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PETROGRAPHY OF IGNEOUS ROCKS FROM AMLIA ISLAND, ALEUTIAN ISLAND ARC, ALASKA

by

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INTRODUCTION

This report presents the results of detailed microscopic examination of of igneous rock thin sections from Amlia Island of the Aleutian chain (Fig. 1), and interpretations of those data. The rocks were collected in July, 1979, as part of a larger study of island arc, forearc, and trench sedimentation and tectonics of the Amlia Corridor of the Aleutian Island Arc (Hein and McLean, 1980; McLean and others, 1981; Scholl and others, 1981; Vallier and others, 1981). These studies are designed to deduce the geologic evolution of the Aleutian Ridge by examination of the geophysical and lithologic records in a 200-km-wide corridor traversing the Aleutian Island Arc perpendicular to its axis from the Pacific Basin to the Bering Sea. Amlia Island (173°W) is included in this corridor.

Prior to the reconnaissance geology of McLean and others (1980), no geologic study of Amlia Island had been undertaken. The main thrust of the investigations in 1979 centered on sample-collection and recording of field observations and relations. Among the many samples collected that summer was a suite of forty-nine igneous rocks. A sub-suite of thirty-one samples was chosen from the forty-nine for chemical and other studies. Detailed microscopic thin section examinations of the forty-nine igneous rocks were undertaken and 500-point modal counts were performed on the thirty-one selected for chemistry. The other eighteen sections were examined in detail and percentages of mineral phases, vesicles, and amygdules were estimated using the visual percentage estimation diagram of Terry and Chilingar (1955). Rock names for the thirty-one samples selected for chemistry were derived from the chemical classification of Irvine and Baragar (1971), whereas names for the eighteen remaining samples were derived from petrographic criteria. The samples in this study were also analyzed by X-ray diffraction technique which aided in the identification of mineral phases in thin section.

GEOLOGIC SETTING

The Aleutian Ridge represents a typical ensimatic volcanic arc which is mostly submerged. The Aleutian Islands represent peaks on a generally flat-topped structure that is 2,200 km long and 200-250 km wide. Amlia Island is one of these "mountain peaks" of the Aleutian Ridge. It is near the east end of the Andreanof Island group, adjacent to Atka Island. The island is 72 km long in an east-west orientation, about 8 km wide at its maximum, and its central ridge reaches a maximum elevation of about 600 m. The topography of the island is rugged and its coastline is characterized by many seacliffs, bays, and coves. It is barren except for low summertime tundra vegetation. Although there is no active volcanism on Amlia, it is evident that volcanism was responsible for its construction. The rocks of Amlia are tilted generally ten to fifteen degrees to the south, allowing exposure of a partial stratigraphic section. Weak folding and abundant faulting are evident in the volcanic pile, and the rocks have been altered by diagenesis and low grade metamorphism. The igneous rocks range in composition from basalt through rhyolite, and the sedimentary rocks represent first cycle erosion products from a nearby volcanic landmass.

The processes which formed Amlia Island are thought to have begun in

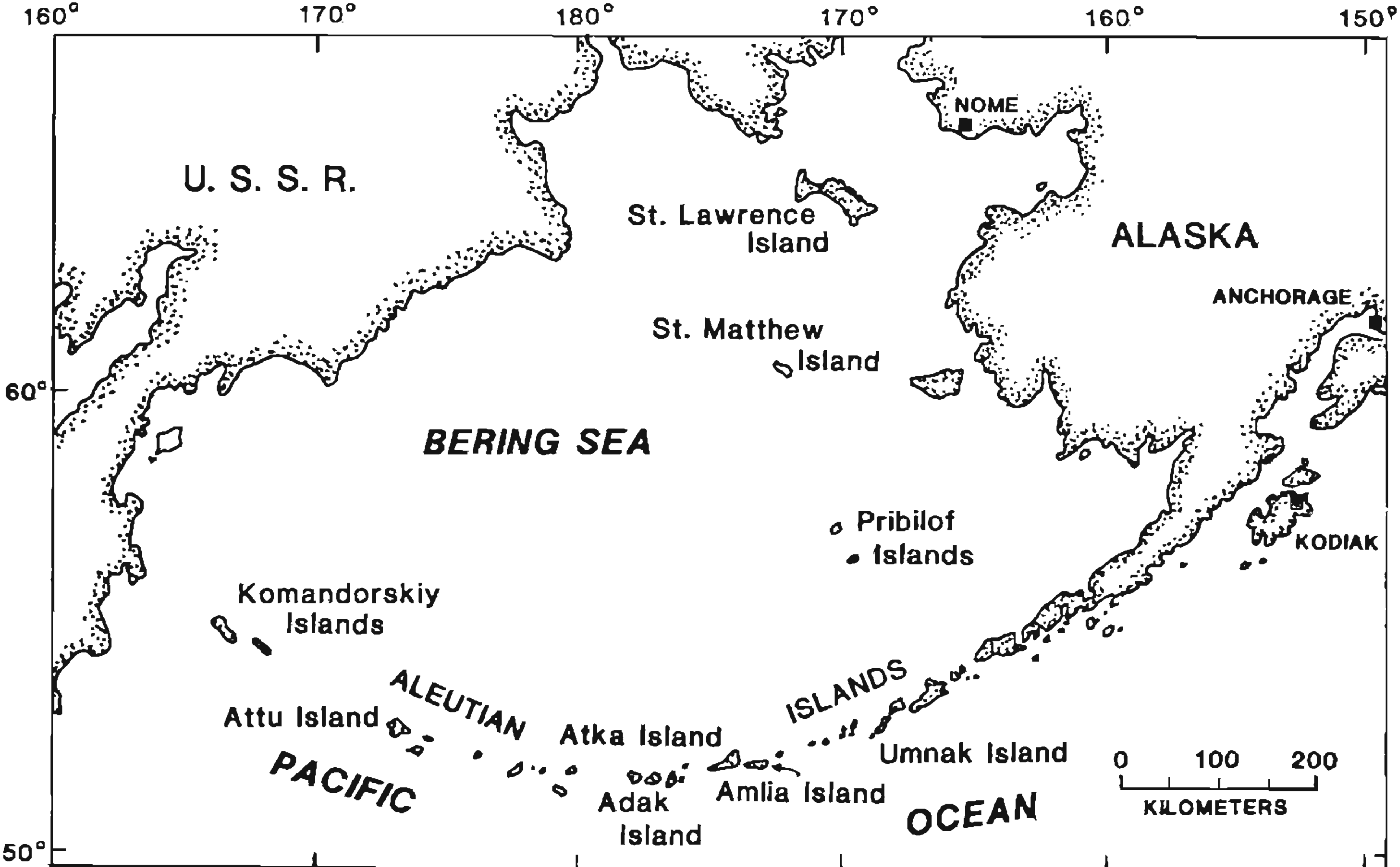

Fig. 1. Index map of the north Pacific showing the location of Amlia Island in the Aleutian Chain. (Courtesy H. McLean)

Eocene time and continued into the Neogene (McLean and others, 1981). Extrusive volcanism began the construction and intrusive activity, tectonism, and erosion/deposition cycles augmented it. The volcanic rocks of Amlia Island apparently include both submarine and subaerial, consisting of flow breccias and massive, columnar and pillowed lava flows. The intrusive rocks consist of dikes, sills, and other hypabyssal intrusions. Figure 2 is a geologic sketch map of Amlia Island, with sample localities indicated.

PETROGRAPHY

Extrusive rocks of Amlia Island include basalt, basaltic andesite, andesite, dacite, and rhyolite. The intrusive rocks include gabbro, basalt, basaltic andesite, tonalite, and dacite. The extrusive rocks are generally quite glassy, displaying much incipient crystallization and are plagioclase/pyroxene phyric. The intrusive rocks frequently have intersertal glass in the groundmass but are otherwise plagioclase/pyroxene phyric granular. All the rocks display incipient to thorough propylitic alteration.* The mineralogy of the rocks is rather constant. The main variations are in the <u>proportion</u> of minerals to one another rather than differences in mineralogy. Table 1 summarizes the primary mineralogy by rock type. All samples contain plagioclase, clinopyroxene, orthopyroxene, and Fe-Ti oxides. Primary phases which occur in only rare samples are amphibole, apatite, potash feldspar, olivine, and quartz. Most of the rocks contain phenocrysts of plagioclase, clinopyroxene, and orthopyroxene. Rocks exclusive of basalt, gabbro, and tonalite contain phenocrysts of potash feldspar and all rocks exclusive of basaltic andesite contain Fe-Ti oxide (ore) phenocrysts. Only tonalite contains primary amphibole. Primary groundmass phases include plagioclase, clinopyroxene, orthopyroxene, quartz, potash feldspar, ore, olivine, and apatite. Potash feldspar, as a groundmass phase, is found only in rhyolite and basaltic andesite. Apatite is an accessory phase in all rock types exclusive of basaltic andesite and tonalite. Olivine (totally replaced by calcite) is found only in isolated samples. Textures in the Amlia rocks are felted, hyaloophitic, hyalopilitic, hypidiomorphic granular, intergranular, intersertal, microlitic, subophitic, and subtrachytic. All the volcanic rocks are porphyritic with most samples having groundmass textures from intergranular to intersertal, tending towards hyalopilitic. Deformational textures are absent in the rocks and phase changes are restricted to simple devitrification and recrystallization. Vesicle percentages in the Amlia volcanics are rather low; most samples contain less than ten percent. Maximum vesiculation, determined by modal analyses, is thirty percent in a basalt sample taken from the north coast of the island.

Metasomatic alteration of the Amlia rocks is most evident in the groundmass glasses. In most instances, these glasses have totally devitrified to zeolites and clay minerals. Microlites and skeletal crystals of amphibole(?), analcite(?), biotite(?), celadonite, chlorite, chlorophaeite**,

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* refers to hydrothermal alteration resulting in the formation of calcite, chlorite, epidote, and similar low-grade metamorphic minerals.

** Green to greenish-brown smectite mineral of variable Fe and Mg contents, with composition between nontronite and saponite.

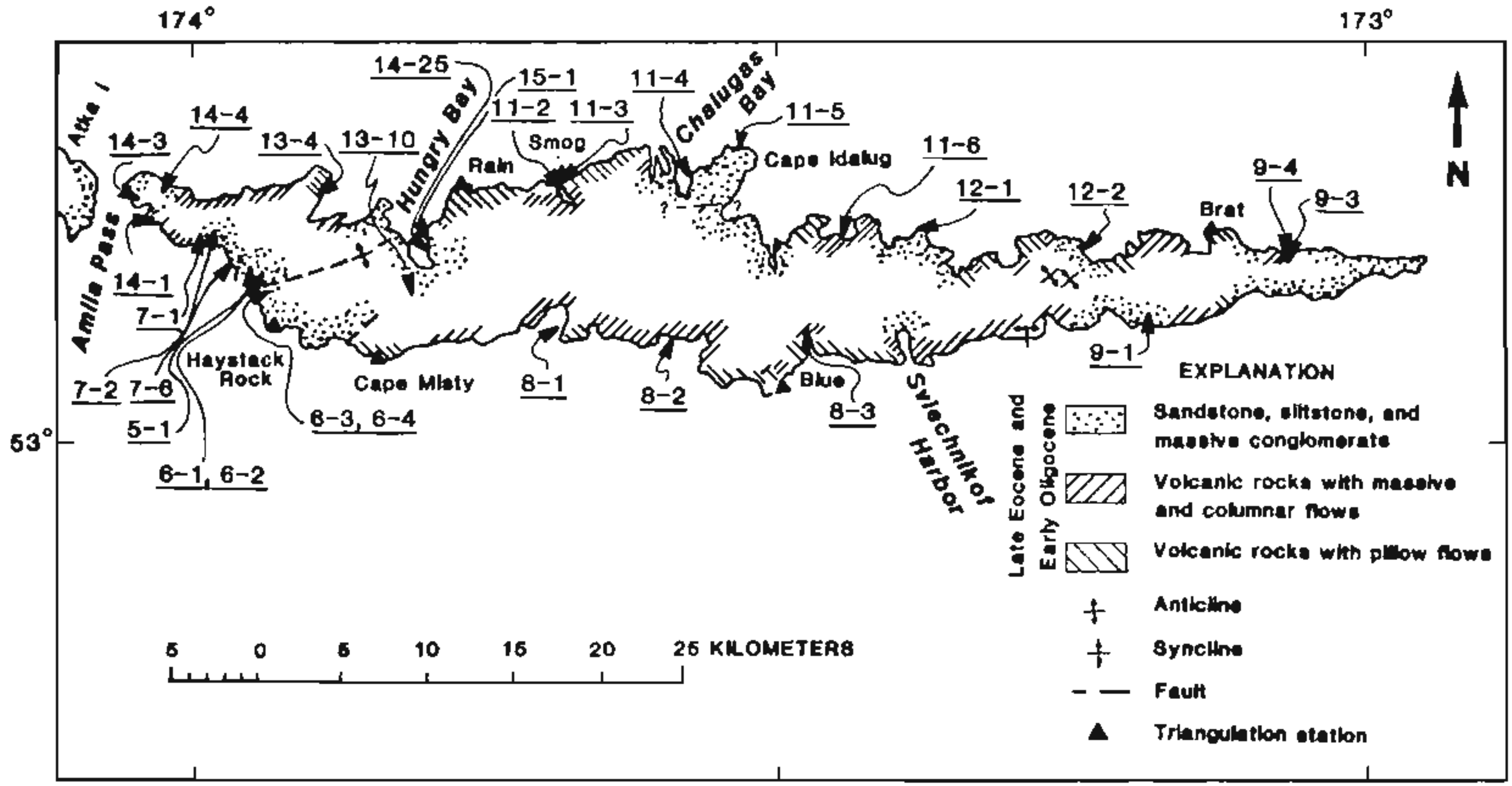

Fig. 2. Geologic Sketch Map of Amlia Island showing igneous rock sample localities. (Courtesy H. McLean)

Table 1. Summary ot primary mineralogy, igneous rocks of Amlia Island.

Extrusive Rocks

Rock Type	Phenocrysts						Groundmass								
	Clino-pyroxene	Fe-Ti oxide ore	Olivine	Ortho-pyroxene	Plagio-clase	Potash Feldspar	Apatite	Clino-pyroxene	Fe-Ti oxide ore	Glass	Olivine	Ortho-pyroxene	Plagio-clase	Potash Feldspar	Quartz
Basalt	x	x	x	x	x		x	x	x	x	x	x	x		x
Basaltic Andesite	x			x	x			x	x	x			x		x
Andesite	x	x		x	x	x	x	x	x	x		x	x		x
Dacite	x	x		x	x	x	x	x	x	x		x	x		x
Rhyolite	x	x		x	x	x	x	x	x	x		x	x	x	x

Intrusive Rocks

Rock Type	Phenocrysts						Groundmass								
	Amphi-bole	Clino-pyroxene	Fe-Ti oxide ore	Ortho-pyroxene	Plagio-clase	Potash Feldspar	Apatite	Biotite?	Clino-pyroxene	Fe-Ti oxide ore	Glass	Ortho-pyroxene	Plagio-clase	Potash Feldspar	Quartz
Basalt		x			x				x	x	x		x		x
Basaltic Andesite		x		x	x	x			x	x	x	x	x	x	x
Dacite		x	x		x		x		x	x	x	x	x		x
Gabbro		x	x	x	x		x	x	x	x	x	x	x		x
Tonalite	x	x	x	x	x				x	x		x	x		x

and other smectites, epidote(?), goethite(?), hematite, magnetite(?), pumpellyite, and zeolites are visible in various associations in almost all of the glasses. Propylitic or secondary mineral phases observed in the Amlia igneous rocks include amphibole, analcite, biotite(?), calcite, celadonite, chlorite, chlorophaeite and other smectites, epidote, goethite, hematite, kaolinite, leucoxene, prehnite(?), pumpellyite, sericite(?), and natrolite and other zeolites (Table 2). Clinopyroxene is replaced by amphibole, chlorite, smectite(?), pumpellyite(?), and chlorophaeite. Olivine is replaced by calcite, smectite, and chlorophaeite. Ore phases are replaced by hematite and leucoxene. Potash feldspar is replaced by kaolinite, pumpellyite, sericite(?), and zeolites. Orthopyroxene is replaced by calcite, chlorite, hematite, and chlorophaeite and other smectites. Plagioclase is replaced by epidote, kaolinite, prehnite(?), pumpellyite, sericite(?), smectite, and zeolites.

Deuteric activity in the form of vesicle fillings and cross-cutting veinlets is abundant in many of the rocks, particularly the extrusive rocks (Tables 3 and 4). Vesicle fillings in basalts include calcite, chlorophaeite and other smectites, quartz, natrolite(?), and other zeolites. Chlorophaeite, quartz, pumpellyite(?) and zeolite amygdules were seen in basaltic andesites. Quartz, smectite, and zeolite amygdules occur in andesites. The dacites contain only smectite amygdules, whereas the rhyolites have amygdules of chlorophaeite, quartz, and zeolites. Deuteric minerals deposited in cross-cutting veinlets cover an even larger, but similar, range of mineral phases. Veinlets containing analcite, calcite, goethite, quartz, smectite, and zeolites were observed in basalts. Andesites displayed veinlets containing hematite, manganic oxide(?) and quartz. Dacites have veinlets composed of chlorophaeite and other smectites, goethite, hematite, kaolinite, prehnite(?), quartz, natrolite(?) and other zeolites. Rhyolites showed veinlets made up of epidote(?), hematite, pumpellyite, and quartz. Table 5 summarizes all petrographic data.

PETROLOGY AND DISCUSSION

Major, minor, and trace element chemistry of selected igneous rock samples from Amlia Island are presented and discussed by McLean and others, (1981), and Vallier and others, (1981; in preparation). In this study, an attempt is made to document the distribution and alteration of primary phases in the igneous rocks of Amlia Island through space and time, and to suggest mechanisms for the origin and subsequent metamorphism of these phases.

The rocks have calc-alkaline/tholeiitic mineral assemblages when reconstructed by chemical and normative techniques (Vallier and others, 1981). The range and distribution of the component phases are rather remarkable, however, in that mafic minerals like clinopyroxene, are often abundant in the rhyolites, and minerals such as quartz are often abundant even in basalt. Both phenocryst and groundmass plagioclase compositions determined by the optical method of Michel-Levy, have high anorthite content characteristic of plagioclase of the tholeiitic suite. Even higher anorthite contents were obtained by microprobe analysis. Table 6 summarizes microprobe analyses of plagioclase in selected Amlia samples.

Potash feldspar was identified by the presence of solitary Carlsbad twinning and axial angles (2E) of less than 40°. They are probably potassium-

Table 2. Mineral phase replacement, igneous rocks of Amlia Island

								Extrusive Rocks							
Rock Type	Amphibole? replaces	Analcite? replaces	Biotite? replaces	Calcite replaces	Celadonite replaces	Chlorite replaces	Chlorophaeite replaces	Epidote replaces	Hematite replaces	Kaolinite replaces	Leucoxene replaces	Pumpellyite replaces	Sericite? replaces	Smectite (alkali) replaces	Zeolites (undiff.) replaces
Basalt	cpx Glass	Glass plag		Olivine opx		Glass opx	Glass Olivine opx	Glass plag	Fe-Ti oxide (ore)	plag	Fe-Ti oxide (ore)	Glass plag	plag	cpx Glass opx plag	Glass plag
Basaltic Andesite			Glass	opx		Glass opx	cpx Glass opx		Fe-Ti oxide (ore)		Fe-Ti oxide (ore)	cpx Glass plag	plag	Glass opx	Glass
Andesite	cpx Glass			opx	Glass	Glass opx	Glass opx	plag	Glass opx	plag		Glass plag	plag	cpx Glass opx plag	Glass plag
Dacite							cpx Glass		Fe-Ti oxide (ore)	plag	Fe-Ti oxide (ore)	Glass	plag	Glass opx	Glass
Rhyolite					Glass		cpx Glass opx	plag	cpx Fe-Ti oxide (ore) Glass opx	plag	Fe-Ti oxide (ore)	cpx Glass opx plag	plag	Glass opx	Glass plag

Table 2. (Continued).

Intrusive Rocks													
Rock Type	Amphibole replaces	Biotite? replaces	Calcite replaces	Chlorite replaces	Chlorophaeite replaces	Hematite replaces	Kaolinite replaces	Leucoxene replaces	Prehnite? replaces	Pumpellyite replaces	Sericite? replaces	Smectite (alkali replaces)	Zeolites (Undif) replaces
Basalt					Glass		plag				plag	Glass plag	
Basal-tic Andes-ite		Glass	opx	Glass opx	opx			Fe-Ti oxide (ore)		Glass plag cpx	plag	Glass	Glass
Dacite					Glass opx	Fe-Ti oxide (ore)		Fe-Ti oxide (ore)	plag		plag		
Gabbro	cpx			cpx opx		Fe-Ti oxide (ore)	plag	Fe-Ti oxide (ore)			plag	cpx Glass opx plag	Glass
Tonalite					opx		plag	Fe-Ti oxide (ore)		plag	plag		plag

Table 3. Deuteric mineral veinlet distribution, extrusive rocks of Amlia Island.

Rock Type	Mineralogy Analcite	Calcite	Chloro-phaeite	Epidote?	Goethite	Hematite	Kaolinite	Manganic Oxide?	Natro-lite?	Preh-nite?	Pumpe-llyite	Quartz	Smectite (alkali)	Zeolites (undiff.)
Basalt	x	x			x							x	x	x
Andesite						x		x				x		
Dacite			x		x		x		x	x		x	x	x
Rhyolite				x		x		x			x	x		

Table 4. Mineralogy and distribution of amygdules in the extrusive rocks of Amlia Island.

Rock Type	Mineralogy Calcite	Chloro-phaeite	Chlorite	Natro-lite?	Pumpel-lyite?	Quartz	Smectite	Zeolites (undiff)
Basalt	x	x	x	x		x	x	x
Basaltic andesite		x			x	x		x
Andesite						x	x	x
Dacite							x	
Rhyolite		x				x		x

Table 5. Thin Section Petrography, Igneous Rocks of Amlia Island. Components are given in volume percent. Phenocrysts plus groundmass components represent primary minerals. Alteration component percentages are from petrographic analyses. Point counts, 300 per thin section.

No.	Sample Number	Rock Types	Texture	Phenocrysts [2] Component	Percent	Groundmass Component	Percent	Vesicles/Amygdules Filling	Percent	Phenocrysts [3] Component	Percent	Groundmass Component	Percent	Alteration [4] Alteration Component	Primary Component	Percent	Remarks
1.	779-5-1	Basaltic andesite [1]	Intersertal	Plagioclase	13	Plagioclase	59	Quartz	7	Plagioclase	12	Plagioclase	47	Smectite	Glass	24	Dike, ~2m thick, SW coast of island. Plagioclase is glomerophyric with light brown to neutral, altered cpx and totally altered opx(?), and is strongly zoned; glass is totally altered.
				Orthopyroxene(?)	1	Glass	26			Orthopyroxene(?)	<1	Glass	26	Chlorite	Glass, opx(?)	2	
				Clinopyroxene	<1	Clinopyroxene	10			Clinopyroxene	<1	Clinopyroxene	11	Calcite	Orthopyroxene(?)	<1	
						Ore	4					Ore	7				
						Orthopyroxene(?)	1					Orthopyroxene(?)	1				
				Total [2]		99+				Total		100+					
2.	779-6-1A	Basalt	Intersertal	Plagioclase	30	Plagioclase	22	Chlorophaeite	10	Plagioclase	33	Plagioclase	24	Zeolites	Glass, plag.	28	Flow rock clast in volcanic breccia, SW coast of island. Plagioclase is unit phyric* and is highly zeolitized along stress cracks; cpx is fresh, neutral in color, and unit phyric; opx(?) is totally altered and unit phyric; glass is totally altered.
				Orthopyroxene(?)	8	Clinopyroxene	14	Calcite		Orthopyroxene(?)	9	Clinopyroxene	16	Chlorophaeite	opx(?), glass	4	
				Clinopyroxene	1	Glass	8	Zeolites		Clinopyroxene	1	Glass	9	Calcite	Orthopyroxene(?)	3	
						Ore	6					Ore	7				
						Orthopyroxene(?)	1					Orthopyroxene(?)	1				
				Total [2]		100				Total		100					
2.	779-6-1B	Basalt	Intergranular to intersertal	Plagioclase	35	Plagioclase	15	Zeolites	20	Plagioclase	44	Plagioclase	19	Zeolites	Glass, plag.	35	Clast in volcanic breccia described above. Plagioclase is unit phyric, strongly zoned and zeolitized along stress cracks; cpx is unit phyric, neutral in color, with a yellowish tinge, and shows evidence of resorption; opx (?) is unit phyric and totally altered; glass is totally altered.
				Clinopyroxene	1	Clinopyroxene	10	Chlorite		Clinopyroxene	1	Clinopyroxene	13	Chlorophaeite	opx(?), glass	10	
				Orthopyroxene(?)	<1	Glass	10	(60% are empty)		Orthopyroxene(?)	<1	Glass	13				
						Ore	8					Ore	10				
				Total [2]		99+				Total		100+					
4.	779-6-2	Andesite [1]	Hyalopilitic	Plagioclase	11	Glass	34	None						Chlorite	Glass, opx(?)	6	Pillow lava, individual pillows ~1-2m in dia., SW coast of island. Plagioclase is glomerophyric with itself. orthoclase(?), cpx, opx(?), and ore, is rarely unit phyric, is kaolinitized and saussuritized; orthoclase(?) is glomerophyric, and altered; cpx is fresh, yellowish to greenish-neutral in color, is usually glomerophyric but also rarely unit phyric; opx(?) is glomerophyric and totally altered; ore is microglomerophyric; matrix phases are largely microlitic, set in highly altered quartz-charged glass.
				Orthoclase(?)	3	Plagioclase	21							Zeolites	Feldspars, glass	6	
				Clinopyroxene	2	Quartz	19							Smectite	Glass, opx(?)	1	
				Ore	1	Clinopyroxene	6							Kaolinite	Feldspars	<1	
				Orthopyroxene(?)	<1	Ore	2							Epidote	Feldspars	<1	
				Total [2]		99+								Pumpellyite(?)	Feldspars	<1	
														Calcite	Orthopyroxene(?)	<1	
														Hematite	Glass	<1	
5.	779-6-3C	Andesite [1]	Hyalopilitic	Plagioclase	10	Glass	41	Zeolites	9(?)	Plagioclase	11	Glass	46	Smectite	Glass, opx(?)	15	Massive flow interbedded with coarse sandstone, SE coast of island. Plagioclase is glomerophyric with fresh, pale smoky yellow cpx and totally altered opx(?); glass is totally altered.
				Clinopyroxene	3	Plagioclase	21	Quartz		Clinopyroxene	3	Plagioclase	24	Zeolites	Glass, plag.	5(?)	
				Orthopyroxene(?)	1	Clinopyroxene	9	(may be part of the matrix)		Orthopyroxene(?)	1	Clinopyroxene	10	Quartz	(devitric)	4	
						Ore	3					Ore	3	Sericite(?)	Plagioclase	2	
						Orthopyroxene(?)	2					Orthopyroxene(?)	2				
				Total [2]		99+				Total		100					

1)Chemical classification of Irvine and Baragar (1971). Remainder are classified petrographically.
2)Phenocrysts + groundmass + vesicles = 100%. 3)Normalized percentages where vesicle percentages are >2. 4)Total alteration of all phases.

* distinguishes single phenocrysts from clustered phenocrysts.

Table 3. cont.

No.	Sample	Rock	Texture	Phenocrysts	%	Minerals	%	Secondary	%	Phenocrysts	%	Minerals	%	Alteration product	Replacing	%	Remarks
6.	779-4-a	Basaltic andesite 1)	Intersertal	Plagioclase Clinopyroxene Orthoclase(?) Orthopyroxene(?) Total 2)	12 9 3 <1	Plagioclase Orthoclase(?) Glass Clinopyroxene Ore Quartz Orthopyroxene(?) 99+	31 15 13 7 6 3 <1	Zeolites	2	Plagioclase Clinopyroxene Orthoclase(?) Orthopyroxene(?) Total	12 9 3 <1	Plagioclase Orthoclase(?) Glass Clinopyroxene Ore Quartz Orthopyroxene(?)	32 16 13 7 6 1 <1 99+	Chlorite Zeolites Pumpellyite(?) Leucoxene Biotite(?) Sericite(?)	Glass,opx(?) Glass Pla.,glass,cpx Ore Glass Plagioclase	12 7 2 2 1 1	Dike, about 4m wide. NW coast of island. Plagioclase and orthoclase(?) are unit phyric and also often glomerophyric with each other, and also with very fresh, pale smoky yellow cpx and totally altered opx(?); glass is totally altered.
7.	779-7-1	Basalt	Hyalopilitic	Plagioclase Clinopyroxene Orthopyroxene(?) Total 2)	15 6 3	Glass Plagioclase Clinopyroxene Ore Orthopyroxene(?) 100	25 13 11 6 1	Zeolites	18	Plagioclase Clinopyroxene Orthopyroxene(?) Total	19 8 4	Glass Plagioclase Clinopyroxene Ore Orthopyroxene(?) 100	30 16 16 8 1	Smectite Zeolites Calcite Sericite(?)	Glass Glass, Plag. Orthopyroxene(?) Plagioclase	25 15 4 1	Pillow lava interior, extreme NW coast of island. Plagioclase is glomerophyric with fresh, neutral-colored cpx, and includes glass; opx(?) is unit phyric and totally altered; glass is totally altered.
8.	779-7-4a	Basalt	Intersertal	Plagioclase Orthopyroxene(?) Clinopyroxene Total 2)	34 5 2	Plagioclase Clinopyroxene Glass Ore Orthopyroxene(?) 100+	21 20 15 6 <1	Calcite Smectite	1	Plagioclase Orthopyroxene(?) Clinopyroxene Total	30 5 2	Plagioclase Clinopyroxene Glass Ore Orthopyroxene(?) 99+	33 20 15 6 <1	Smectite Calcite	Opx(?), glass Orthopyroxene(?)	20 5	Pillow lava, extreme NW coast of island. Plagioclase is glomerophyric with itself and with cpx, and includes glass; opx(?) is glomerophyric with itself or with cpx only, and is totally altered to calcite rimmed with smectite, cpx is neutral in color and shows evidence of resorption; glass is totally altered; rock texture is locally hyalopilitic (around vesicles).
9.	779-3-4d	Basalt 1)	Subophitic to intersertal	Plagioclase Orthopyroxene(?) Clinopyroxene Total 2)	27 4 1	Glass Plagioclase Clinopyroxene Ore Orthopyroxene(?) 100+	27 16 16 7 <1	Smectite	2	Plagioclase Orthopyroxene(?) Clinopyroxene Total	20 4 1	Glass Plagioclase Clinopyroxene Ore Orthopyroxene(?) 100+	30 14 16 7 <1	Smectite Calcite Sericite(?)	Glass,opx(?) Orthopyroxene(?) Plagioclase	31 <1 <1	Top of pillowed lava flow, same locality as above. Plagioclase is mostly unit phyric, is strongly zoned and complexly twinned; some of it is glomerophyric with cpx and includes glass; cpx is either unit phyric or is glomerophyric with totally altered opx(?), rare microphenocrysts of ore are glomerophyric with each other only and show evidence of resorption; glass is totally altered.
10.	779-8-1a	Dacite 1)	Hyalopilitic	Plagioclase Clinopyroxene Orthoclase(?) Ore Total 2)	2 2 <1 <1	Glass Quartz Plagioclase Clinopyroxene Ore Apatite Orthopyroxene(?) 99+	53 18 16 4 2 <1 <1	Zeolites	1	Plagioclase Clinopyroxene Orthoclase(?) Ore Total	2 2 <1 <1	Glass Quartz Plagioclase Clinopyroxene Ore Apatite Orthopyroxene(?) 100+	51 18 16 4 3 <1 <1	Zeolites Smectite Sericite(?) Kaolinite Pumpellyite(?)	Glass Glass Plagioclase Plagioclase Glass	35 25 1 <1 <1	Massive thick flow with columnar jointing, south coast of island along east side of first bay west of Sharp Point. Plagioclase and orthoclase(?) are glomerophyric with each other and with the other phyric phases as well; cpx is neutral in color and quite fresh; opx is totally altered, glass is totally altered, apatite observed in the matrix.

Table 5. cont.

11.	77B-8-1B	Andesite[1)]	Hyalopilitic	Plagioclase Clinopyroxene Orthopyroxene Orthoclase(?) Ore Total [2)]	4 2 <1 <1 <1	Glass Plagioclase Clinopyroxene Orthopyroxene Ore 99+	59 12 12 5 1	Zeolites	2	Plagioclase Clinopyroxene Orthopyroxene Total	6 7 <1	Glass Plagioclase Clinopyroxene Orthopyroxene Ore 99+	61 12 12 5 1	Zeolites Smectite Sericite(?)	Glass Glass, opx Plagioclase	58 30 <1	Clast in volcanic breccia, same locality as above. Plagioclase and rare orthoclase(?) are unit phyric and also infrequently glomerophyric with each other and with other phyric phases; cpx, along with other phyric phases, is frequently subhedral, neutral in color, and often includes ore and apatite; opx is almost totally altered; glass is is extensively altered and crowded with spherulitic microlites.
12.	77B-8-2A	Tonalite[1)]	Porphyritic granular	Plagioclase Orthopyroxene(?) Ore Clinopyroxene Amphibole Total [2)]	8 2 2 1 1	Plagioclase Quartz Orthopyroxene(?) Ore Clinopyroxene 99+	70 19 3 3 1	Quartz (lining)	<1					Chlorophaeite Kaolinite Pumpellyite(?) Zeolites Sericite(?)	Orthopyroxene(?) Plagioclase Plagioclase Plagioclase Plagioclase	5 2 2 <1 <1	Massive sill, 3 m thick, south side of island in first bay east of Sharp Point. Highly altered plagioclase is glomerophyric with totally altered opx(?), fresh embayed, yellowish cpx, and microphyric, subhedral ore; rare prisms of greenish-yellowish amphibole are associated with the opx(?), anhedral quartz is abundant in the matrix.
13.	77B-8-2B	Tonalite[1)]	Porphyritic granular	Plagioclase Clinopyroxene Orthopyroxene(?) Ore Total [2)]	19 1 1 <1	Plagioclase Quartz Ore Orthopyroxene(?) Clinopyroxene 100+	56 14 1 2 <1	Rarely quartz, usually empty	4	Plagioclase Clinopyroxene Orthopyroxene(?) Ore Total	30 1 1 <1	Plagioclase Quartz Ore Orthopyroxene(?) Clinopyroxene 100+	34 15 3 2 <1	Kaolinite Chlorophaeite Sericite(?) Zeolites	Plagioclase Orthopyroxene(?) Plagioclase Plagioclase	5 4 <1 <1	Massive sill, same as 8-2A. Plagioclase is glomerophyric with itself or with fresh, neutral-colored cpx, totally altered opx(?), and rarely with subhedral ore; quartz is abundant interstitially in the groundmass.
14.	77B-8-2C	Tonalite[1)]	Porphyritic granular	Plagioclase Clinopyroxene Orthopyroxene(?) Total [2)]	24 3 1	Plagioclase Quartz Ore Clinopyroxene Orthopyroxene(?) 100	64 21 2 2 1	Quartz Zeolites	<1					Pumpellyite(?) Kaolinite Chlorophaeite Zeolites Sericite(?) Leucoxene	Plagioclase Plagioclase Orthopyroxene(?) Plagioclase Plagioclase Ore	6 5 2 1 <1 <1	Massive sill, same as 8-2A. Zeolitized plagioclase is glomerophyric with fresh, skeletal, neutral-colored cpx and totally altered opx(?); opaques display two distinct grain sizes; matrix texture is microlitic in part; quartz occurs as tiny blebs disseminated abundantly through the groundmass.
15.	77B-8-3A	Andesite[1)]	Intergranular	Plagioclase Clinopyroxene Orthopyroxene(?) Ore Total [2)]	12 6 3 <1	Plagioclase Glass Quartz Clinopyroxene Ore Orthopyroxene(?) 99+	42 21 9 4 3 <1	None						Smectite Kaolinite Zeolites Sericite(?) Smectite Pumpellyite(?)	Glass, opx(?) Plagioclase Glass Plagioclase Glass (OutZaric)	19 10 5 1 <1 <1	Massive flow, lower part of first flow from bay east of Blue Point. Plagioclase is glomerophyric with ore and almost colorless cpx, and is highly sassed and kaolinitized; opx(?) is totally altered and almost exclusively glomerophyric with cpx; matrix phases are almost microlitic and the ore phases range from dendritic to granular in two distinct grain sizes; matrix opx(?) is totally altered and difficult to distinguish from totally altered glass; quartz appears as blebs in the glass.

Table 1.cont.

16. 779-6-3B	Andesite(?)	Intergranular	Plagioclase Clinopyroxene Orthopyroxene Ore Total 2)	3 3 2 1	Plagioclase Orthopyroxene(?) Ore Glass Clinopyroxene Quartz 100	50 25 16 2 1 1	None						Smectite Zeolites Sericite(?)	Glass, opx(?) Plagioclase Plagioclase	23 7 <1	Massive flow, lower part of second flow, same locality as 8-3A. Plagioclase is glomerophyric with all other phyric phases; cpx is very fresh, nearly colorless, and often unit phyric, including microphyric ore; opx(?) is highly to totally altered, faintly pleochroic from pinkish to greenish in unaltered parts, usually glomerophyric, rarely unit phyric, and then rimmed with cpx; glass and matrix opx(?) are totally altered and difficult to distinguish.
17. 779-6-3C	Basaltic andesite 1)	Intergranular	Plagioclase Clinopyroxene Total 2)	3 <1	Plagioclase Clinopyroxene Glass Ore 99+	46 19 15 12	Pumpellyite(?) Zeolites	1	Plagioclase Clinopyroxene Total	3 <1	Plagioclase Clinopyroxene Glass Ore 100	47 19 15 12	Hematite Chlorite Pumpellyite Natrolite(?) Sericite(?)	Ore Glass Glass,plag. (Deuteric) Plagioclase	12 11 4 <1 <1	Massive flow, upper part of second flow, same locality as 8-3A. Plagioclase is unit phyric and also glomerophyric with almost colorless, internally deformed, fresh cpx; matrix cpx is the freshest phase, but matrix ore is totally altered to red, translucent hematite.
18. 779-9-1A	Basaltic andesite 3)	Intersertal	Plagioclase Clinopyroxene Orthopyroxene(?) Total 2)	7 1 <1	Plagioclase Glass Clinopyroxene Ore Quartz 100+	24 21 19 6 3	Zeolites Chlorophaeite	17	Plagioclase Clinopyroxene Orthopyroxene(?) Total	6 1 <1	Plagioclase Glass Clinopyroxene Ore Quartz 99+	31 25 21 7 4	Chlorophaeite Zeolites Sericite(?) Hematite	Opx(?),cpx,glass Glass Plagioclase Ore	16 1 <1 <1	Massive, columnar flow just west of Conma Point, south side of island. Plagioclase is glomerophyric with itself, less frequently with cpx and opx(?); cpx is usually unit phyric and neutral in color; opx(?) is usually glomerophyric with plagioclase, totally altered and quite rare, matrix phases' grain sizes and textures vary markedly within the section; glass is totally altered and bears minor quartz.
19. 779-9-1B	Basalt 1)	Intersertal	Clinopyroxene Total 2)	2	Plagioclase Glass Clinopyroxene Ore Quartz 98+	48 22 17 4 3	Smectite	<1	Clinopyroxene Total	2	Plagioclase Glass Clinopyroxene Ore Quartz 100	49 23 17 4 3	Smectite	Glass, plag.	22	Dike, same location as 9-1A. Clinopyroxene is microphyric, neutral in color, strongly sector-zoned, and often partially encloses matrix phases; matrix plagioclase is reticulated with smectite-filled fractures, ore phases are frequently skeletal; glass is totally altered and bears minor quartz.
20. 779-9-3A	Basalt (?)	Hyalopilitic	Plagioclase Orthopyroxene Ore Clinopyroxene Total 2)	5 3 2 1	Glass Plagioclase Clinopyroxene Orthopyroxene Ore 100	56 15 15 2 2	None						Smectite Zeolites Natrolite(?) Goethite(?)	Glass Glass,deuter. (Deuteric) (Deuteric)	5 2 2 2	Glassy selvage of pillow lava, first bay west of East Base on north side of island. Plagioclase is glomerophyric with all other phyric phases, is strongly zoned, and remarkably fresh; cpx is neutral in color and shows evidence of resorption; opx is remarkably fresh and faintly pleochroic from pinkish to greenish; ore is glomerophyric with itself as well as all other phyric phases; glass is mahogany brown in color and only partially altered, displaying numerous perlitic fractures.

Table 5.cont.

21. 77P-9-3B	Dacite [1]	Hyalopilitic	Plagioclase	4	Glass	55	Zeolites	3	Plagioclase	4	Glass	57	Zeolites	Glass	15	Pillow lava interior, same locality as 9-3A. Plagioclase is glomerophyric mostly with itself, less frequently with cpx, opx, and ore; cpx is neutral in color and glomerophyric with all other phyric phases; opx is quite fresh and is faintly pleochroic from pinkish to greenish; matrix ore displays three distinct grain sizes; quartz appears as blebs in glass which is charged with hematite dust.
			Clinopyroxene	1	Plagioclase	18	(Veinlets)		Clinopyroxene	1	Plagioclase	19	Hematite	Glass	5	
			Orthopyroxene	<1	Clinopyroxene	9	Smectite	<1	Orthopyroxene	<1	Clinopyroxene	9	Smectite	Glass,Opx	2	
					Quartz	9	Zeolites				Quartz	9	Goethite	(Deuteric)	<1	
					Ore	1					Ore	1				
			Total [2]		100+				Total		100+					
22. 77P-9-4A	Rhyolite [1]	Intergranular	Orthoclase (?)	4	Glass	48	None						Pumpellyite	Glass, cpx	8	Pillow lava interior, near locality 9-3A. Orthoclase(?) and plagioclase are both unit phyric and glomerophyric with cpx, opx, and ore; cpx is yellowish and includes microphyric ore; opx is most often unit phyric and ranges from quite fresh to totally altered; matrix orthoclase(?) occurs as short laths; matrix ore and plagioclase display two distinct grain sizes and the ore is highly altered; glass is totally altered.
			Plagioclase	1	Plagioclase	26							Zeolites	Glass	5	
			Clinopyroxene	1	Quartz	13							Smectite	Ore	<1	
			Orthopyroxene	<1	Clinopyroxene	6							Leucoxene	Ore	<1	
					Orthoclase(?)	4										
					Ore	3										
			Total [2]		100+											
23. 77P-11-2	Gabbro [1]	Hypidiomorphic granular			Plagioclase	72	None						Kaolinite	Plagioclase	11	Small hypabyssal pluton from second small bay west of Smog Point, north side of island. Plagioclase is highly altered, and reticulated with fractures; cpx occurs as unit crystals or as clusters composed of ore, opx, and and rare apatite. It is peripherally amphibolized and includes microlites of apatite; ore phases are skeletal in aspect.
					Clinopyroxene	16							Smectite	Opx, cpx	7	
					Orthopyroxene	7							Sericite(?)	Plagioclase	4	
					Ore	4							Amphibole	Cpx	<1	
					Apatite	<1										
					Quartz	<1										
			Total [2]		100											
24. 77P-11-3	Basalt [1]	Intergranular	Plagioclase	11	Plagioclase	51	None						Smectite	Glass,opx(?),cpx	7	Pillow lava interior, near Smog Point, north side of island. Plagioclase is unit phyric, strongly zoned, and includes totally altered glass, altered matrix ore, and fresh, neutral-colored matrix cpx; cpx phenocrysts are glomerophyric with each other and also with totally altered opx(?), and often include matrix plagioclase and totally altered glass; matrix plagioclase is fresher than phyric plagioclase, and includes rare microlites of apatite; ore is skeletal in aspect; all glass is totally altered.
			Clinopyroxene	1	Clinopyroxene	26							Chlorophaeite	Glass	6	
			Orthopyroxene(?)	1	Glass	6							Chlorite	Glass	6	
					Ore	5							Kaolinite	Plagioclase	3	
					Quartz	2							Sericite(?)	Plagioclase	<1	
					Orthopyroxene(?)	2							Amphibole	Cpx	<1	
					Apatite	<1										
			Total [2]		100											

Table 1 contd.

25. 779-11-4A Basalt 1)	Intergranular	Plagioclase	35	Plagioclase	38	Chlorite	1	Plagioclase	36	Plagioclase	30	Chlorite	Opx(?), glass	6	Massive flow from east side of Chalugas Bay, north side of island. Plagioclase is massively glomerophyric with itself and ore, totally altered opx(?), includes matrix phases and totally altered glass, and is kaolinitized and sericitized; matrix plagioclase is also altered similarly. ore is skeletal to dendritic in aspect and is highly altered; glass is totally altered.
		Orthopyroxene(?)	1	Clinopyroxene	15	Chlorophaeite		Orthopyroxene(?)	1	Clinopyroxene	15	Calcite	Opx(?)	3	
				Glass	18	Natrolite(?)				Glass	10	Analcite(?)	Glass	2	
				Ore	4					Ore	4	Leucoxene	Ore	2	
				Orthopyroxene(?)	2					Orthopyroxene(?)	2	Sericite(?)	Plagioclase	<1	
				Quartz	2					Quartz	2	Natrolite(?)	(Deuteric)	<1	
		Total 1)		100				Total		100		Kaolinite	Plagioclase	<1	
26. 779-11-4B Dacite (?)	Intersertal, subtrachytic	Clinopyroxene	6	Plagioclase	43	None						Chlorophaeite	Glass, opx(?), deuter.	17	Dike, same locality as 11-4A. Plagioclase is usually unit phyric, infrequently glomerophyric with cpx and ore, and is highly altered; cpx varies in color from pale smoky yellow to purplish-neutral, partially encloses matrix plagioclase, is both microphyric and glomerophyric, and is partly resorbed; ore is hypidiomorphic and glomerophyric, and as a matrix phase, is highly altered to leucoxene and hematite; glass is totally altered; cpx includes microlitic apatite.
		Ore	5	Glass	13							Kaolinite	(Deuteric)	10	
		Plagioclase	1	Clinopyroxene	13							Quartz	(Deuteric)	8	
				Quartz	18							Leucoxene	Ore	2	
				Orthopyroxene(?)	6							Prehnite(?)	Plagioclase, deuter.	1	
				Ore	<1							Sericite(?)	Plagioclase	<1	
				Apatite	<1							Hematite	Ore	<1	
		Total 2)		99+											
27. 779-11-4D Basalt	Intersertal	Clinopyroxene	7	Plagioclase	33	Quartz	1	Clinopyroxene	7	Plagioclase	34	Chlorophaeite/ Smectite	Glass	18	Clast from volcanic sandstone, same locality as 11-4A. Plagioclase is unit phyric, infrequently glomerophyric with cpx and ore; cpx is usually microphyric, neutral in color, and often subophitically encloses plagioclase laths; ore is microphyric and microglomerophyric, and is partly altered to hematite; matrix opx is remarkably fresh and faintly pleochroic from pinkish to greenish. quartz occurs as blob-like bodies in totally altered glass.
		Ore	5	Clinopyroxene	37			Ore	5	Clinopyroxene	37				
		Plagioclase	2	Glass	18			Plagioclase	2	Glass	18	Quartz	(Deuteric)	1	
				Quartz	5					Quartz	5	Sericite(?)	Plagioclase	<1	
				Orthopyroxene	1					Orthopyroxene	1	Hematite	Ore	<1	
				Ore	1			Total		Ore					
		Total 3)		100						100					
28. 779-11-5A Rhyolite 1)	Hyalopilitic	Plagioclase	3	Plagioclase	34	None						Smectite	Glass	15	Pillow lava interior, east of Cape Idalug, north side of island. Plagioclase is glomerophyric with cpx, opx(?), and ore, and is kaolinitized and sericitized, cpx is neutral in color and quite fresh, opx(?) is totally altered; ore is glomerophyric with pyroxene only, displays evidence of resorption and alteration to hematite; matrix plagioclase is microlitic and is felted intergrowth with highly altered cpx; matrix ore is highly altered, matrix opx(?) is totally altered; glass is totally altered.
		Clinopyroxene	<1	Glass	34							Chlorophaeite	Glass	15	
		Ore	<1	Quartz	14							Hematite	Glass, ore, mafics	5	
		Orthopyroxene(?)	<1	Clinopyroxene	11							Quartz	(Deuteric)	5	
				Ore	2							Kaolinite	Plagioclase	4	
				Orthopyroxene(?)	1							Sericite(?)	Plagioclase	2	
		Total 3)		99+								Pumpellyite(?)	Plag., (Deuteric)	1	
												Epidote	(Deuteric)	<1	

Table 3 cont.

29. 779-11-6A Rhyolite?	Hyalopilitic	Plagioclase	10	Plagioclase	39	Chlorophaeite	<1					Chlorophaeite	Glass, pyroxenes	17	Massive flow with columnar jointing, from semicircular bay four miles east of Cape Idalug. Plagioclase is glomerophyric with cpx, opx(?), and ore, is altered internally, and displays evidence of resorption; cpx is neutral in color and includes glass and microlitic apatite; opx(?) is totally altered and is occasionally unit phyric as well as glomerophyric; ore is occasionally unit phyric as well as glomerophyric, both phyric and matrix ores are highly altered; glass is totally altered; quartz is abundant as minute blebs in the glass.
		Orthopyroxene(?)	1	Glass	37							Zeolites	Glass, plag.	10	
		Ore	<1	Quartz	14							Kaolinite	Plagioclase	4	
		Clinopyroxene	<1	Clinopyroxene	7							Hematite	Glass, ore, pyrox.	4	
				Ore	2							Pumpellyite(?)	Glass, Plag.	2	
				Apatite	<1							Sericite(?)	Plagioclase	<1	
		Total [2]		100+											
30. 779-11-6B Andesite	Hyalopilitic	Plagioclase	12	Glass	58	Quartz	2	Plagioclase	17	Glass	59	Smectite	Glass	1	Glassy flow margin of 11-6A, same locality. Plagioclase is unit phyric and also glomerophyric with cpx, opx, and ore; cpx is neutral in color and often ophitically encloses microphyric ore; opx is remarkably fresh and faintly pleochroic from pinkish to greenish; ore is both unit phyric and glomerophyric; matrix phases are microlitic and generally acicular in form; glass seems quite fresh except for dissolved hematite dust. Large apatite needles occur as inclusions in plagioclase and pyroxenes.
		Orthopyroxene	2	Plagioclase	10	Smectite		Orthopyroxene	2	Plagioclase	10	Zeolites	Glass	1	
		Ore	2	Clinopyroxene	7	Zeolites		Ore	2	Clinopyroxene	7	Hematite	Glass	1	
		Clinopyroxene	3	Ore	3			Clinopyroxene	2	Ore	3	Quartz	(Deuteric)	<1	
				Orthopyroxene	2					Orthopyroxene	3				
				Apatite	<1					Apatite	<1				
		Total [2]		100+				Total		99+					
31. 779-11-6C Rhyolite	Hyalopilitic to holohyaline	Plagioclase	~3	Glass	75-78	Quartz	1-7? (Varies greatly within the section)					Quartz	(Deuteric)	50-75	Green altered Rhyolite, same locality as 11-6A. Composite sample with three distinct lithologies: a) (original rock) glass charged with plagioclase and orthoclase(?) glomerophyric with greenish-neutral, sparry cpx, totally altered opx, and ore. b) glass, darker in color and more opaque than (a), probably representing an inclusion of older, more altered material with similar texture and phases. (c) glass, totally altered and cellular, perhaps originally a froth with gas cavities now filled with quartz.
		Orthoclase(?)	~1	Plagioclase	7-10	Smectite						Celadonite	Glass	5-30	
		Clinopyroxene	1	Clinopyroxene	<1-5	Zeolites						Smectite	Glass, mafics	25	
		Ore	1	Orthopyroxene	~2							Goethite(?)	Glass	5	
		Orthopyroxene	1	Ore	<1-1							Kaolinite	Plagioclase	1	
				Apatite	<1							Hematite	(Deuteric)	1	
		Total [2]		100								Manganic oxide(?)	(Deuteric)	1	
												Sericite(?)	Plagioclase	<1	
32. 779-11-6D Rhyolite?	Hyalopilitic	Plagioclase	1	Glass	37	Quartz	5	Plagioclase	1	Glass	33	Zeolites	(Deuteric)	15	Massive columnar Rhyolite, same locality as 11-6A. Plagioclase is highly altered and glomerophyric with neutral-colored cpx, hypidiomorphic ore, and rare, totally altered opx(?); matrix Plagioclase and cpx are microlitic and highly altered; matrix ore displays two distinct grain sizes; glass is totally altered; quartz is abundant as minute blebs in the glass; microlitic apatite observed as inclusions in cpx.
		Clinopyroxene	1	Quartz	24	Zeolites		Clinopyroxene	1	Quartz	25	Smectite	Glass	9	
		Orthoclase(?)	1	Plagioclase	21			Orthoclase(?)	3	Plagioclase	22	Hematite	Glass	7	
		Ore	<1	Clinopyroxene	9			Ore	<1	Clinopyroxene	9	Quartz	(Deuteric)	5	
				Ore	4					Ore	4	Pumpellyite(?)	Felds., px., (deuter.)	4	
				Orthoclase(?)	1					Orthoclase(?)	3				
		Total [2]		101+						99+		Kaolinite	Plagioclase	4	
								Total				Leucoxene	Ore	1	
												Chlorophaeite	Opx(?)	<1	

Table 5, cont.

33. 779-12-1A(1)	Basalt	Intergranular to intersertal	Plagioclase	30	Plagioclase	40	Smectite	20	Plagioclase	25	Plagioclase	22	Smectite	Glass, opx(?)	10	Clast in volcanic breccia, small bay about 10 miles east of Cape Idaleq, north of side of island. Plagioclase is sometimes unit phyric, more often glomerophyric, with totally altered opx(?) and fresh, neutral-colored cpx, which are both unit phyric and glomerophyric also; both matrix and phyric plagioclase display minor saussuritization, zeolitization, sericitization, and kaolinitization; matrix opx is granular in habit and quite fresh; glass is totally altered.
			Orthopyroxene(?)	7	Clinopyroxene	14	Zeolites		Orthopyroxene(?)	3	Clinopyroxene	22	Kaolinite	Plagioclase	2	
			Clinopyroxene	2	Ore	10			Clinopyroxene	1	Ore	17	Calcite	Opx(?)	2	
					Glass	10					Glass	12	Zeolites	(Deuteric)	<1	
			Total 1)		100				Total		99+		Sericite(?)	Plagioclase	<1	
													Epidote	Plagioclase	<1	
34. 779-12-1B(2)	Basalt	Microlitic intergranular	Plagioclase	25	Clinopyroxene	24	Chlorophaeite	15	Plagioclase	79	Clinopyroxene	28	Chlorophaeite	Opx(?)(deuteric)	26	Clast from same volcanic breccia as 12-1A(1). Plagioclase is unit phyric and also glomerophyric, frequently with itself and opx(?), rarely with cpx, which is usually unit phyric, sometimes glomerophyric with plagioclase (often poikilitically enclosed by it), and is neutral in color; opx(?) is totally altered and usually unit phyric, but is also glomerophyric, displaying embayed, resorbed crystals; matrix plagioclase and cpx display two distinct grain sizes; matrix opx(?) is totally altered and displays a distinctly coarser grain size than the other matrix phases; matrix ore is microlitic with a dendritic aspect.
			Orthopyroxene(?)	5	Plagioclase	20	Calcite		Orthopyroxene(?)	6	Plagioclase	24				
			Clinopyroxene	5	Ore	5	Zeolites		Clinopyroxene	6	Ore	6	Calcite	Opx(?)(deuteric)	5	
					Orthopyroxene(?)	1					Orthopyroxene(?)	1	Kaolinite	Plagioclase	2	
			Total 2)		100				Total		100		Zeolites	(Deuteric)	<1	
35. 779-12-2A	Basalt 1)	Intergranular to intersertal	Plagioclase	34	Plagioclase	31	None						Chlorite	Glass, opx(?)	14	Massive columnar flow, west side of major bay east of "560" Cove. Plagioclase is glomerophyric mainly with itself, rarely with opx(?), includes totally altered glass, and is highly kaolinitized, saussuritized, and sericitized(?); opx(?) is totally altered and usually unit phyric, rarely glomerophyric; matrix plagioclase displays two distinct grain sizes; matrix opx(?) is totally altered, matrix cpx is neutral in color and granular in habit; matrix ore displays three distinct grain sizes; glass is totally altered.
			Orthopyroxene(?)	3	Clinopyroxene	30							Epidote	Plag., glass	16	
			Clinopyroxene	1	Glass	7							Kaolinite	Plagioclase	4	
					Ore	5							Magnetite(?)	Glass	1	
					Orthopyroxene(?)	2							Sericite(?)	Plagioclase	<1	
			Total 2)		100								Leucoxene	Ore	<1	
36. 779-12-2B	Rhyolite 1)	Hyalopilitic	Plagioclase	2	Glass	45	Zeolites	9	Plagioclase	2	Glass	66	Quartz	(Deuteric)	6	Pillow lava interior, same locality as 12-2A. Plagioclase is usually glomerophyric with cpx and ore, rarely unit phyric; orthoclase(?) is glomerophyric and, with plagioclase, is kaolinitized and saussuritized; cpx is glomerophyric and neutral in color; ore tends to be microphyric and included in large cpx crystals, or as small crystals in matrix; groundmass is composed of microlites suspended in highly altered glass charged with hematite dust; quartz is abundant as blebs and veinlets.
			Orthoclase(?)	2	Quartz	33	Chlorophaeite		Orthoclase(?)	2	Quartz	22	Pumpellyite(?)	Plag.,glass,cpx	4	
			Clinopyroxene	1	Plagioclase	10			Clinopyroxene	1	Plagioclase	11	Hematite	Glass, cpx	3	
			Ore	<1	Clinopyroxene	5	Quartz	5	Ore	<1	Clinopyroxene	5	Smectite	Glass, opx	2	
					Ore	4	(Veinlets)				Ore	4	Kaolinite	Plagioclase	1	
					Orthoclase(?)	2					Orthoclase(?)	2	Zeolites	(Deuteric)	1	
			Total 2)		101+				Total		99+		Epidote	Feldspars	<1	

Table 5, cont.

37. 779-13-4	Basalt	Hyalopilitic to microlitic intergranular	Plagioclase	1	Glass	35	Smectite	30	Plagioclase	1	Glass	50	Zeolites	(Deuteric), feldspar	42	Massive flow along north side of Hungry Bay. Plagioclase is highly zeolitized and is glomerophyric with fresh, neutral-colored cpx; opx(?) is unit phyric and totally altered; matrix phases are microlitic except for opx(?) which is larger than the others; glass is totally altered.
			Clinopyroxene	1	Plagioclase	11	Zeolites		Clinopyroxene	1	Plagioclase	16				
			Orthopyroxene(?)	<1	Clinopyroxene	10			Orthopyroxene(?)	<1	Clinopyroxene	10	Smectite	Glass	20	
					Ore	10					Ore	14	Quartz	(Deuteric)	5	
					Orthopyroxene(?)	3					Orthopyroxene(?)	3	Calcite	Opx(?)	2	
					100+				Total		99+		Chlorophaeite	Opx(?)	1	
38. 779-13-10D	Basalt [?]	Intersertal	Plagioclase	31	Clinopyroxene	16	Chlorite	12	Plagioclase	34	Clinopyroxene	18	Zeolites	Plagioclase	20	Massive flow from north side of Hill "1732", south of Hungry Bay, el. 1050 ft. Plagioclase is unit phyric and also glomerophyric with neutral-colored cpx and, rarely, totally altered opx(?), includes much totally altered glass, and displays incipient to intense zeolitization, kaolinitization, and sericitization(?); opx(?) is normally unit microphyric; matrix phases are generally microlitic; glass is totally altered.
			Clinopyroxene	8	Plagioclase	16			Clinopyroxene	9	Plagioclase	35	Analcite(?)	Glass, plag.	11	
			Orthopyroxene(?)	<1	Glass	14			Orthopyroxene(?)	<1	Glass	15	Smectite	Clinopyroxene	8	
					Ore	7					Ore	8	Kaolinite	Plagioclase	7	
			Total [3]		100				Total		99+		Chlorite	Glass, opx(?)	7	
													Pumpellyite(?)	Plagioclase	<1	
													Sericite(?)	Plagioclase	<1	
39. 779-13-10E	Andesite	Hyalopilitic	Plagioclase	12	Glass	32	Empty	10	Plagioclase	11	Glass	33	Smectite	Glass, opx	35	Massive flow from Hill "1732", sampled at el. 1120 ft. Plagioclase is glomerophyric with itself, neutral-to-greenish-colored cpx, microphyric ore, and remarkably fresh opx, includes totally altered glass, and displays kaolinitization and sericitization(?); matrix phases are generally microlitic and set in totally altered glass.
			Clinopyroxene	5	Plagioclase	16			Clinopyroxene	6	Plagioclase	11	Zeolites	Glass	5	
			Orthopyroxene	1	Clinopyroxene	14			Orthopyroxene	1	Clinopyroxene	11	Chlorophaeite	Glass, opx	5	
			Ore	<1	Quartz	12			Ore	<1	Quartz	11	Hematite	Glass, cpx	3	
					Ore	7					Ore	8	Kaolinite	Plagioclase	2	
					Orthopyroxene(?)	5					Orthopyroxene(?)	6	Amphibole(?)	Glass, cpx	1	
			Total [3]		100+				Total		100+		Sericite(?)	Plagioclase	1	
40. 779-14-1A	Basalt	Microlitic intergranular	Plagioclase	20	Plagioclase	38	Chlorophaeite	7	Plagioclase	22	Plagioclase	30	Chlorophaeite	Orthopyroxene(?)	5	Clast in coarse volcanic breccia from major point just south of Amlia Pass. Plagioclase is generally glomerophyric with itself, cpx, and opx, displays incipient kaolinitization and sericitization, and includes much altered glass; cpx displays a pale greenish color and is usually unit phyric, rarely glomerophyric; opx is remarkably fresh and faintly pleochroic in greenish and pinkish tints, and is usually unit phyric, rarely glomerophyric, matrix phases generally display several distinct grain sizes each.
			Clinopyroxene	4	Clinopyroxene	20	Quartz		Clinopyroxene	4	Clinopyroxene	30	Smectite	Orthopyroxene(?)	5	
			Orthopyroxene	2	Ore	10	Calcite		Orthopyroxene	3	Ore	11	Zeolites	Plagioclase, (Deuteric)	5	
					Orthopyroxene(?)	1	Zeolites				Orthopyroxene(?)	1				
			Total [3]		100				Total		100		Calcite	Orthopyroxene(?)	2	
													Analcite	(Deuteric)	2	
													Quartz	(Deuteric)	1	

Table 1-cont.

41. 779-14-1B	Basalt	Microlitic intersertal to intergranular	Plagioclase Clinopyroxene Orthopyroxene(?) Olivine(?) Ore Total 2)	25 9 3 1 <1	Plagioclase Clinopyroxene Glass Ore Orthopyroxene(?) Olivine(?) 100+	25 25 5 4 1 1	Chlorophaeite	2	Plagioclase Clinopyroxene Orthopyroxene(?) Olivine(?) Ore Total	35 9 2 1 <1	Plagioclase Clinopyroxene Glass Ore Orthopyroxene(?) Olivine(?) 100+	20 26 5 4 1 1	Chlorophaeite Kaolinite Calcite Sericite(?)	Glass, opx(?), olivine(?) Plagioclase Opx(?), ol(?) Plagioclase	7 5 <1 <1	Clast in volcanic breccia, same location as 14-1A. Plagioclase is unit phyric, strongly zoned, rimmed with fresh, cored with kaolinitized and sericitized(?) feldspar, and includes much altered glass; cpx is neutral in color, is usually unit phyric, and often includes matrix phases; ore is microphyric and includes, or is included by cpx crystals; opx(?) and olivine(?) are totally altered, usually unit phyric, rarely glomerophyric; matrix phases display several distinct grain sizes each and are set in rather fresh, brownish glass.
42. 779-14-3A	Basalt 1)	Intersertal	Plagioclase Clinopyroxene Total 2)	34 5	Glass Plagioclase Clinopyroxene Ore 101	31 18 10 3	Chlorite Zeolites	14	Plagioclase Clinopyroxene Total	34 8	Glass Plagioclase Clinopyroxene Ore 102	24 21 13 2	Chlorophaeite Kaolinite Chlorite Zeolites Sericite(?)	Glass, (Deuteric) Plagioclase (Deuteric) (Deuteric) Plagioclase	21 10 4 2 <1	Dike near Tody Point, north side of island. Plagioclase is usually glomerophyric with itself, less often with cpx, is generally rimmed with fresher feldspar, includes much totally altered glass, and displays intense kaolinitization and sericitization; cpx is neutral in color and microphyric, the crystals often poikilitically enclosed in larger plagioclases; grain sizes and textures display extreme variation within the section; glass is totally altered.
43. 779-14-4A	Basalt 1)	Intersertal	Plagioclase Clinopyroxene Orthopyroxene(?) Olivine(?) Total 2)	23 3 1 <1	Glass Clinopyroxene Plagioclase Ore 99+	31 19 15 5	Empty	2	Plagioclase Clinopyroxene Orthopyroxene(?) Olivine(?) Total	24 3 1 <1	Glass Clinopyroxene Plagioclase Ore 100+	32 20 15 5	Chlorophaeite Pumpellyite(?) Zeolites Calcite Kaolinite	Glass, opx(?), olivine Glass, plag. Plag., glass Opx(?), ol(?) Plagioclase	17 15 6 5 <1	Massive flow base along west side of first major bay west of Hungry Bay. Plagioclase is generally glomerophyric with itself and cpx, and is strongly zoned and altered; cpx is neutral in color and is sometimes poikilitically enclosed by plagioclase; opx(?) and olivine(?) are totally altered and more frequently glomerophyric with themselves only than with other phyric phases; matrix phases are microlitic to very granular in form; glass is totally altered.
44. 779-14-4B	Basalt 1)	Hyalopilitic	Plagioclase Clinopyroxene Ore Orthopyroxene(?) Total 2)	45 12 2 <1	Glass Plagioclase Quartz Ore Clinopyroxene 100+	28 4 4 2 1	Rarely lined with quartz, smectite	2	Plagioclase Clinopyroxene Ore Orthopyroxene(?) Total	46 12 2 <1	Glass Plagioclase Quartz Ore Clinopyroxene 99+	28 4 4 2 1	Smectite	Glass	28	Flow interior, same location as 14-4A. Plagioclase is glomerophyric with itself, cpx, and ore, or is rarely unit phyric, and includes much glass; cpx is neutral in color and glomerophyric with other phyric phases except opx(?); ore is microphyric, is often included in pyroxenes, and displays a characteristic skeletal aspect; matrix phases generally display several distinct grain sizes each; glass is totally altered; quartz occurs as bleb-like bodies in the glass.

Table 1, cont.

65. 779-14-4C	Basalt [1]	Intersertal	Plagioclase	35	Glass	24	Chlorophaeite	6	Plagioclase	37	Glass	31	Smectite	Glass	21	Flow interior, same location as 14-4A. Plagioclase is usually glomerophyric with itself, infrequently with cpx, and is also unit phyric; cpx is neutral in color and usually glomerophyric with opx(?), which is both glomerophyric and unit phyric, and is totally altered; matrix phases generally display two distinct grain sizes each; cpx frequently includes microlites of plagioclase and ore; glass is totally altered.
			Clinopyroxene	4	Plagioclase	16	Smectite		Clinopyroxene	4	Plagioclase	17	Chlorite	Glass	2	
			Orthopyroxene(?)	1	Clinopyroxene	7			Orthopyroxene(?)	1	Clinopyroxene	7	Zeolites	Glass	1	
					Quartz	5					Quartz	5				
					Ore	4			Total		Ore	4				
			Total [2]		100						100					
66. 779-14-4D	Basalt [1]	Hyalophitic	Plagioclase	43	Glass	33	None						Smectite	Glass, (Deuteric)	39	Top of flow, same locality as 14-4A. Plagioclase is both unit phyric and glomerophyric with cpx and ore, and is much zeolitized internally; cpx is neutral in color, granulated internally, and glomerophyric with other phyric phases; ore is glomerophyric with other phyric phases and is decidedly skeletal; matrix phases are quite granular in habit, with cpx subophitically enclosing other phases; matrix ore is quite skeletal in aspect; glass is totally altered.
			Clinopyroxene	11	Quartz	12							Zeolites	Glass	7	
			Ore	1	Plagioclase	4							Kaolinite	Plagioclase	<1	
					Clinopyroxene	1							Amphibole(?)	Glass	<1	
					Ore	1										
			Total [2]		100											
67. 779-14-23A	Gabbro [1]	Porphyritic granular	Plagioclase	4	Plagioclase	63	None						Chlorite	Opx(?), cpx	9	Hypabyssal pluton, north side of Hungry Bay. Plagioclase is glomerophyric with neutral-colored cpx, includes altered glass, and is itself highly altered; cpx poikilitically encloses matrix phases; ore is glomerophyric with other phyric phases and is quite skeletal in aspect; opx(?) is totally altered and is glomerophyric with all other phyric phases except plagioclase; matrix phases differ but little from the phyric phases except by size; glass is totally altered.
			Clinopyroxene	3	Clinopyroxene	14							Amphibole	Clinopyroxene	1	
			Orthopyroxene(?)	1	Glass	10							Zeolites	Glass	1	
			Ore	<1	Ore	1							Hematite	Ore	<1	
					Orthopyroxene(?)	1							Smectite	Opx(?), glass	<1	
			Total [2]		99+								Sericite(?)	Plagioclase	<1	
													Leucoxene	Ore	<1	
68. 779-14-25A	Gabbro [1]	Porphyritic granular	Plagioclase	30	Plagioclase	29	None						Smectite	Glass, opx(?), plagioclase	20	Hypabyssal pluton, north side of Hungry Bay. Plagioclase is usually unit phyric, rarely glomerophyric with cpx, includes altered glass, is strongly zoned, and displays evidence of resorption; cpx is neutral in color, often unit phyric or glomerophyric with opx(?) only, and often ophitically encloses the opx(?) and also plagioclase; opx(?) is totally altered and is both unit phyric and glomerophyric; matrix phases reflect the phyric phases on a smaller scale; microlitic apatite, quartz, and biotite(?) occur in pools of totally altered glass.
			Clinopyroxene	7	Glass	10							Pumpellyite(?)	Plag., glass	3	
			Orthopyroxene(?)	5	Clinopyroxene	9							Sericite(?)	Plagioclase	<1	
					Orthopyroxene(?)	7										
					Ore	2										
					Apatite	1										
					Biotite(?)	<1										
			Total [2]		100+											

Table 3, cont.

69.779-13-1C	Basalt	Intersertal	Plagioclase Clinopyroxene Ore Total 21	15 22 4	Glass Quartz Plagioclase Ore Orthopyroxene(?) 100+	18 11 6 1 <1	Calcite Smectite	1	Plagioclase Clinopyroxene Ore Total	15 22 4	Glass Quartz Plagioclase Ore Orthopyroxene(?) 99+	20 11 6 1 <1	Smectite Leucoxene Calcite	Glass, opx(?) 20 Ore <1 Opal(?), (Zeolite?) <1	Massive flow rock, north side of Hungry Bay. Plagioclase is usually [illegible] phyric, is strongly zoned, and displays considerable evidence of resorption; cpx is neutral in color, microglomerophyric with itself or with ore, ophitically encloses matrix plagioclase, and displays strong sector-zoning; ore is glomerophyric and highly skeletal in aspect; matrix plagioclase displays a wide range of grain sizes; matrix cpx and ore are like their phyric counterparts in aspect; opx(?) and glass are totally altered.

Table 6. Representative microprobe analyses of plagioclase, Amlia Island volcanic rocks. David Clague and Walter Friesen, Analysts.

	779-14-25A (Gabbro)				779-7-6B (Basalt)			
	1	2	3	4	PC1	PC2	PC3	PC4
SiO_2	46.88	45.95	47.98	48.29	48.33	47.84	46.75	50.83
Al_2O_3	33.52	33.90	32.61	32.34	32.62	33.07	34.33	31.10
FeO_T	0.66	0.66	0.82	0.79	0.93	0.91	0.88	0.95
CaO	18.10	18.63	16.60	17.25	16.20	16.58	16.77	14.65
Na_2O	1.32	1.01	1.84	1.87	2.11	2.11	2.07	3.22
K_2O	0.03	0.04	0.06	0.05	0.08	0.07	0.06	0.11
Total	100.51	100.19	99.91	100.59	100.26	100.58	100.86	100.86
Atomic proportions, O = 8								
Si	2.152	2.120	2.207	2.211	2.215	2.190	2.138	2.306
Al	1.814	1.844	1.768	1.745	1.762	1.784	1.851	1.663
Fe^{+2}	0.025	0.026	0.032	0.030	0.036	0.035	0.034	0.036
Ca	0.890	0.921	0.818	0.846	0.796	0.813	0.822	0.712
Na	0.117	0.091	0.164	0.166	0.187	0.187	0.183	0.283
K	0.002	0.002	0.003	0.003	0.005	0.004	0.003	0.006
Or, mol%	0.2	0.2	0.3	0.3	0.5	0.4	0.3	0.6
Ab, mol%	11.6	9.0	16.7	16.4	18.9	18.6	18.2	28.3
An, mol%	88.2	90.8	83.0	83.3	80.6	81.0	81.5	71.1

Table 6. (Continued)

	779-11-4A (Basalt)		779-15-1C (Basalt)			779-11-2 (Basalt)		
	1	2	PC1	PC2	PC3	PC1	PC2	PC3
SiO_2	48.81	48.43	49.69	54.26	49.79	45.22	50.18	52.76
Al_2O_3	32.39	32.40	32.11	28.87	31.66	35.44	32.10	29.91
FeO_T	0.65	0.63	0.92	0.69	0.92	0.75	0.94	0.86
CaO	17.47	17.05	14.86	11.28	14.57	17.88	14.51	13.29
Na_2O	1.69	1.83	3.01	4.99	2.87	1.23	3.05	3.93
K_2O	0.06	0.06	0.08	0.12	0.06	0.03	0.10	0.14
Total	101.07	100.40	100.67	100.21	99.87	100.55	100.88	100.89
Atomic proportions, O = 8								
Si	2.221	2.217	2.261	2.451	2.279	2.078	2.275	2.381
Al	1.737	1.748	1.722	1.537	1.708	1.920	1.715	1.591
Fe^{+2}	0.025	0.024	0.035	0.026	0.035	0.029	0.036	0.032
Ca	0.851	0.836	0.725	0.546	0.715	0.880	0.705	0.642
Na	0.149	0.162	0.266	0.437	0.255	0.110	0.268	0.344
K	0.003	0.004	0.004	0.007	0.004	0.002	0.006	0.008
Or, mol%	0.3	0.4	0.4	0.7	0.4	0.2	0.6	0.8
Ab, mol%	14.9	16.2	26.7	44.1	26.2	11.1	27.4	34.6
An, mol%	84.8	83.4	72.9	55.2	73.4	88.7	72.0	64.6

Table 6. (Continued)

	779-9-1B (Bas. Andesite)		779-14-4B (Bas. Andesite)			
	PC1	PC2	PC1	PC2	PC3	PC4
SiO_2	50.83	54.23	50.49	46.89	50.23	50.74
Al_2O_3	31.10	28.48	29.28	32.59	30.45	29.54
FeO_T	0.95	0.84	1.04	0.86	1.16	1.05
CaO	14.65	10.98	13.73	17.62	14.25	13.42
Na_2O	3.22	5.14	3.63	1.47	3.22	3.73
K_2O	0.11	0.12	0.13	0.05	0.11	0.14
Total	100.86	99.79	98.30	99.48	99.42	98.62
Atomic proportions, O = 8						
Si	2.306	2.461	2.349	2.175	2.313	2.351
Al	1.663	1.523	1.606	1.782	1.653	1.614
Fe^{+2}	0.036	0.032	0.040	0.033	0.045	0.040
Ca	0.712	0.534	0.685	0.876	0.703	0.665
Na	0.283	0.452	0.328	0.132	0.288	0.335
K	0.006	0.007	0.008	0.003	0.006	0.008
Or, mol%	0.6	0.7	0.8	0.3	0.6	0.8
Ab, mol%	28.3	45.5	32.1	13.1	28.9	33.2
An, mol%	71.1	53.8	67.1	86.6	70.5	66.0

Table 6. (Continued).

	779-8-1B (Andesite)				779-9-3B (Rhyolite)	
	PC1	PC2	PC3	PC4	PC1	PC2
SiO_2	54.98	55.61	54.55	55.21	56.54	56.17
Al_2O_3	28.28	27.64	28.74	28.09	27.41	27.40
FeO_T	0.63	0.62	0.63	0.60	0.63	0.58
CaO	11.76	10.61	10.80	10.45	8.89	9.57
Na_2O	4.75	5.22	5.21	5.17	6.11	5.74
K_2O	0.20	0.32	0.25	0.57	0.13	0.13
Total	100.60	100.02	100.18	100.09	99.71	99.59
Atomic proportions, 0 = 8						
Si	2.474	2.510	2.463	2.493	2.547	2.536
Al	1.500	1.470	1.529	1.495	1.455	1.458
Fe^{+2}	0.024	0.023	0.024	0.023	0.024	0.022
Ca	0.567	0.513	0.522	0.506	0.429	0.463
Na	0.414	0.457	0.456	0.453	0.534	0.502
K	0.024	0.018	0.014	0.033	0.008	0.022
Or, mol%	2.4	1.8	1.4	3.3	0.8	2.2
Ab, mol%	41.2	46.3	46.0	45.7	55.0	50.9
An, mol%	56.4	51.9	52.6	51.0	44.2	46.9

rich sanidine in composition. They are, in general, rarely phanerocrystalline and are, when phaneritic, mostly very highly altered. The clinopyroxene is generally augite, often displaying a black or greenish-black color in hand specimen and, usually, a neutral color in thin section. Optically, they yield inclined extinctions to about 45°, with an axial angle (2E) of about 60°. They often include acicular microlites of apatite, characteristic of tholeiitic differentiation. Orthopyroxene (rarely unaltered) is, in general, iron-poor hypersthene. It is faintly pleochroic from pale pink to pale green and generally yields an axial angle (2E) of about 65°, indicating the presence of about 30 percent ferrosilite end-member. No fresh olivine was observed in any of the Amlia samples, but some of the basalts have calcite pseudomorphs bearing the rhombic aspect of olivine crystals. Ore phases occur as phenocrysts in nearly all the Amlia igneous rocks. Phenocrysts of elongate orthogonal and large hexagonal aspect often display gray reflectance with a violet tint, and are often altered peripherally and internally to leucoxene. Cubic and rhombic ore phases generally display gray reflectance with a bluish tint. Some of these phases have altered superficially to leucoxene and hematite. More have altered to hematite alone. Some are so completely altered to hematite that they are uniformly translucent in blood-red hues. The primary mineral phases present in the ores are probably magnetite, titanomagnetite, and ilmenite. Quartz does not occur as phenocrysts in the rocks of Amlia Island, yet it is a constituent in many samples where it often appears as an anhedral groundmass phase. More frequently, quartz appears as microscopic to submicroscopic rounded blebs that apparently crystallized from glass. Primary biotite(?) was observed only in a gabbro sample from a small hypabyssal intrusion exposed on the north side of Hungry Bay. All other biotite(?) observed appears to be secondary. Primary amphibole was noted only in a tonalite sample from a sill exposed at the first bay east of Sharp Point.

It appears from the mineralogy observed in thin section, hand specimen, and in the field that the igneous rocks of Amlia Island were derived from magmas of calc-alkaline and tholeiitic character. They are not characteristic of olivine-rich mid-ocean ridge petrogenesis nor of the silica-poor, alkali-olivine basalts associated with Hawaiian-type island chains. The simple and rather continuous primary mineralogy of calcic plagioclase, augite, and hypersthene, iron-titanium oxide ore phases, apatite, and rather rare quartz suggests island arc or continental margin-type volcanism.

There is considerable evidence in thin section indicating that crystallization occurred close to the liquidus and that some wallrock or earlier crystallizing phases were incorporated in the magmas that formed the Amlia rocks. Most of the rocks, even the intrusive ones, are glomerophyric, and usually bear numerous isolated phenocrysts as well. Orthopyroxene is least commonly glomerophyric and occurs as small euhedra. Perhaps this indicates initial slow cooling and stable conditions as crystallization began in the magma chamber or chambers, allowing the uninhibited crystallization of the orthopyroxene in a rather viscous melt. Plagioclase, too, is frequently an isolated phenocryst, as are clinopyroxene and the ore phases. Rarely, however, are any of the last three phases euhedral, and they often show evidence of resorption. Plagioclase and clinopyroxene frequently display strong zonation, indicating later changes in magmatic composition. Often, all four major phenocryst phases are found grown together in small clusters of half-a-dozen to a dozen crystals. In sample θ-1B, a few gabbroic xenolith-like clusters were observed suspended in a much finer-grained groundmass.

These observations suggest much crystal settling with subsequent disturbance and mobilization of crystals in the magma, accompanied by influxes of material (perhaps by stoping of wall rock) of different composition. Plagioclase and clinopyroxene often include numerous blebs of glass, indicating rapid crystal growth and resorption. Groundmass phases are often included in feldspar and clinopyroxene phenocrysts, indicating late, rapid, phenocryst growth.

Ongoing magmatic activity was likely responsible for the low-grade metamorphism of the Amlia rocks. The rocks have been hydrothermally altered, beginning with ubiquitous smectitization and proceeding through the rarer and more isolated saussuritization. The exposed stratigraphic sequence on Amlia is cut by numerous dikes, sills, and small, stock-like hypabyssal intrusions composed of rocks similar in composition to their hosts. Since different types of alteration such as smectitization, sericitization, kaolinitization, zeolitization, and calcitization are virtually ubiquitous throughout the island, and rather uniform in their effect, it may be suggested that several types of metasomatic activity probably were at work through space and time and were rather regional in scope. McLean and others (1981) proposed batholithic-scale intrusion in the region of nearby Atka Island as the source for the generalized heating, deformation, and exhalative activities responsible for the alteration of the Amlia rocks, and localized intrusion by feeders to supply the higher temperatures and fluids necessary for saussuritization and intense zeolitization. Some of these same, or at least similar, plutons may extend beneath the outcrops on Amlia Island.

Apparently, the first phases to be altered in the rocks were olivine and orthopyroxene. They are typically altered to calcite or calcite and smectites. The alteration, sometimes only patchy, is least severe in rocks from the southeast end of the island. This is typically where the youngest rocks are exposed. Perhaps the earliest fluids migrating through the rocks were rich in CO_2, H_2O, silicon, calcium, sodium, and aluminum. In several rocks from western Amlia, calcite replacement of orthopyroxene was succeeded by alkali-rich smectite and then by alkali-iron smectite (chlorophaeite) in successive rims.

Ore phases display minor to total alteration throughout the exposed volcanic pile. The principal alteration products are hematite and leucoxene. Heating, and changes in water vapor pressure due to magma chamber breaching, together with freely-migrating oxygen in hydrothermal fluids, could account for the partial-to-total oxidation of the ore phases to hematite and anatase(?) (leucoxene) that is frequently seen in the Amlia rocks. Alteration of the ores to hematite is seen in all Amlia rocks, but is most intense and complete in samples from the north central coast. Leucoxene alteration is apparent only in the eastern three-quarters of the island, with the greatest intensity observed in rocks from the north central coast.

Clinopyroxene and its included apatite are the least altered of all the phases encountered in the Amlia rocks. Although frequently rather deformed, sector-zoned, resorbed, and internally granulated, clinopyroxene generally stands out fresh amid its more altered neighbors. Although alteration of clinopyroxene is infrequent, the usual products are smectite, pumpellyite, or amphibole. The amphibolization may represent deuteric alteration. The alteration is most apparent in the intrusive rocks and in the more acidic rocks subjected to the highest metamorphic grades.

Plagioclase and potash feldspar display a broad range of alteration, from the most superficial (as in 9-3A) to total replacement (as in 13-4). The least altered feldspar occurs in a dacite pillow lava from the east end of Amlia, whereas the most altered feldspar (zeolitized) occurs in a massive basalt flow near the northwest end of the island. The most ubiquitous alterations of both plagioclase and potash feldspar are sericitization and kaolinitization. These alterations may be seen to a greater or lesser extent throughout the volcanic pile. Sericite(?) occurs most abundantly in some of the intrusive rocks of the island and in their volcanic host rocks. Kaolinitization of the feldspars is also generalized, but spottier in intensity than the sericitization. The basic trend, however, follows that of the sericite: more intense kaolinitization in the rocks of western and northern Amlia, more intense kaolinitization in certain intrusive rocks and their volcanic hosts, and more intense kaolinitization associated with rocks subjected to higher metamorphic grade. Zeolitization is frequently observed in the feldspars, particularly in the rocks from the north and west of Amlia. Zeolitization of the feldspars is generally much localized (i.e., to obvious zones of hydrothermal activity). The feldspars of the volcanic breccias are characteristically the most zeolitized. Zeolitization occurs first along fractures, then proceeds to included glass, and finally moves to total replacement. Smectitization, rare in the feldspars, sometimes accompanies zeolitization. This suggests hydration and ion-exchange by fluid migration through the rocks. The feldspars themselves are infrequently saussuritized, although epidote, pumpellyite, and prehnite are occasionally observed as alteration products. Here, higher grade metamorphism associated with magmatic intrusion and concomittent circulation of hydrothermal fluids rich in iron, calcium, magnesium, aluminum, silicon, and hydroxyl ions is apparent. Albitization was not observed in the Amlia rocks. The groundmass feldspars are generally too calcic, typically skeletal, and retain their twinned forms. Also, temperatures of metamorphism appear to be too low to generate secondary albite.

The rocks of Amlia Island were highly glassy. The greatest spectrum of alteration is to be found in the glasses. Devitrification is usually total in all the rocks. There are a few curiously-spaced exceptions! The glasses are most often altered to zeolites and smectites. In certain instances, however, the metamorphic grade was higher. Heat and migrating hydrothermal fluids produced less common phases from the glasses such as biotite(?), celadonite, chlorite, hematite, magnetite(?), and pumpellyite. In one such intensely altered rhyolite flow from near Cape Idalug on Amlia's north central coast (sample 11-6C), as much as fifty percent of the alteration is bright green celadonite. Associated alteration minerals (quartz, goethite, manganic oxide(?), and sericite(?) lead to the conclusion that this host rock had been hydrothermally altered by deuteric fluids rich in potassium, iron, magnesium, aluminum, silicon, and hydroxyl ions. Not far away, at Chalugas Bay, the most intense magnesian alteration of glass occurs (sample 11-4A). Here, in a massive basalt flow rock, the groundmass glass is totally converted to spherulitic magnesian chlorite and minor analcite. A striking example of propylitization, this rock displays phases almost totally altered to other minerals. In this instance, perhaps another source of fluids and metamorphism brought in abundant magnesium, aluminum, silicon, and hydroxyl ions, accompanied by smaller amounts of oxygen, carbonate, iron and sodium ions.

That the rocks of Amlia Island were metamorphosed hydrothermally by exhalatives of varying compositions and at various times from some nearby magmatic source or sources seems without question. Direct evidence of this is seen again and again in the thin sections. Veinlets bearing secondary deposits of the same mineral phases seen in the adjacent host rocks are commonplace in the rocks of Amlia Island. Zeolites, smectites, quartz, and calcite are the most common vein-filling phases. Less frequently seen are hematite, goethite (may have originally been sulphides), manganic oxide(?) (may have originally been carbonate phases), kaolinite, prehnite, pumpellyite, and epidote. Other processes, such as seawater alteration of pillow lavas, may have had a part in the alteration of the original phases, but a notable example of relatively unaltered glassy selvage from a dacite pillow lava sampled near East Base on the northeast end of Amlia shows but little alteration other than the zeolite and iron-oxide-bearing veinlets that crosscut it. Even the orthopyroxenes here are remarkably fresh. Zeolite- and smectite-rich aureoles spread out into the fresh host rock away from the veinlets. Surely hydrothermal activity must have been a very important agency of metamorphism on Amlia. Deuteric deposits in the gas vesicles of the rocks reflect hydrothermal activity as well: the phases filling or lining the vesicles usually reflect the phases found in the hydrothermal veinlets cutting their hosts (exceptions: epidote, kaolinite, hematite, manganese oxide(?), and goethite). It must be remembered that many factors and variables affect metasomatism in rocks and that many complex changes can take place over long periods of time. Large uncertainties as to the relationships that original rock compositions, porosity, and permeability, bear to temperatures, pressures, and ion concentrations in fluids through space and time greatly complicate the interpretation of metamorphosed rocks. It is also difficult to make definitive interpretations or to draw firm conclusions mainly from the study of thin sections.

SUMMARY AND CONCLUSIONS

The samples selected for this study are representative of a series of intercalated volcanic and volcanogenic sedimentary rocks, and their associated intrusive rocks that make up Amlia Island and probably large parts of the more extensive Aleutian Ridge. The volcanic rocks range in composition from basalt through rhyolite and the intrusive rocks are of similar compositions through dacite. The modal mineralogies of the rocks are remarkably similar, varying mainly in the proportions of the mineral phases rather than in mineralogic differences. Primary mineral phases present in nearly all the rocks include plagioclase, clinopyroxene, orthopyroxene, and ores. The ubiquitous presence of orthopyroxene and the general poverty of olivine in the basic rock is curious. Plagioclase is highly calcic, becoming more sodic in the acidic rocks. Few other striking changes are apparent. These data suggest a single magmatic source for the Amlia igneous rocks, with compositional variation due to localized assimilation of materials from the host environment and differentiation by fractional crystallization. This implies a stability of the Aleutian plate tectonic regime during the period of construction of, at least, the Amlia portion of the Aleutian Ridge (Vallier and others, 1981).

Metamorphism of the Amlia rocks is generally propylitic, with alteration principally in the form of simple hydration, hydroxylation, and light-element ion-exchange. Smectitization and zeolitization are the principal agencies of alteration apparent in the rocks, followed by oxidation, sericitization, and silicification. Saussuritization and amphibolization are rare and localized. Secondary minerals observed in thin section include actinolitic amphibole,analcite, biotite(?), calcite, celadonite, chlorite, chlorophaeite and other smectites, epidote, goethite, hematite, kaolinite, leucoxene, manganic oxide(?), prehnite, pumpellyite, quartz, sericite(?), natrolite and other zeolites.

Evidence of heating, fluid migration, ion diffusion, and ion exchange through the rocks of Amlia is apparent from the trend toward uniformity of low level oxidation, carbonation, ion enrichment and removal, and from hte abundance of cross-cutting zeolite, calcite, and quartz veinlets in the rocks. Abundant, localized enrichment with uncharacteristic suites of elements, such as potassium and iron, also indicates a hydrothermal origin for most of the metamorphic processes. Interpretation of the rocks of Amlia Island is made difficult by large uncertainties concerning variables such as original rock compositions, pH_2O, pCO_2, pH, porosity, permeability, temperature, and ions in introduced fluids. Working with little other than thin sections increases the difficulties and uncertainties.

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