14768	MW/5	South-east Valley, pre 6/3/58, north branch, main flow.
R.14769	MW/6	South-east Valley, pre 6/3/58, north branch, main flow.
R.14736	MW/7	South-east Valley, pre 6/3/58, centre of lava road, on terminal apron about 2500 feet above sea level.
R.14737	MW/8	South-east Valley pre 6/3/58, levee banks, about 2500 feet a.s.l.
R.14738	MW/9	South-east Valley pre 6/3/58, inner wall of lava road.
R.24770	MP/1	Nuee debris, 18/10/57
R.14739	MP/2	Nuee debris, 18/10/57
R.14740	MP/3	Nuee debris, 18/10/57
R.14741	MP/4	Nuee debris, 18/10/57
R.14742	MP/5	Nuee debris, 13/10/57
R.14743	MP/6	Nuee debris, 13/10/57
R.14744	MP/7	Nuee debris, 13/10/57
R.14745	MP/8	Nuee debris, 13/10/57
R.14746	MP/10	Nuee debris, 13/10/57
R.14747	MP/11	Nuee debris, 13/10/57
R.14748	MP/12	Nuee debris, 13/10/57
R.14749	MP/14	Nuee debris, 25/1/58. Budua
R.14771	MP/15	Nuee debris, 25/1/58, S.E. Valley

Table 5 (cont.)

Registered No.	Field No.	Location
R.14750	MP/16	Nue debris, 25/1/58
R.14754	MP/20	Nuee debris, 5/3/58
R.14755	MP/21	Nuee debris, 5/3/58
R.14756	MD/1	Nuee dust, 18/10/57 } S.E. Valley
R.14757	MD/2	Nuee dust, 13/12/57 } S.E. Valley
R.14758	MD/3	Nuee dust, 25/1/58 Budua
R.14759	MD/4	Nuee dust, 25/1/58 S.E. Valley
R.14760	MD/5	Nuee dust, 25/1/58 S.E. Valley
R.14761	MD/6	Subaerial deposit, 25/1/58, Awar.
R.14762	MD/7	Subaerial deposit, 16/2/58, Waris.
R.14772	ME/1	Liquid bomb, S.E. Valley, collected January, 1959.
R.14763	ME/2	South-east Valley, flank of terminal apron, 24/11/57
R.14764	ME/3	North-east Valley, flank of terminal apron, collected 1/1/59.
R.14765	ME/4	20 feet below surface of cone near Kulugumwa.
R.14766	ME/5	Fragment thrown out by adventive cone on northern side of Manam.

TABLE 6

Flow Erupted in 1960, Manam Island

Registered No.	Field No.	Location
R.15647	P.1048	North-east valley.

TABLE 7

Registered No.	Field No.	Location
R.15648	P.1049	South-east valley
R.15649	P.1050	South-east valley
R.15882	P.1050	South-east valley
R.15650	P.1051	South-east valley
R.15651	P.1052	South-east valley
R.15883	P.1052	South-east valley.

TABLE 8

April, 1964 Eruption, Manam Island

Registered No.	Field No.	Location
R.17706	-	South-east Avalanche valley.

Most of the rocks are slightly to moderately vesicular; a few are scoriaceous.

The phenocrysts consist of plagioclase, diopsidic augite, and olivine; in many of the specimens, small amounts of hypersthene are present.

Plagioclase phenocrysts are tabular to sub-tabular crystals that commonly have embayed margins and which are frequently clustered to form parallel and interpenetrant growths. Plagioclase composition in crystal cores is within the range An 75-85; it is zoned to labradorite on crystal margins. Compositional zoning is commonly oscillatory. In many rocks, plagioclase contains numerous minute intergrowths that apparently consist of alkali feldspar. The intergrowths are present in the marginal zone of crystals, or else form several thin zones roughly similar in position to the oscillatory zoning. Quite commonly, plagioclase crystals containing these intergrowths are more strongly embayed than those without them.

Diopsidic augite phenocrysts form pale green, prismatic, slightly embayed crystals, many of which show a faint oscillatory zoning under crossed nicols. Many crystals are clustered. In some specimens, fine granular clinopyroxene occurs in small inclusion - like aggregates. Other pyroxene aggregates contain grains of hypersthene, these commonly occur in rocks which, otherwise, contain no discrete hypersthene phenocrysts. In many specimens, clinopyroxene - plagioclase aggregates are also present.

In the analysed specimen of ancient flow material (R.15639), diopsidic augite has $2E(+) = 54^{\circ}$; in the 1957 eruption, R.15636, $2E(+) = 57^{\circ} - 64^{\circ}$; R.14723 and R.14770 (1957-58 eruption), $2E(+) = 58^{\circ} - 61^{\circ}$; R.15649 and R.15651 (1962 eruption), $2E\ (+)$ ranges between 57° and 65°. In R.17706, (1964 eruption), $2E(+) = 57^{\circ}$. Several crystals in each specimen were measured; the range of values in each specimen suggests that the crystals are not in equilibrium with each other - this is to be expected in volcanic rocks.

Olivine phenocrysts are present in nearly all specimens, one notable exception being the chemically analysed ancient flow sample (R.15639). Olivine forms colourless, commonly embayed crystals which, in many specimens, is surrounded by a very thin reaction rim composed of finely granular clinopyroxene. Where measured, $2V(-)$ ranges between 80° and 96°.

Hypersthene is present in three of the four specimens of ancient flows sampled in the south-west valley.

The groundmass in most specimens has an intersertal texture in which the constituent crystals have a random orientation. In others, however, a flow texture may be seen, particularly around phenocrysts. Most rocks are holocrystalline; some, however, have interstitial glass. The groundmass grain-sizes range between about 0.01 and 0.05 mm. Plagioclase forms laths and microcrystalline anhedra. Clinopyroxene and, where present, hypersthene, occur as granular to prismatic crystals. Black iron oxide is octahedral. Where present, interstitial glass is brown, and is quite commonly somewhat altered.

Some ash samples collected during the 1957-58 eruption consist of subhedral, broken crystals of plagioclase, pyroxene, and olivine, together with small fragments of dark brown, ferruginized basaltic glass, and some basalt lapilli. The grain-size of the ash fragments range between 0.04 and 0.75. Basalt lapilli, where present, are about 6 mm. in diameter.

Modal analyses of specimens and visual estimates of minerals contained in the groundmass are shown in Tables 9 and 10 respectively.

TABLE 9

Modal Analyses of Manam Island Lavas

	R.15639	R.15636	R.14723	R.14770	R.15649	R.15651	R.17706
Groundmass	78	56	63	59	62	72	68
Plagioclase	14	31	14	31	24	22	23
Clinopyroxene	5	9	17	8	10	5	6
Hypersthene	1	2	-	2	Tr.	-	-
Olivine	-	1	6	Tr.	4	1	3
Black iron oxide	2	1	Tr.	Tr.	Tr.	Tr.	Tr.

TABLE 10

Visual Estimates of Percentages of Minerals in Groundmass

	R.15639	R.15636	R.14723	R.14770	R.15649	R.15651	R.17706
Plagioclase	50	30	65	55	65	50	30
Pyroxene	15	25	30	25	30	30	20
Black iron oxide	<1	5	<5	5	<5	<5	<5
Glass	35	40	-	15	-	20	50

R.15639 Hypersthene - clinopyroxene hyaloandesite; ancient flow.
R.15636 Olivine-bearing hypersthene - clinopyroxene andesite erupted January, 1957.
R.14723 Olivine-bearing basalt; erupted January, 1958.
R.14770 Olivine-bearing basalt; erupted October, 1957.
R.15649 Olivine-bearing basalt; erupted 1962.
R.15651 Olivine-bearing basalt; erupted 1962.
R.17706 Olivine-bearing basalt; erupted April, 1964.

TABLE 11

Analyses	R.15636	R.15639	R.15649	R.15651	R.17706
SiO_2	53.90	62.00	52.70	52.90	51.10
TiO_2	0.38	0.44	0.37	0.39	0.58
Al_2O_3	16.60	16.10	17.00	17.00	16.65
Fe_2O_3	4.90	3.35	4.45	4.35	4.98
FeO	3.90	3.25	4.40	4.45	4.00
MnO	0.17	0.14	0.17	0.16	0.16
MgO	6.70	2.80	6.80	6.70	6.80
CaO	10.50	6.85	10.75	10.65	10.60
Na_2O	2.40	3.05	2.50	2.55	4.25
K_2O	0.69	1.61	0.66	0.67	0.88
P_2O_5	0.12	0.23	0.11	0.12	0.19
H_2O+	0.06	0.07	0.08	0.15	nil
H_2O-	0.07	0.13	0.00	0.03	nil
CO_2	0.05	0.01	0.02	0.02	N.D.
Total	100.44	100.03	100.01	100.14	100.19

Norms		R.15636	R.15639	R.15649	R.15651	R.17706
qz		8.34	20.03	5.16	5.11	–
or		3.34	9.45	3.89	3.89	5.56
ab		20.44	25.68	20.96	21.48	30.92
an		32.80	25.58	33.36	33.08	23.63
ne		–	–	–	–	2.84
di	wo	7.66	3.13	8.12	7.77	11.72
	en	5.90	2.10	6.00	5.50	9.00
	fs	0.92	0.79	1.32	1.58	1.45
hy	en	10.80	4.90	11.00	11.30	–
	fs	1.72	1.98	2.64	2.77	–
ol	fo	–	–	–	–	5.60
	fs	–	–	–	–	0.92
mt		7.19	4.87	6.50	6.26	7.19
il		0.76	0.76	0.76	0.76	1.06
ap		0.34	0.34	0.34	0.34	0.34
cc		0.10	–	0.05	0.05	–
Water		0.13	0.20	0.08	0.18	–

Manam Island lava specimens

R.15636 Olivine-bearing hypersthene-augite andesite; erupted January, 1957.

R.15639 Hypersthene-augite hyaloandesite; ancient flow.

R.15649 Olivine-bearing basalt; erupted 1962.

R.15651 Olivine-bearing basalt; erupted 1962.

R.17706 Olivine-bearing basalt; erupted April, 1964.

Analyst: L. Castanelli and R.L. Bruce, A.M.D.L.

TABLE 12

1957-8 Eruption, Manam Island

A. Analyses

	Md.21	Md.23	Md.25	Md.31	Md.56	Md.58	Md.59	Md.60	Md.61	Md.62	Md.63	Md.64
SiO_2	53.20	53.08	53.05	52.79	52.16	51.80	51.76	51.76	51.74	51.74	51.52	51.45
TiO_2	0.33	0.35	0.35	0.34	0.30	0.33	0.31	0.32	0.32	0.31	0.30	0.35
Al_2O_3	14.39	14.84	13.90	14.28	16.62	14.19	16.01	16.29	16.68	15.84	16.18	14.56
Fe_2O_3	6.11	5.96	6.07	4.90	6.23	6.18	5.87	5.20	5.20	6.33	5.75	5.01
FeO	3.60	3.81	3.99	4.75	2.73	4.02	3.25	3.02	3.65	2.99	3.16	4.49
MnO	0.15	0.16	0.16	0.16	0.16	0.15	0.14	0.14	0.18	0.13	0.12	0.16
MgO	8.30	7.37	8.60	8.66	8.45	8.73	8.45	8.31	8.71	8.42	8.37	8.64
CaO	10.93	10.70	10.68	11.08	10.96	10.58	11.00	11.10	11.10	11.15	10.90	10.99
Na_2O	2.44	2.61	2.57	2.46	1.80	2.50	1.44	2.10	1.80	1.26	2.32	2.48
K_2O	0.74	0.83	0.90	0.79	0.70	0.83	0.70	0.74	0.72	0.72	0.71	0.91
P_2O_5	0.22	0.19	0.25	0.17	0.22	0.19	0.20	0.18	0.18	0.20	0.20	0.15
H_2O (+)	Absent	0.07	Absent	Absent	Absent	0.13	Absent	Absent	Absent	Absent	Absent	Absent
H_2O (–)	0.03	0.03	Absent	0.02	Absent	0.08	Absent	Absent	Absent	Absent	Absent	0.02
Total	100.44	100.00	100.52	100.40	100.33	99.71	99.13	99.16	100.28	99.09	99.53	99.15

B. Norms

		Md.21	Md.23	Md.25	Md.31	Md.56	Md.58	Md.59	Md.60	Md.61	Md.62	Md.63	Md.64
qz		4.32	6.36	4.44	2.94	7.56	3.60	8.70	4.90	4.98	9.60	4.44	1.62
or		4.45	4.45	5.56	5.00	3.89	5.00	3.89	4.45	4.45	4.45	3.89	5.56
ab		20.44	22.01	21.48	20.96	15.20	20.96	12.05	17.82	15.20	10.48	19.39	20.96
an		26.13	26.41	23.63	25.30	35.31	25.02	35.58	32.80	35.31	35.31	31.97	25.85
di	wo	11.37	10.79	11.95	12.06	7.19	11.14	7.54	8.93	7.89	8.00	8.93	11.60
	en	9.40	8.70	9.60	9.00	6.20	9.00	6.30	7.40	6.30	6.86	7.50	8.80
	fs	0.53	0.66	0.92	1.85	–	0.79	0.26	0.33	0.66	0.04	0.26	1.58
hy	en	14.00	9.70	11.90	12.70	14.90	12.80	14.80	13.40	15.50	14.24	13.40	12.80
	fs	0.79	0.66	1.19	2.51	–	1.19	0.53	0.59	1.58	0.09	0.40	2.24
mt		8.32	8.82	8.82	7.19	8.12	9.05	8.58	7.66	7.66	9.05	8.35	7.19
hm		–	–	–	–	0.64	–	–	–	–	–	–	–
il		0.61	0.76	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.76
ap		0.34	0.34	0.34	0.34	0.67	0.34	0.34	0.34	0.34	0.34	0.34	0.34
water		0.03	0.10	–	0.02	–	0.21	–	–	–	–	–	–

Md.21 – Nuee deposit, 25/1/58; composite sample. Md.23 – Nuee deposit, 18/10/57. Md.25 – Basalt flow from main crater. Md.31 – Nuee deposit. Md. 56. Basalt flow from main crater. Md.58 – Volcanic ash fall (on mainland) 25/1/58. Md.59 – scoriaceous lapilli. Md.60 – Volcanic ash, 16/2/58 (on Waris). Md. 61 – Basalt from main crater. Md.62 – Lava bomb, March, 1958. Md. 63 and Md.64 – Nuee deposit (Md.63 – 26/12/57).

Analysts – Md. 21 to 31, 58, 63 and 64 – A. McLure, B.M.R.
Md. 56, 59 to 62 – S. Baker, B.M.R.

CHEMISTRY

Chemical analyses and norms of Manam Island lavas are shown in Tables 11 and 12, and are plotted on the variation diagrams shown in Plates II, III and IV. The analyses in Table 12 are quoted from Joplin (1963), although the norms were calculated by the writer. The analyses show the rocks to be fairly uniform; the main exception is R. 15639 an ancient flow, which is far more acid than the others. R. 17706 records a greater percentage of total alkalies than all the other specimens, although it has the least amount of silica; in the norm, nepheline is present. Petrographically and mineralogically the specimen is fairly similar to the 1957-58 material.

On the F.M.A. diagram of Plate II, the trend across the centre of the diagram; the least differentiate are the 1957 and 1958 lavas, the a962 and (apparently) the 1964 lavas are more alkali rich. The most differentiated sample is the ancient flow.

KARKAR ISLAND

PETROGRAPHY

This account of the petrography of the Karkar Island lavas is divided into two parts. The first is on the "old" flows in the south wall of the crater, at Gial Village, and in the Koroput area. The second describes younger flows in the crater, and at Bagiari and Uluman cones. All the lavas described here consist of porphyritic basaltic andesite and andesite. The old flows contain hypersthene in addition to augite and plagioclase; the younger flows contain olivine in place of hypersthene. The locations of specimens of old flows are given in Table 13; those of the newer flows in Table 15, Modal analyses of chemically analysed specimens are shown in Table 14.

Old Flows

South Wall of Crater. All the specimens except R.15621 are somewhat vesicular, porphyritic rocks; R.15621 is strongly scoriaceous. In all specimens, the phenocrysts range from groundmass size up to two or three millimetres in diameter. The phenocrysts in most specimens form less than 5% of the rocks; in £.15878, however, 15 to 20% are present.

TABLE 13

Old flows, Karkar Island

Registered No.	Field No.	Location	Name
R.15618	P.1055	Base of south wall of crater	Hypersthene-clinopyroxene andesite.
R.15619	P.1056	Base of south wall of crater	Hypersthene-clinopyroxene andesite.
R.15620	P.1057	Mid-way up south wall of crater.	Hypersthene-clinopyroxene andesite.
R.15621	P.1058	Top of south wall of crater, terminal flow.	Olivine-bearing hypersthene-clinopyroxene andesite.
R.15622	P.1059	Koroput quarry, north coast of Karkar.	Hypersthene - clinopyroxene andesite.
R.15623	P.1060	Koroput village.	Hypersthene- clinopyroxene andesite.
R.15624	P.1061	Gial Village.	Hypersthene - clinopyroxene andesite.
R.15878	P.1055	Base of south wall of crater.	clinopyroxene andesite.

Plagioclase phenocrysts are present in all specimens. They occur as tabular crystals that commonly have embayed margins. Their composition ranges from bytownite in crystal cores to labradorite on their margins. Diopsidic augite forms pale green, somewhat embayed prismatic phenocrysts with $2Ez = 50^{\circ}$ in R.15618. Hypersthene phenocrysts are also prismatic; they are pleochroic from very pale green to very pale pink. Some have a very thin rim composed of fine-grained, granular clinopyroxene; this rim overlies slight embayments in the margins of hypersthene crystals. In R.15618, hypersthene has 2E x of 65°. No hypersthene is present in R.15878. A few olivine phenocrysts are present in R.15621; here, they form small rounded, colourless grains.

In specimens R.15619 and R.15621 the groundmass is holocrystalline in the others it is hyalocrystalline, colourless to pale brown glass forming between 5 and 20% of the groundmass. In all specimens, groundmass plagioclase occurs as euhedral laths and microcrystalline anhedra; the laths, in some rocks, are flow-oriented. Clinopyroxene occurs as pale green columnar to granular crystals, and black iron oxide is octahedral. In specimens R.15618 and R.15620, some prismatic hypersthene crystals are present in the groundmass. The average grainsize of the groundmass ranges from about 0.01 mm. in some specimens to 0.1 mm. in others.

Koroput Area. Specimen R.15622, from Koroput Quarry, is a very fine-grained, scoriaceous rock in which microphenocrysts about 0.13 mm. diameter, and a few larger phenocrysts, ranging up to 1.5 mm. across, are seen to be enclosed in a very dark groundmass; the phenocrysts form about 5 to 10% of the rock. The phenocrysts consist of calcic plagioclase laths, prismatic to subhedral pale green diopsidic augite, and a few prismatic crystals of hypersthene; a few crystals of colourless olivine are present. The groundmass is seen to consist of felted to sub-radially arranged plagioclase microlites that measure about 0.03 mm. long, granular augite grains about 0.003 mm. diameter, and octahedral black iron oxide measuring 0.001 mm. across. All these are enclosed by brown, partly devitrified glass.

TABLE 14A

Modal Analyses of Karkar Island Lava Samples

	R.15618	R.15628	R.15633	R.15635	R.15879
Groundmass	95	65	71	61	75
Plagioclase	4	32	27	36	23
Clinopyroxene	1	2	1	2	2
Hypersthene	Tr.	-	-	-	-
Olivine	-	Tr.	1	1	Tr.
Black iron oxide	-	Tr.	Tr.	Tr.	-

TABLE 14 B

Visual Estimates of Groundmass Mineral Percentages

	R.15618	R.15628	R.15633
Plagioclase	50	25	55
Pyroxene	25	25	15
Black iron oxide	-	<5	10
Glass	5	50	20

R.15618: Hypersthene-bearing clinopyroxene andesite - Old flow.

R.15628: Olivine-bearing clinopyroxene andesite
R.15633: Olivine-bearing clinopyroxene andesite
R.15635: Olivine-bearing clinopyroxene andesite
R.15879: Olivine-bearing clinopyroxene andesite

New flow

Specimen R.15623, from Koroput village is a porphyritic rock in which the phenocrysts form about 15% of the rock, and range up to about 2 mm. across. Texturally and mineralogically it is similar to the specimens from the south wall of the crater.

Gial Village. In thin section, R.15624 is seen to be porphyritic; there appear to be two generations of phenocrysts. First, some large plagioclase crystals about 1 to 2 mm. diameter. Second, smaller crystals, about 0.4 mm. across, formed of plagioclase, diopsidic augite, hypersthene, and black iron oxide.

The larger plagioclase phenocrysts have a composition of about An_{82}; they are almost unzoned, apart from a thin area around crystal margins. Mostly they are euhedral, but one or two strongly embayed crystals are present. The second generation plagioclase phenocrysts are tabular, and have a composition of about An_{75}. Diopsidic augite forms pale green prismatic crystals, and hypersthene is colourless to pale greenish-brown. Some hypersthene crystals have a thin rim of fine-grained granular clinopyroxene.

The groundmass consists of randomly oriented plagioclase laths, about 0.04 mm. long, together with prismatic clinopyroxene and octahedral black iron oxide. All are enclosed in dark brown altered glass that forms about 25% of the groundmass.

Young Flows

The locations of specimens representing young flows are given in Table 15.

Crater. Specimen R.15625, in thin section, is seen to be seriate porphyritic, the phenocrysts ranging from groundmass size up to 2 mm. in diameter. The phenocrysts form about 30% of the rock, and consist of tabular plagioclase (with a composition of almost An_{75}), pale green zoned diopsidic augite, colourless to very pale brown hypersthene, and colourless olivine. Hypersthene crystals commonly have a thin, discontinuous rim of minute granular clinopyroxene grains. Olivine crystals are rounded and embayed, and have a thin rim of granular clinopyroxene and orthopyroxene. The groundmass consists of laths of plagioclase, about 0.03 mm. long, together with granular clinopyroxene and octahedral black iron oxide. Small amounts of interstitial colourless glass are present.

The specimens representing the lava flow that covers the crater floor are all very similar to one another. Texturally and mineralogically they are fairly similar to R.15625; there are, however, a few differences. First, no hypersthene is present in this flow. Second, the plagioclase is more calcic than in R.15625 - in general, it has a composition of An_{82}; in R.15628, a composition of An_{92} was measured in the core of one crystal.

Olivine in R.15628, was found to have $2Ex = 84^{\circ}$; diopsidic augite has $2Ez = 52^{\circ}$. A modal analysis of the phenocrysts and a visual estimate of the percentages of minerals in the groundmass of this specimen are given in Tables 14A and B.

Bagiari Cone. The specimens from Bagiari Cone (R.15631 to R.15634, and R.15879 to R.15881) represent bombs, blocks, and lapilli. Mineralogically and texturally, all specimens are very similar to each other, and to the young lavas from the crater. They are moderately porphyritic rocks; the phenocrysts range up to about 1.5 mm. across in most specimens, and form about 20 to 30% of the rock. The phenocrysts consist of plagioclase, pale green diopsidic augite, and colourless olivine. Some olivine crystals are embayed, and many have a thin rim composed of finely granular pyroxene.

In the groundmass, all the specimens have a grainsize ranging between 0.01 and 0.08 mm., and contain plagioclase laths, columnar to granular clinopyroxene, and octahedral black iron oxide. Some rocks are holocrystalline, others contain about 10 to 30% glass. In R.15633, glass is restricted in occurrence to vesicle-like pockets that range from minute openings up to about 2 mm. in diameter.

Modal analyses of phenocrysts, and visual estimates of the amounts of minerals present in the groundmass of specimens R.15633 and R.15879 can be found in Tables 14A and B. In these specimens, diopsidic augite was found to have 2Ez of 53°, and olivine to have 2Ex of 84 to 86°.

Uluman Cone. Specimen R.15635 is a scoriaceous, porphyritic rock in which the phenocrysts range in size between 0.13mm. and 1 mm. The phenocrysts consist of plagioclase, diopsidic augite, and small amounts of olivine; they make up nearly 40% of the rock. Plagioclase is tabular, and is zoned from An_{84} in crystal cores to An_{70} on margins. Diopsidic augite forms pale green, prismatic crystals; it has 2Ez = 55°. Colourless, somewhat embayed crystals of olivine are commonly surrounded by a thin rim of granular clinopyroxene, and have 2Ex of about 87°. A modal analysis of the phenocrysts can be found in Table 14A.

In the groundmass, the rock contains tabular plagioclase, granular to prismatic clinopyroxene, and octahedral black iron oxide. The average grainsize is about 0.02 mm. All the grains are enclosed in dark brown altered glass.

Inclusions

In several of the specimens representing the old and young lavas, probable cognate xenolithic inclusions are present. Some consist of aggregates of coarse, somewhat intergrown grains of clinopyroxene. Others are composed of aggregates of fine-grained, granular olivine. Still others consist of clinopyroxene and plagioclase with, in some, hypersthene. In these, pyroxene and plagioclase are sometimes sub-ophitically intergrown.

CHEMISTRY

Chemical analyses and norms of Karkar Island specimens are shown in Table 16, and are plotted in Plates II, III and IV. Except for R.15633, the rocks have a fairly uniform composition. In R.15633, the larger amount of silica present is presumably contained in the acid glass that fills the vesicle-like pockets in this specimen. The Karkar Island specimens, as will be seen from Plate I, are relatively rich in total iron oxide, and poor in magnesia, when compared with the other lavas described in this report.

TABLE 15

Locations of Specimens of Young Flows, Karkar Island.

Registered No.	Field No.	Location	Name
R.15625	P.1062	Near small cone, S.E. wall of5 crater.	Olivine and hypersthene-bearing augite.
R.15626	P.1063	Flow covering crater floor.	Olivine-bearing clinopyroxene andesite.
R.15627	P.1063A	Margin of flow covering crater floor.	Olivine-bearing clinopyroxene andesite.
R.15628	P.1063B	In from margin of floor covering crater floor.	Olivine- bearing clinopyroxene andesite.
R.15629	P.1063C	Midway between cone and wall, flow covering crater floor.	Olivine-bearing clinopyroxene andesite.
R.15630	P.1063D	Near cinder cone, flow covering crater floor.	Olivine-bearing clinopyroxene andesite.
R.15631	P.1064	Foot of Bagiari cone.	Olivine-bearing clinopyroxene andesite.
R.15632	P.1065	Bomb from Bagiari cone.	Olivine-bearing clinopyroxene andesite.
R.15633	P.1066	Block lava, Bagiari cone	Olivine-bearing clinopyroxene andesite.
R.15879	P.1065	Bomb from the foot of Bagiari cone.	Olivine-bearing clinopyroxene andesite.
R.15634 R.15880 R.15881	P.1067	Lapilli from Bagiari cone.	Olivine-bearing clinopyroxene andesite.
R.15635	P.1068	Uluman cone.	Olivine-bearing clinopyroxene andesite.

TABLE 16

Chemical Analyses and C.I.P.W. Norms of Karkar Island Lava Specimens

Analyses

	R.15618	R.15628	R.15633	R.15635	R.15879
SiO_2	56.30	54.20	60.10	54.20	54.20
TiO_2	0.69	0.57	0.56	0.75	0.59
Al_2O_3	15.60	18.30	16.40	18.10	18.60
Fe_2O_3	2.75	2.35	4.25	2.85	2.45
FeO	8.55	7.30	5.30	6.90	7.20
MnO	0.18	0.17	0.12	0.17	0.16
MgO	3.30	3.75	3.10	3.25	3.50
CaO	7.70	9.70	7.30	9.65	9.80
Na_2O	2.85	2.50	1.75	2.50	2.60
K_2O	1.15	0.88	0.84	0.89	0.89
P_2O_5	0.23	0.17	0.15	0.16	0.17
H_2O (+)	0.59	0.26	0.11	0.12	0.15
H_2O (-)	0.20	0.13	0.16	0.11	0.07
CO_2	0.01	0.02	0.06	0.04	0.05
Total	100.10	100.30	100.20	99.69	100.43

Norms

	R.15618	R.15628	R.15633	R.15635	R.15879
qz	11.21	8.10	24.20	9.54	6.36
or	7.23	5.56	5.00	5.00	7.78
ab	24.10	20.96	14.67	20.96	22.01
an	26.13	35.86	34.47	35.86	35.03
di wo	4.76	4.18	0.46	4.52	5.22
di en	1.90	1.90	0.26	2.10	2.30
di fs	2.90	2.24	0.19	2.38	2.90
hy en	6.60	7.50	7.54	6.00	6.20
hy fs	9.50	8.45	5.36	6.86	7.52
mt	4.18	3.48	6.26	4.18	3.71
il	1.37	1.06	1.06	1.52	1.22
ap	0.34	0.67	0.34	0.34	0.34
cc	-	0.05	0.10	0.10	0.10
Water	0.79	0.39	0.27	0.23	0.22

R.15618 Hypersthene-bearing augite andesite; old flow from the base of the south wall of the crater.

R.15628 Olivine-bearing clinopyroxene andesite. Young flow covering the floor of the crater.

R.15633 Olivine-bearing clinopyroxene andesite. Young flow, Bagiari cone.

R.15635 Olivine- bearing clinopyroxene andesite. Young flow, Uluman cone.

R.15879 Olivine-bearing clinopyroxene andesite. Young flow; bomb from the foot of Bagiari cone.

Analyst: L. Castanelli and R.L. Bruce, A.M.D.L.

BAGABAG ISLAND

PETROGRAPHY

Two specimens of lava from Bagabag were examined. R.15612 (field number P.1053) was collected from a locality west of Mungen Anchorage. R.15613 (P.1054) is from a point east of Mungen. The specimens are similar to each other. They are porphyritic olivine-bearing hypersthene-clinopyroxene andesites, the phenocrysts forming nearly 40% of each of the specimens. The phenocrysts range up to 4 mm. across. Plagioclase phenocrysts have a composition of An_{85}, zoned to labradorite on crystal margins; some crystals are slightly to strongly altered to clay minerals. Diopsidic augite phenocrysts are pale green and prismatic; in R.15612, 2Ez = 51 to 52°. Hypersthene is faintly pleochroic from colourless to very pale pink; 2Ex = 68° in R.15612. Hypersthene crystals commonly have a very thin rim of fine-grained clinopyroxene. In R.15613, one pyroxene phenocryst is composed of a broad, optically continuous marginal area of augite enclosing an euhedral core of hypersthene. Olivine occurs in very minor quantities; it forms colourless, fairly strongly embayed crystals that, in R.15612, have ferruginous margins.

In the groundmass of both rocks, plagioclase forms flow-oriented laths measuring 0.02 by 0.007 mm., clinopyroxene occurs as columnar green crystals that have similar dimensions, and black iron oxide is octahedral, the grains having an average diameter of 0.01 mm.

The modal analysis of R.15612 is:-
groundmass: 61%; plagioclase: 26%; diopsidic augite: 10%; hypersthene: 3%; black iron oxide: 1%; olivine: trace amounts. A visual estimate of the percentages of minerals in the groundmass is: plagioclase: 70; pyroxene: 25; black iron oxide: 5.

CHEMISTRY

A chemical analysis and C.I.P.W. norm of specimen R.15612 is presented in Table 17, and is plotted on Plates II, III, and IV. In spite of modal olivine occurring in the rock, some quartz is present in the norm. In general the analysis is fairly similar to some of the Karkar Island specimens, in that it has fairly high alumina, and rather low magnesia. On Plate II, its plotted position is fairly close to those of Karkar Island. However, on Plates III and IV, it is seen to be rather more basic than the Karkar specimens.

TABLE 17

Analysis		Norm		
SiO_2	53.30		qz	8.10
TiO_2	0.68		or	3.89
Al_2O_3	17.80		ab	20.44
Fe_2O_3	3.50		an	35.86
FeO	6.40	di	wo	4.29
MnO	0.17	di	en	2.50
MgO	4.90	di	fs	1.58
CaO	9.50	hy	en	9.80
Na_2O	2.40	hy	fs	6.47
K_2O	0.72		mt	5.10
P_2O_5	0.20		il	1.37
$H_2O(+)$	0.31		ap	0.34
$H_2O(-)$	0.46		cc	0.05
CO_2	0.02		Water	0.77
Total	100.36			

Specimen R.15612. Olivine-bearing hypersthene-clinopyroxene andesite. West of Mungen Anchorage. Bagabag.

Analysts. L. Castanelli and R.L. Bruce, A.M.D.L.

TABLE 18

Locations and Names of Long Island

Lavas and Pyroclasts

Registered No.	Field No.	Location	Name
R.15284	P.1007	East Caldera wall	Augite andesite.
R.15285	P.1009	East Caldera wall	Augite andesite.
R.15286	P.1010	East Caldera wall, overlies bomb and andesite horizon	Vitric, lithic and crystal tuff.
R.16701	P.1014	Flank of Mani cone.	Lapilli of basaltic or andesitic glass.
R.16702	P.1016	Summit of Mani cone.	Lapilli of basaltic or andesitic glass, with crystal fragments.
R.16703	P.1015	Base of Mani cone.	Olivine-bearing basaltic andesite.
R.16704	P.1019	Summit, Mani cone.	Olivine-bearing basaltic andesite.
R.16705	P.1018	Summit, Mani cone.	Olivine-bearing basaltic andesite.
R.16707	P.1021	Central east coast.	Olivine-bearing basaltic andesite.
R.16708	P.1021B	Central east coast.	Olivine-bearing basaltic andesite.
R.16709	P.1021C	Central east coast.	Olivine-bearing basaltic andesite.
R.16710	P.1 022	Mani cone, plug.	Olivine-bearing basaltic andesite.
R.17700	P.1015	Base of Mani cone.	Olivine-bearing basaltic andesite.

LONG ISLAND

PETROGRAPHY

The Long Island lava specimens consist mostly of olivine-bearing basaltic andesite; a few samples containing hypersthene are also present. This account of their petrography is divided into three parts. The first describes specimens from the east caldera wall, the second, samples from Mani cone, and the third, specimens from the central east coast of Long Island. The locations of specimens described here are shown in Table 18.

East Caldera Wall

R.15284 is a scoriaceous andesite. Phenocrysts form less than 5% of the rock; most of them range up to 0.3 mm. in size, although one very strongly embayed plagioclase phenocryst measures 0.75 mm. across. The phenocrysts consist of fairly calcic plagioclase and colourless, prismatic diopsidic augite. The flow-textured groundmass is seen to consist of plagioclase microlites about 0.02 mm. long, prismatic clinopyroxene, and octahedral black iron oxide. The crystals are enclosed in a pale brown glass.

Specimen R.15285 is also an andesite. Texturally and mineralogically it is very similar to R.15284, except that it is much less vesicular, and contains a few cognate xenoliths of andesite or basaltic andesite.

R.15286 is a crystal, lithic, and vitric tuff. Most of the fragments consist of angular to sub-angular grains of glass; the glass is pale brown, and has a refractive index of about 1.55. It encloses microlites of calcic plagioclase and clinopyroxene. Many of the glass fragments are partly or completely devitrified to goethite and smectite. A few of the fragments consist of holocrystalline and hyalocrystalline basaltic andesite. Grains composed of individual crystals of plagioclase and diopsidic augite are also present.

Mani Cone

Specimens R.16703 and R.17700 were collected from the base of Mani cone, R.16704-5 are from its summit, and R.16710 represents material in the plug of Mani cone. The other specimens, R.16701 and R.16702 are samples of lapilli from the flank and summit of the cone respectively.

The lava samples and plug material are, texturally and mineralogically, very similar to each other. In them, the phenocrysts form between 5 and 10% of the rock and range up to about 4 mm. in size, although in R. 16704 the largest phenocryst seen was 0.5 mm.across. Plagioclase phenocrysts are tabular; commonly, groups of two or three of them form interpenetrant and parallel growths. Their composition was found to be An_{90-95} in crystal cores zoned rather sharply near crystal margins to labradorite. Diopsidic augite phenocrysts occur as pale green, prismatic, somewhat embayed crystals which, in places, show oscillatory zoning. Olivine phenocrysts form colourless prismatic to rounded, somewhat embayed crystasls.

The groundmass of most of these specimens is hyalocrystalline, the interstitial brown glass forming about 10% of the rock. The average grain-sizes range between 0.01 and 0.07 mm. Plagioclase laths, granular to prismatic clinopyroxene, and octahedral black iron oxide are present. In some (R.16703, R.16710), granular olivine was also seen. In others (R.16703 and R.16704) small amounts of prismatic hypersthene are present. The crystals in these lavas are commonly flow-oriented around phenocrysts.

The groundmass of R.16705 is composed of small laths and microlites of plagioclase, together with prisms and minute aborescent growths of clinopyroxene enclosed in a brown, basic glass that forms about 30-40% of the rock.

Several of the specimens contain polymineralic inclusion - like phenocryst clusters that are formed of plagioclase, diopsidic augite, and sometimes olivine; other inclusions are ultramafic; these are composed of somewhat intergrown grains of diopsidic augite and olivine. In two of the specimens (R.17700 and R.16704), one or two of the ultramafic clusters contain a few grains of hypersthene.

Specimens R.16701-2 consist of fragments of ash and lapilli. In R.16701 the fragments range between 0.5 and 4.0 mm. diameter, and are sub-rounded to sub-angular in shape. In R.16702, the fragments range from 0.25 to 2.5 mm. across, and are angular to sub-angular. In R.16701, most fragments consist almost entirely of pale brownish-green glass that has a high refractive index. The glass encloses micro-phenocrysts of plagioclase, green diopsidic augite, and colourless olivine, together with fine microlites of plagioclase and minute prisms of clinopyroxene. A measurement on one plagioclase phenocryst showed a composition of Au_{94}. Other fragments consisted of scoriaceous lapilli and single crystals of basaltic minerals. The fragments in R.16702 are in general, similar to those in R.16701, except that there are more single crystal fragments present; however, many of these have a thin rim of glass.

Central East Coast

Specimens R.16707 and R.16708 are porphyritic olivine-bearing basaltic andesites in which phenocrysts form about 15% of the rock and range up to 4 mm. diameter. Plagioclase phenocrysts are tabular, and are commonly clustered, forming parallel growths. Some have embayed margins. Their composition is about Au_{95}, zoned to labradorite on crystal margins. Diopsidic augite occurs as somewhat embayed pale green prismatic crystals that commonly have faint oscillatory zoning. Some crystals have a thin rim of more iron-rich augite deposited around them, forming euhedral crystal faces over originally embayed surfaces. Olivine occurs as colourless prismatic crystals. The groundmass of these specimens has an average grain size of 0.02 mm., and is formed of plagioclase laths which are, in places, flow-oriented around phenocrysts; granular to prismatic clinopyroxene and octahedral black iron oxide are also present, together with an interstitial, somewhat altered brown glass that forms about 10% of the rock. A few grains of olivine are present in the groundmass.

Specimen R.16709 is, mineralogically, very similar to the other two samples from this locality. Texturally, however, the groundmass is rather unusual for these lavas; it is formed of stumpy, rectangular, almost granular plagioclase crystals that range in size between 0.06 mm. and 0.8mm., together with granular clinopyroxene and octahedral black iron oxide. In general appearance, the groundmass gives the impression of being tuffaceous; however, the grains are seen to be enclosed in a fine-grained, hyalocrystalline material composed of glass containing plagioclase microlites and minute pyroxene crystals. The phenocrysts in this specimen form about 20% of the rock, and consist of highly calcic plagioclase, pale green diopsidic augite, and colourless olivine.

CHEMISTRY

A chemical analysis of a specimen of andesite from the east caldera wall is presented in Table 19. Unfortunately, an analysis of one of the basaltic andesites is not available. On Plate II, the Long Island andesite sample plots in a position fairly close to the Karkar Island lavas, but is rather more rich in alkalis.

TABLE 19

Analysis		Norm		
SiO_2	55.60		qz	7.32
TiO_2	0.81		or	11.12
Al_2O_3	16.50		ab	26.72
Fe_2O_3	2.90		an	25.30
FeO	8.20	di	wo	3.36
MnO	0.21	di	en	1.40
MgO	3.10	di	fs	1.98
CaO	7.30	hy	en	6.40
Na_2O	3.13	hy	fs	9.77
K_2O	1.93		mt	4.18
P_2O_5	0.36		il	1.52
$H_2O(+)$	0.13		ap	1.01
$H_2O(-)$	0.23		cc	0.05
CO_2	0.02		Water	0.36
Total	100.42			

Specimen R.15285. Clinopyroxene andesite, from the east caldera wall, Long Island. Analyst: L.Castanelli and R.L. Bruce, A.M.D.L.

FERGUSSON ISLAND

PETROGRAPHY

Specimens R.16490 to R.16496 were all obtained from Lamonai Crater. R.16692 to R.16694 and R.17698 were collected from Oiau cone. All the specimens described here consist of either peralkaline rhyolite of aegirine obsidian. Their detailed locations and names are given in Table 20.

Lamonai Crater

Specimens R.16490 - 3 are peralkaline rhyolites. All are sparsely porphyritic, the phenocrysts forming less than 1% of the rock, and ranging up to 2.3 mm. across. The phenocrysts consist mainly of anorthoclase; some small aegirine phenocrysts are also present. The anorthoclase crystals are tabular; some show a very fine, indistinct grid twinning. In R.16490, 2Ex was found to range between 42° and 48°. The aegirine forms pale green, prismatic crystals. In R.16490, these were found to have 2Ez = 63 to 66°.

The groundmass of these specimens consists mostly of felted microlites of alkali feldspar measuring about 0.01 mm. long. Quartz is interstitial. Green aegirine and bluish-green (?)riebeckite form anhedral grains. Probable cossyrite occurs as sub-prismatic to anhedral crystals that are fairly strongly pleochroic from deep purple-brown to red-brown.

Specimens R.16494-6 are obsidian. They are sparsely porphyritic; like the peralkaline rhyolites, the phenocrysts consist of anorthoclase and aegirine. These are enclosed in a groundmass composed almost entirely of a pale brown acid glass that contains a few microlites, sometimes flor-oriented, composed of alkali feldspar and aegirine. The glass commonly has a slight perlitic structure. In R.16496, the perlitic structure is well developed, and its feldspar phenocrysts are entirely replaced by clay minerals.

Oiau Cone

Two of the specimens described here are aegirine obsidian, one is peralkaline rhyolite, and the other a peralkaline trachyte.

R.16692, collected from close to the crater, is a strongly vesicular, almost pumiceous obsidian formed mostly of a colourless acid glass. The few phenocrysts range up to 2.5 mm. across; they consist of tabular anorthoclase and green, prismatic aegirine. Microlites of alkali feldspar, about 0.08 mm. long, together with prismatic and acicular aegirine crystals about 0.03 mm. across are also enclosed in the glass.

R.16693 is a sparsely porphyritic, non-vesicular aegirine obsidian similar to those occurring at Lamonai Crater.

R.16694 is a porphyritic hyalocrystalline peralkaline rhyolite. The phenocrysts consist mostly of anorthoclase crystals; these range up to 2 mm. long. Other phenocrysts consist of green aegirine, these are about 0.6 mm. across. One phenocryst of (?)fayalite was observed; this crystal is prismatic, and has slightly embayed margins. It is coloured pale grey-brown, and has second-order birefringence. The mineral is moderately altered to hydrated iron oxide. The groundmass consists of flow-oriented alkali feldspar laths, together with prismatic aegirine and octahedral black iron oxide, all enclosed in a pale brown acid glass that forms about 60-70% of the rock.

TABLE 20

Fergusson Island Lavas

Registered No.	Field No.	Location	Name
R.16490	P.1029	Lamonai crater floor.	Peralkaline rhyolite.
R.16491	P.1030	Centre of floor of Lamonai crater.	Peralkaline rhyolite
R.16492	P.1031	Beneath north wall of Lamonai crater.	Peralkaline rhyolite.
R.16493	P.1032	South-east wall of Lamonai crater.	Peralkaline rhyolite.
R.16494	P.1033	South-east floor of Lamonai crater.	Aegirine obsidian
R.16495	P.1034	South-west wall of Lamonai c crater.	Aegirine obsidian.
R.16496	P.1035	Ana Du'udu'u, thermal area north of Deder, Lamonai Crater area.	Altered obsidian.
R.16692	P.651	Oiau cone, close to crater.	Aegirine obsidian (pumiceous).
R.16693	P.652	Oiau cone, close to crater.	Aegirine obsidian.
R.16694	P.652	Oiau cone, crater.	Peralkaline rhyolite.
R.17698	P.652	Oiau cone, crater.	Peralkaline trachyte.

TABLE 21

Chemical Analyses and C.I.P.W. Norms of Fergusson Island Lavas

Analyses

	R.16490	R.16494	R.16692
SiO_2	70.90	69.80	69.60
TiO_2	0.27	0.30	0.29
Al_2O_3	14.50	14.90	14.60
Fe_2O_3	1.39	1.17	0.84
FeO	1.57	1.98	2.10
MnO	0.07	0.10	0.10
MgO	0.18	0.20	0.20
CaO	0.46	0.59	0.48
Na_2O	5.75	6.15	6.25
K_2O	4.60	4.50	4.50
P_2O_5	0.03	0.03	0.04
H_2O (+)	0.10	0.26	0.52
H_2O (-)	0.13	0.08	0.11
CO_2	0.03	0.06	0.07
Total	99.98	100.12	99.70

Norms

	R.16490	R.16494	R.16692
qz	18.44	15.16	14.71
or	27.24	26.69	26.69
ab	48.73	51.35	49.78
ac	-	0.46	2.31
di wo	0.77	1.08	0.70
di en	0.20	0.22	0.10
di fs	0.53	0.94	0.66
hy en	0.30	0.28	0.40
hy fs	0.79	1.17	2.77
mt	2.09	1.62	-
il	0.61	0.61	0.61
ap	0.07	0.07	0.10
cc	0.07	0.10	0.16
sodium metasilicate	-	-	0.12
Water	0.23	0.34	0.63

R.16490 Peralkaline rhyolite. Lamonai crater floor.

R.16494 Aegirine obsidian. South east floor of Lamonai crater.

R.16692 Pumiceous aegirine obsidian. Oiau cone, close to the crater

Analysts : L. Castanelli and R.L. Bruce.

R.17698 is a very sparsely porphyritic, holocrystalline, peralkaline trachyte. The few phenocrysts consist almost entirely of anorthoclase, although one crystal of strongly embayed biotite, pleochroic from straw to dark brown, was seen. The groundmass is texturally and mineralogically similar to that of the peralkaline rhyolites of Lamonai crater, except that no quartz was seen. However, some vesicles are filled with tridymite.

CHEMISTRY

Chemical analyses and C.I.P.W. norms of Fergusson Island specimens are given in Table 21, and are plotted on Plates II, III and IV. Their alkaline character is well shown; no anorthite appears in any of the norms, whereas acmite is present in two, and sodium metasilicate in one.

DOBU ISLAND

PETROGRAPHY

Generally speaking, the specimens described here are similar to those from Fergusson Island, i.e., they are peralkaline rhyolite and obsidian. One sample, however, is a porphyritic olivine-bearing basaltic andesite, similar in general appearance and mineralogy to the basalts occurring on the volcanic islands along the north coast of New Guinea.

Of the obsidians, R.16695 (field number P.654) was collected from an ancient dome structure on Dobu Island, R.16697 (P.656) is from the small east crater on the island, and R.17699 (P.657) is from "Dome Island", on the eastern side of Dobu. R.16697, an aegirine obsidian, is the most fresh of the three. It is sparsely porphyritic; the phenocrysts range up to 2 mm. across, and are composed mostly of anorthoclase. Some euhedral aegirine phenocrysts are also present. The groundmass consists almost entirely of pale brown acid glass, which encloses flow-oriented alkali feldspar microlites and minute acicular crystals of aegirine. In addition to the acicular aegirine crystals, the mineral also occurs as sub-rounded aggregates of grains; the aggregates range up to 0.1 mm. diameter.

R.17699 is a pumiceous aegirine obsidian. R.16695 is a strongly altered vesiculated obsidian that appears to have been fairly similar to R.16697.

Of the peralkaline rhyolites, R.16696(P.655) is from the small east crater, and R.16700 (P.658) was collected from the western side of the rim of the large crater on Dobu. Texturally and mineralogically they are similar to the peralkaline rhyolites of Fergusson Island; the sparse phenocrysts consist of anorthoclase and aegirine, and the holocrystalline groundmass contains alkali feldspar laths and interstitial quartz, together with aegirine, riebeckite, and probable cossyrite.

A sample of pumiceous ejectamenta (R.16699, P.1023) collected from the south coast of Dobu Island consists of strongly altered glass enclosing partly altered anorthoclase phenocrysts. The glass is replaced by clay minerals, and the feldspar by clay minerals and carbonate.

The sample of olivine-bearing basaltic andesite is believed by G.A. Taylor to represent a xenolith enclosed in acid lava. It is a strongly vesicular, almost scoriaceous rock that is very sparsely porphyritic. The phenocrysts form about 5% of the rock. Plagioclase phenocrysts occur as tabular to sub-rounded, embayed crystals, and probably consist of bytownite zoned to labradorite. Diopsidic augite forms very pale green prismatic crystals. In one place in the thin section, a single crystal of hypersthene was seen to be surrounded by a rim of granular clinopyroxene. Olivine is not common in this rock. Where it occurs, it forms colourless prismatic crystals. The groundmass consists of randomly oriented plagioclase laths, prismatic clinopyroxene, and octahedral black iron oxide, all enclosed in a devitrified glass.

CHEMISTRY

An analysis, together with a C.I.P.W. norm, of R.16696, is given in Table 22. As can be seen, the rock has a very similar composition to the Fergusson Island lavas. In this specimen, the iron is more highly oxidized, so that hematite appears in the norm. Wollastonite (apart from that contained in diopside) is also present.

TABLE 22

Analysis		Norm	
SiO_2	70.10	qz	16.87
TiO_2	0.29	or	27.24
Al_2O_3	14.80	ab	50.30
Fe_2O_3	2.15	ac	0.46
FeO	1.10	wo	0.33
MnO	0.09	di wo	0.64
MgO	0.22	di en	0.55
CaO	0.55	di fs	–
Na_2O	6.00	mt	2.78
K_2O	4.60	hm	0.16
P_2O_5	0.04	il	0.61
$H_2O(+)$	0.18	ap	0.10
$H_2O(-)$	0.09	cc	0.07
CO_2	0.03	Water	0.28
Total	100.24		

R.16696: Peralkaline rhyolite; small east crater, Dobu Island.

Analyst:

DISCUSSION

PETROGRAPHY

The lava specimens collected from the volcanic islands on the north coast of New Guinea (i.e., Blup Blup, Kadover, Manam, Karkar, Bagabag, and Long Island) are andesitic basalts, basaltic andesites, and andesites. Most of them are moderately to strongly porphyritic, and many contain cognate inclusions composed of basic and ultrabasic grain aggregates. It is quite possible that many of the apparent phenocrysts are also cognate inclusions.

A most obvious feature of the lavas from these islands is the generally uniform appearance of the phenocrysts. Plagioclase, in all samples, is strongly calcic. It forms tabular crystals that usually show oscillatory zoning. Very commonly, the crystals have large cores with compositions of about An_{75} to An_{90}; these are surrounded by a fairly narrow, sharply gradational zone composed of labradorite. In plagioclase crystals measured on a universal stage (by the method of Rittman and El-Hinnawi, 1961), it was noted that crystal cores were optically, of "low temperature" type, whereas on crystal margins, the recorded values were intermediate between "high" and "low temperature" phases. The cores presumably crystallized relatively slowly in intratelluric conditions whereas the margins crystallized rapidly, rpobably after extrusion of the lava.

Pale green diopside and diopsidic augite are present as phenocrysts in all lavas examined from the north coast islands. In some specimens, particularly those from Manam Island, the clinopyroxene shows very faint oscillatory zoning in both phenocrysts and crystal aggregates. 2Ez ranges from about 60° in the more basic rocks to about 50° in the most acid ones.

Orthopyroxene is present as phenocrysts and in crystal aggregates in lavas from Blup Blup, Kadovar, Manam, and Bagabag. At Karkar Island it occurs in the older flows, but is not commonly present in the younger flows. None was found in the Long Island samples described here. Orthopyroxene forms prismatic crystals that are faintly pleochroic from colourless or faint green to extremely pale brownish-pink. 2 Ex ranges from 65 in the more acid rocks to 80 in the andesitic basalts, indicating a range in composition between hypersthene and ferrohypersthene (Winchell and Winchell, 1951, p. 406). In lavas from most of the islands, orthopyroxene crystals are surrounded by a very thin rim of fine clinopyroxene grains.

As shown by the chemical analyses, almost all of the olivine-bearing rocks are oversaturated with silica, showing that the rocks as crystallized, are unstable. However, olivine, where it occurs, forms embayed crystals, and is commonly surrounded by a reaction rim composed of fine, granular clinopyroxene. 2Ex ranges between 80° and 95°.

In the groundmass, some of the lavas are holocrystalline. Many, however, have small to moderate amounts of glass present; it commonly has a low refractive index, indicatingit to be fairly acid. Plagioclase (about andesine to labradorite in composition), pale green clinopyroxene, and octahedral black iron oxide are present in the groundmass of all specimens examined. Probable orthopyroxene occurs in the groundmass of some lavas from Manam, Karkar, and Long Islands.

The lavas from Fergusson and Dobu Islands are very different in character from the others. They consist of peralkaline rhyolites and obsidians. They contain phenocrysts of anorthoclase and aegirine. In the groundmass of the peralkaline rhyolites, alkali feldspar laths, interstitial quartz, and small amounts of aegirine, riebeckite, and probable cossynite are present. Only one specimen, from Dobu Island, is at all intermediate or basic in character. This rock is a porphyritic basaltic andesite whose appearance is very similar to the lavas from the islands along New Guinea's north coast.

CHEMISTRY

The chemical analyses presented in this report have been plotted on the diagrams shown in Plates II, III, and IV. For comparison, the writer has also plotted analyses of lavas from Mount Lamington (Taylor, 1958) and from Mounts Yelia and Victory (Morgan, 1963). The symbols on the plates represent the general localities described in the text; the key to them can be found on Plate II.

Plate II is an F.M.A. diagram - i.e., total iron oxides (F), magnesia (M), and total alkalies (A). Plate III is a linear diagram in which the oxides are plotted against silica. Plate IV is of the Solidification Index plotted against silica. The Solidification Index (Kuno, 1959) is a function obtained from:-

$$\frac{MgO \times 100}{(MgO + FeO + Fe_2O_3 + Na_2O + K_2O)}$$

Kuno states that the index represents a measure of the amount of residual liquids in a differentiating magma. As will be shown below, it is not really valid to regard it as such in relation to the New Guinea lavas. However, when it is plotted against silica, it is a useful way of comparing the trends of tholeiitic, alkali, and calc-alkali rock suites.

The writer wishes to emphasize that the diagrams are not being used here to represent variations or trends in magmatic differentiation; there may, in fact, be more than one magma type involved here. The diagrams have been prepared in order to compare the analyses from each locality, and to try and show the relationships, if any, between the lava types from the various localities.

Furthermore, except for the Fergusson and Dobu Island lavas, all the samples described here, and those from Mounts Lamington, Yelia, and Victory, are fairly strongly porphyritic, and thus probably do not represent material that was entirely liquid at a particular stage of differentiation. In fact, many of the rocks are possibly cumulates (i.e., represent liquids in which large crystals accumulated by some means prior to eruption). Thus, the diagrams (and particularly the Solidification Index) are useful only in studying the relationships between the compositions of the rocks, and not for comparing the state of crystallization during differentiation.

F.M.A. Diagram (Plate II)

On this diagram I have plotted the trends of the tholeiites (Tilley, 1950), some calc-alkaline volcanics from Unalaska Island, Aleutian Islands (Drewes, et al. 1961), and the Hawaiian alkali basalt series (McDonald, 1949). In this diagram, the New Guinea lavas fall into four groups.

The samples from Karkar, Bagabag, and Long Islands are relatively iron oxide rich in comparison with the others. The volcanics from Manam, Kadavar, and Blup Blup Islands, and from Mount Yelia form a group across the centre of the diagram; they all have roughly similar amounts of iron oxide - their main variation being in alkalies and magnesia. The Mount Lamington and Mount Victory group are rather more rich in total alkalies than the two previous groups. The Fergusson and Dobu Island volcanics are, as is to be expected, extremely rich in alkalies.

Except for the Fergusson and Dobu Island specimens, the New Guinea lavas fall into the area of calc-alkali rocks, although the iron oxide rich samples occur fairly close to the tholeiite curve. The Manam Island specimens are close to the alkali basalt trend line, but this is probably of little significance, because on the F.M.A. diagram, the trends of the calc-alkali and alkali rocks roughly coincide.

Linear Diagram (Plate III).

On the linear diagram, alumina, total iron oxide, magnesia, lime, soda, and potash are plotted against silica. The alumina values plot in a fairly uniform way, except for a small group of Manam Island specimens - this may possibly be due to a difference in analytical technique. The Karkar Island samples at a silica value of about 55% are especially rich in alumina.

The Mount Lamington lavas, as a series, are poorer in total iron oxides than the others, and slightly more rich in soda. Otherwise, the apparent trends for the oxides are fairly uniform, and are not unduly curved.

Solidification Index (Plate IV).

On the Solidification Index diagram, I have calculated and plotted trend lines for the Unalaska Island lavas (Drewes, et al. 1961), and intrusive rocks of the Batholith of Southern California (Larsen, 1948) - both of these represent the calc-alkaline series. I have also plotted trend lines for the Red Hill tholeiite series (McDougall, 1962) and the Hawaiian alkali basalt series (McDonald, 1949). The diagram shows that the New Guinea lavas (excepting those from Fergusson and Dobu Islands) are calc-alkaline. However, they do not make up one uniform curve. Rather, they branch from the Manam Island group into two curves. One is truly calc-alkaline; it consists of specimens from Mounts Lamington, Victory, and Yelia, together samples from Kadovar, Blup Blup, the ancient Manam flow, and one Karkar flow. The other curve is close to the calc-alkaline trend, but appears to have tholeiitic tendencies. It consists of Bagabag, Long Island, and most of the Karkar samples.

It is not possible to say if the Fergusson and Dobu Islands samples belong to the same general calc-alkaline group, In other parts of the world, acid peralkaline rocks are commonly associated with alkaline igneous provinces. However, it should be noted here that a sample of basaltic andesite similar to those from the north coast islands was collected from Dobu Island, suggesting that the peralkaline lavas in this area are related to the calc-alkaline suite.

REMARKS

At this stage, the writer can make few remarks on the petrogenesis of the rocks. The general appearance of the north coast lavas suggests that hybridization could have taken place. The phenocrysts in all the lavas are fairly similar in different localities, i.e., they consist of calcic plagioclase and diopsidic augite, together with olivine and/or orthopyroxene, no matter how differentiated the rocks may appear to be from their chemical analyses. Furthermore, the phenocrysts seem to be very similar to the minerals contained in the inclusions. Thus, it seems possible that the inclusions and some, at least, of the phenocrysts represent basic material contaminating an acid magma.

On the other hand, the universal stage measurements on the pyroxene phenocrysts show that they are more iron-rich, i.e., more differentiated, in the silica-rich rocks than in the basaltic types, suggesting that if they are contaminant material, they have reacted with their enclosing groundmass.

The main conclusion that can be drawn from this "reconnaissance petrology" survey of these specimens is that the variation in the composition of those from the north coast islands probably depends on two variables. First, the proportion of phenocryst and inclusion material to groundmass - it is noteworthy that the ancient Manam Island flow, the older Karkar Island flow that was analyzed, and the Long Island andesite all have relatively few phenocrysts, when compared with, for example, the more basic Manam Island specimens. Second, the stage of differentiation reached by the groundmass, and the phenocrysts in each sample.

Detailed work in the future on the lavas and pyroclasts from the young volcanoes in New Guinea could be very rewarding. The work could be approached in two ways:-

a. A regional survey of the most recent products of active, dormant and extinct volcanoes, in order to obtain an idea of the distribution of magma types in the Eastern New Guinea area.

b. Detailed stratigraphical, petrological, and chemical investigations of the individual volcanoes, in order to study the mineralogical and chemical variation of the lavas and pyroclasts in time. On an active volcano, the study would be conducted indefinitely into the future, as is being done at Kilauea, in the Hawaiian Islands (e.g., Tilley, 1960, and other papers).

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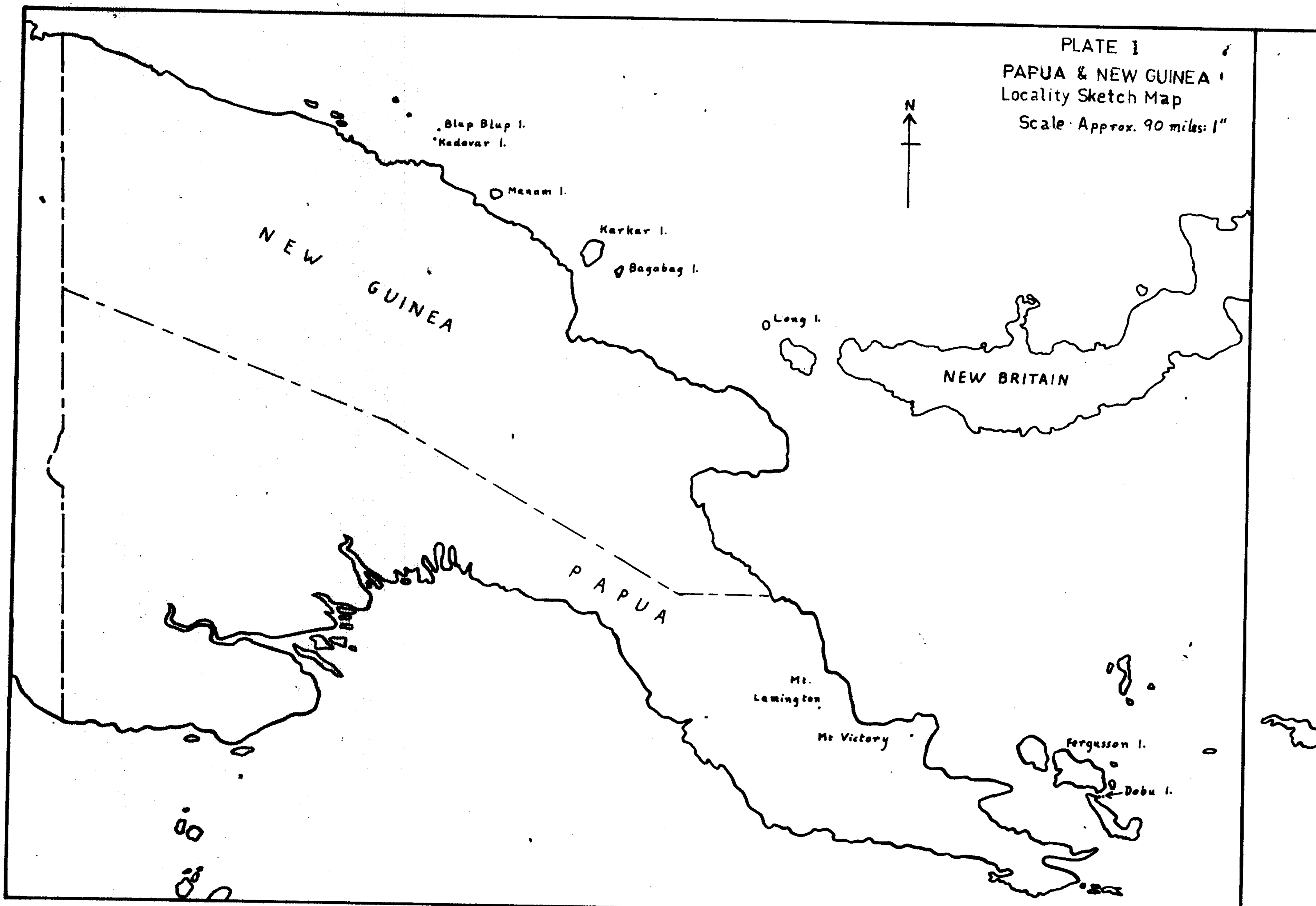


PLATE I
PAPUA & NEW GUINEA
Locality Sketch Map
Scale · Approx. 90 miles: 1"
N
Blup Blup I.
Kadovar I.
Manam I.
Karkar I.
Bagabag I.
Long I.
NEW GUINEA
NEW BRITAIN
PAPUA
Mt. Lamington
Mt Victory
Fergusson I.
Dobu I.

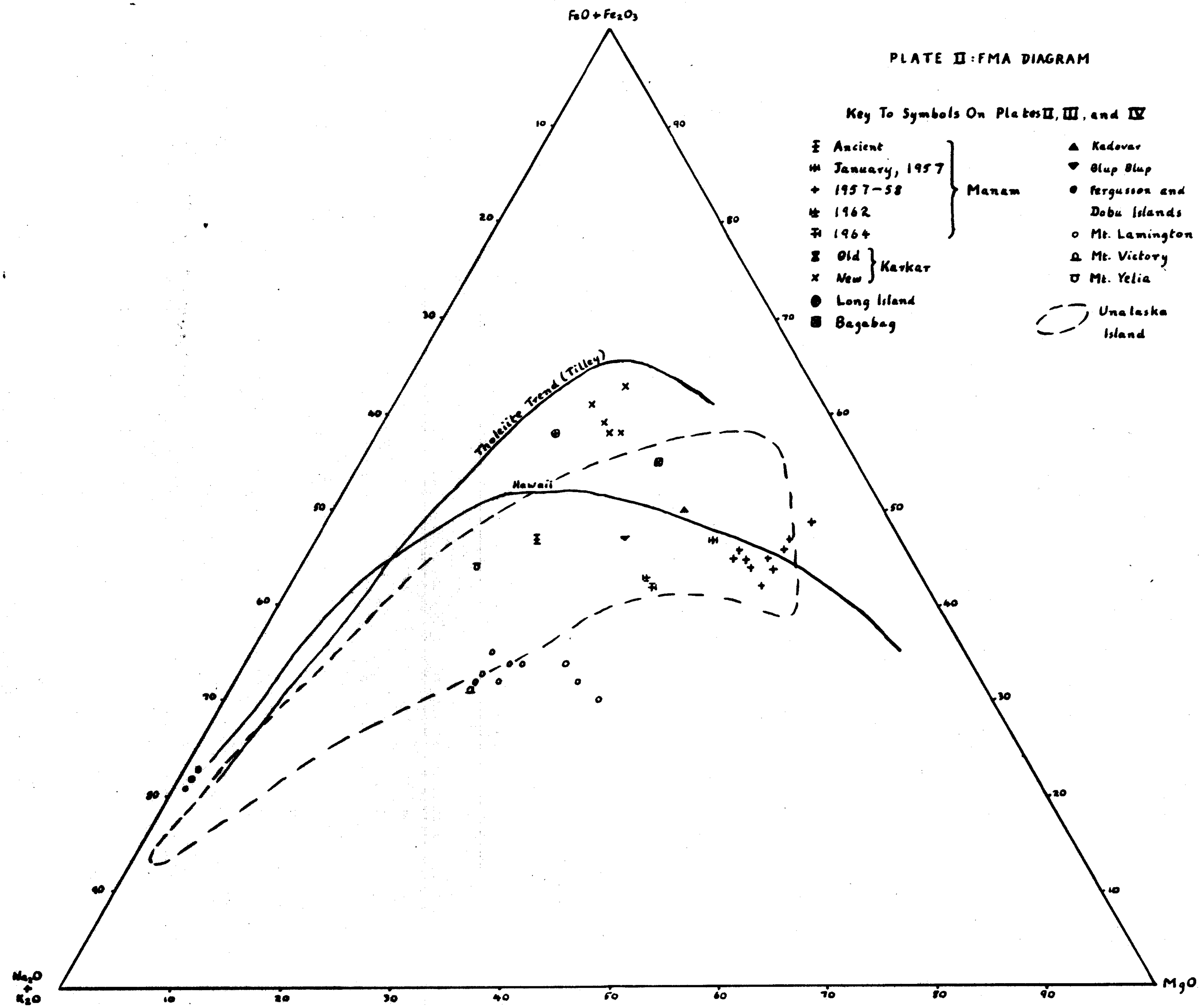


PLATE II: FMA DIAGRAM
Key To Symbols On Plates II, III, and IV
Ancient
January, 1957
1957-58
1962
1964
Manam
Old
New
Karkar
Long Island
Bagabag
Kadovar
Blup Blup
Fergusson and Dobu Islands
Mt. Lamington
Mt. Victory
Mt. Yelia
Unalaska Island
FeO + Fe2O3
Na2O + K2O
MgO
Tholeiite Trend (Tilley)
Hawaii

Plate III

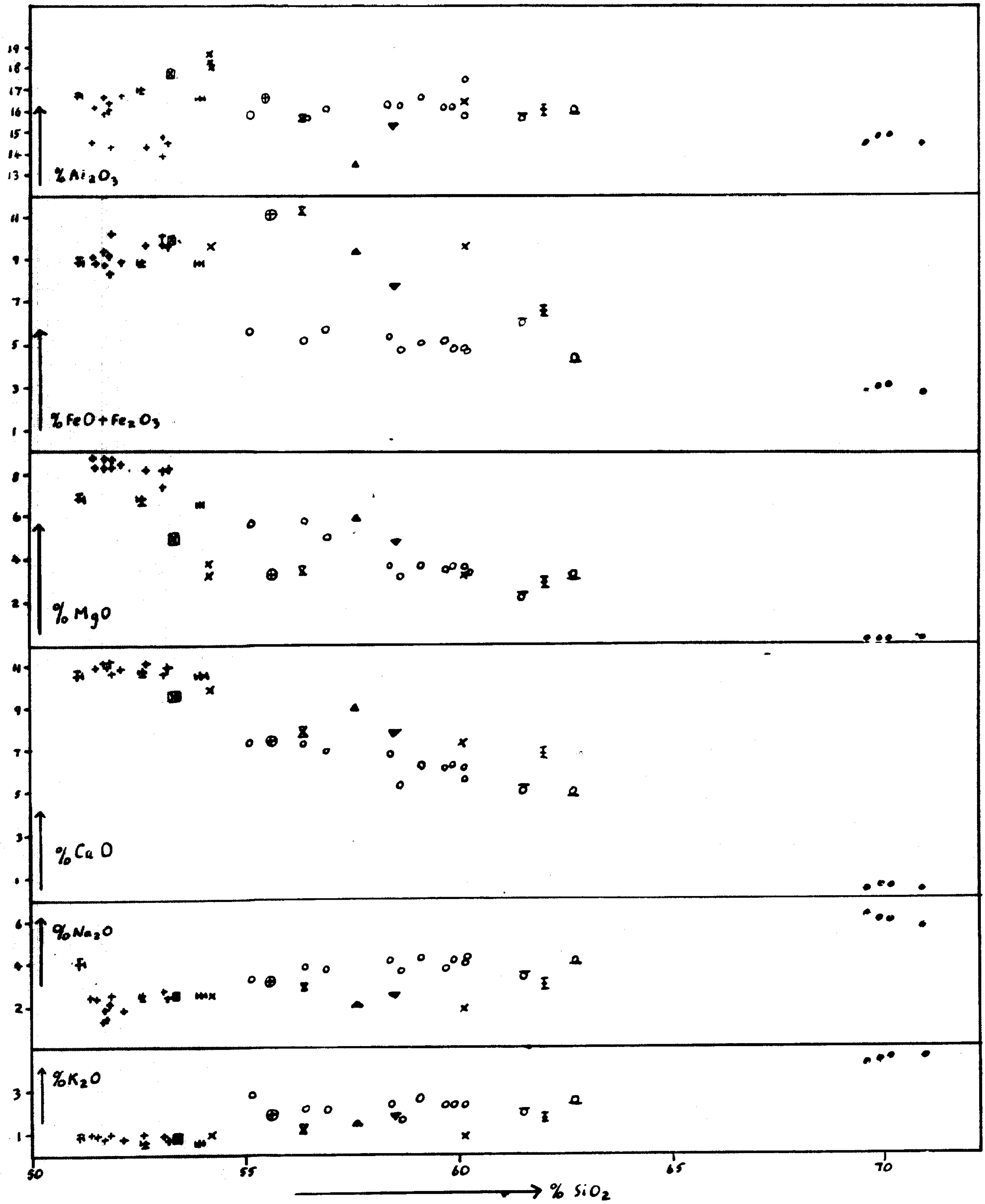
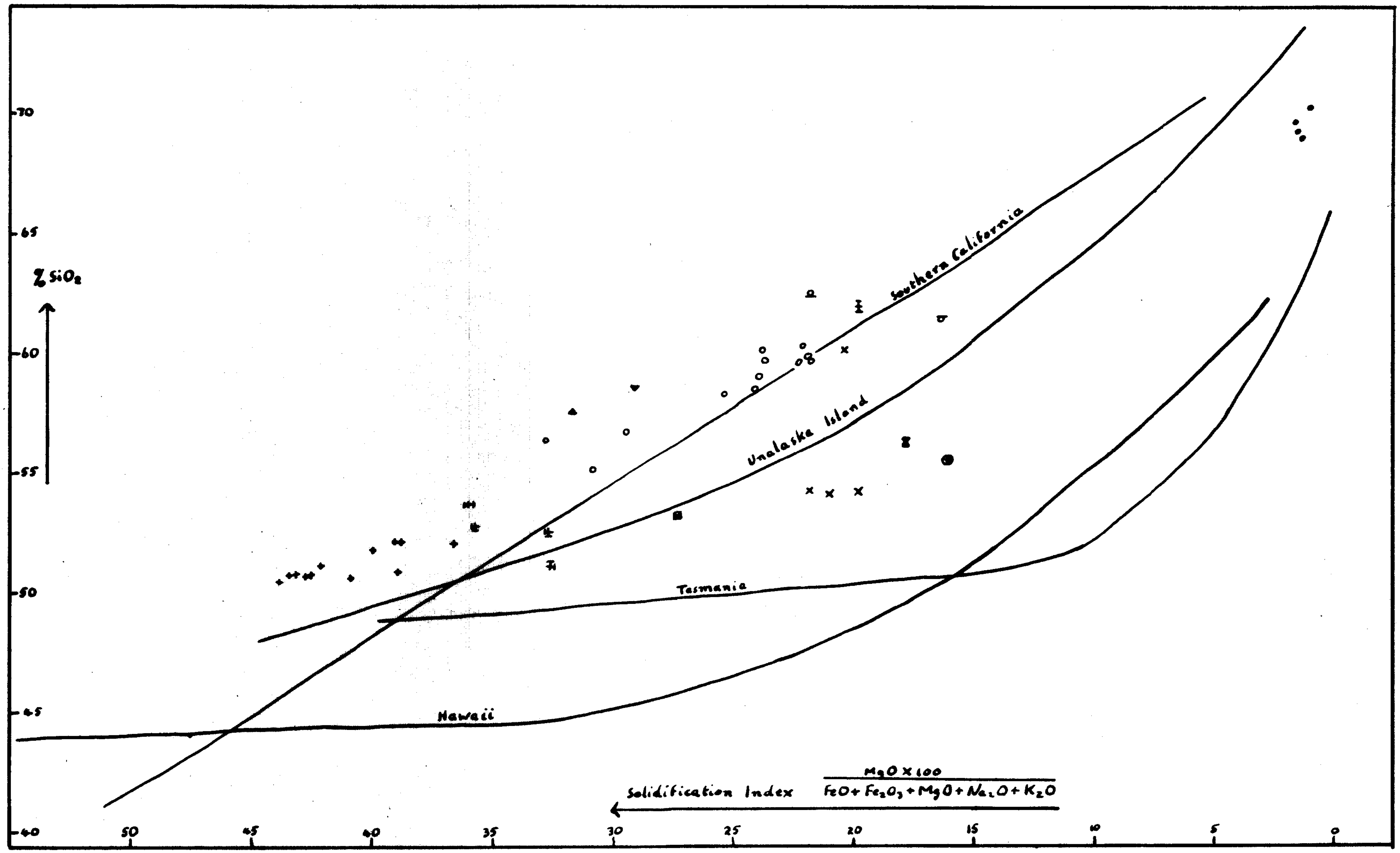


Plate IV



% SiO2
70
65
60
55
50
45
40
Southern California
Unalaska Island
Tasmania
Hawaii
Solidification Index $\frac{MgO \times 100}{FeO + Fe_2O_3 + MgO + Na_2O + K_2O}$
50
45
40
35
30
25
20
15
10
5
0