DEPARTMENT OF THE INTERIOR

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CHEMICAL DATA FROM TERTIARY IGNEOUS ROCKS, ATKA AND AMLIA ISLANDS, CENTRAL ALEUTIAN ISLAND ARC, ALASKA

by

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Introduction

This report presents the results from bulk chemical analyses of Tertiary igneous rocks that were collected on Atka and Amlia Islands during the summers of 1977 and 1979. The rocks were sampled in order to complement offshore geophysical and geological studies in the Amlia Corridor - that part of the Aleutian Ridge between 172°W and 176°W longitude (Fig. 1). We discuss the methods used, the accuracy and precision of the data, and the statistical reliability of the data from 59 rocks (31 from Atka and 28 from Amlia).

This report is also written to provide a readily available reference for routine procedures of chemical analyses that are offered by the Branch of Analytical Chemistry in the U. S. Geological Survey. Most journals will not accept lengthy discussion of methods, accuracy and precision of data, and statistical reliability. The reader should recognize that procedures, equipment, and laboratory personnel change and that methods, accuracy, and precision also change with them.

We are not able to include all contributors to the data base as co-authors, but we gratefully acknowledge their assistance. In particular, we thank Walt Friesen for his careful petrographic studies of the Amlia samples and the following chemists: W. Updegrove (X-ray spectroscopy, Menlo Park), J. Wahlberg (X-ray spectroscopy, Denver), V. Mossotti (X-ray spectroscopy, Menlo Park), J. Baldwin (partial chemical analyses, Menlo Park), H. Millard, Jr. (neutron activation analysis, Denver), and J. Rowe (neutron activation analysis, Reston). We also appreciate the early assistance of J. Seeley (Denver) who recommended the prodecures that were used to produce the analytical data. Special thanks to Joseph Taggart, Ardith Bartel, and Rosemary Sliney for their thoughtful reviews and suggestions, and to David McKown and Greg Wandless for their suggestions.

Previous Work

Prior to 1977, no systematic studies of the Tertiary rocks on Atka and Amlia Islands had been carried out. In 1977 and 1979 reconnaissance mapping of the islands was accompanied by sample collection for petrographic, age, and chemical studies. Results are reported by Hein et al. (1981, 1984) and McLean et al. (1983). Friesen (1982) discussed the petrography of igneous rocks from Amlia Island. Offshore geophysical and geological studies of the Amlia Corridor are given by Scholl et al. (1982; 1983a; 1983b).

Geology

Amlia Island

Amlia Island is the easternmost of the two islands and is separated from Atka Island by the 2 km-wide Amlia Pass (Fig. 2). The rocks are of late Eocene and early Oligocene age and comprise part of the Lower Series (Scholl et al., 1983a). These Lower Series rocks formed during the extensive build-up of the Aleutian Ridge that occurred early in its history.

The rocks are well-exposed along all parts of the coastline. Most are coarse volcaniclastic sediments with thick beds of breccia, conglomerate, and sandstone. Massive and pillowed lava flows are minor contributors and consist of basalt, basaltic andesite, andesite, and rhyolite. Hypabyssal dikes, plugs, and sills are gabbro, diabase, basalt, basaltic andesite, andesite, dacite, rhyolite, and quartz diorite. A thick series of quartz diorite (micro-tonalite) sills form rugged outcrops along several kilometers of the southern coastline.

The rocks on Amlia Island have been metamorphosed to the zeolite and prehnite-pumpellyite facies. The higher-grade rocks occur on the north-eastern part of the island. The strata are nearly horizontal; locally, faults and small folds deform the rocks.

Atka Island

Atka Island can be divided into two parts. The northern part consists of mostly Quaternary stratovolcanoes. The southern part is about 85 km long, averages 10 km wide, and is separated from the northern part by a 3 km-wide isthmus. The shoreline of the southern part is broken by elongate bays, rocky headlands, and small islands. Most of the folds are gently dipping and open resulting in an east-west trending mountain ridge (Fig. 3).

The southern shore of the island is characterized by volcaniclastic rocks of bedded marine sandstones, mudstones, and minor conglomerates interbedded with volcanic flows of dark gray andesite and basalt, volcanic breccias, and rare pillowed flows. These are intruded by coarse-grained plutons. The age of the pre-plutonic sequence is mostly late Eocene and early Oligocene, equivalent to the rocks on Amlia Island (Hein et al., 1984).

A sequence of syn- and post-plutonic rocks, unconformably overlying the pre-plutonic sequence is exposed on the north shore of the southern part of the island. This sequence consists of volcanic flows, breccias, and sedimentary rocks of carbonaceous mudstone and fossil-log-bearing volcanic debris flows. It is middle to late Miocene in age (Hein et al., 1984). Near the isthmus, the Quaternary volcanic complex that composes the northern part of the island overlies the post-plutonic rocks.

There were three major episodes of volcanism. The first was submarine and occurred during late Eocene to early Oligocene. A second episode, consisting of basalt and basaltic andesite, took place in the middle to late Miocene. The third episode formed the stratovolcanoes on the northern part of the island.

Metamorphism on the southern half of Atka Island is higher grade than on Amlia Island and increases in the sedimentary and volcanic rocks from east to west. The grade changes from zeolite to prehnite-pumpellyite to greenschist (albite-epidote and hornblende hornfels) characterized by chlorite, epidote, amphibole, and quartz.

Methods and Results

Field Work and Sampling

Small boats with outboard motors were used during the field studies. Outcrops were selected from the boats and landings were made to choose the samples and to perform detailed outcrop observations. The samples were chosen to be representative of a specific outcrop or a sequence of strata. Generally, the rocks chosen were the least weathered at the outcrop and they were checked for veins, coatings, and amygdules. The rocks were cut into billets for thin sections and into clean 50-100 gram samples for chemical analyses. Summaries of the analyses performed are given in Tables 1 and 2.

Petrography and Rock Classification

The petrography of igneous rocks from Amlia Island was described by Friesen (1982), who supplemented his microscope results with X-ray diffraction studies. Table 3 summarizes the petrographic data. The petrography of igneous rocks from Atka Island is summarized in Table 4.

The rocks (Tables 1 and 2) are classified by modal mineralogy, texture, and SiO_2 content. Important mineralogic distinctions are the presence of abundant hypersthene in norite, to distinguish it from gabbro, and the presence of quartz in tonalite (finer grained) and quartz diorite. Classification by SiO_2 content gives the following rock names and SiO_2 ranges: gabbro, norite, and basalt, <52%; diabase <54%; basaltic andesite and meladiorite, 52-54%; diorite, 54-59%; andesite, 54-61%; dacite, 61-67%; rhyolite, >67%; and quartz diorite and tonalite, 59-66%.

Chemistry

Four types of chemical analyses were performed on the rocks. X-ray spectroscopy was used to analyze 8 major (SiO_2, TiO_2, Al_2O_3, Fe_2O_3, MgO, CaO, Na_2O, and K_2O) and 2 minor (P_2O_5 and MnO) oxides. Instrumental neutron activation analysis (I.N.A.A.) was used to determine trace element abundances, particularly the rare earth elements. Emission spectroscopy was used to analyze approximately 35 minor and trace elements; generally, the precision and accuracy of this method were less than those by other methods. Partial chemical analyses determined H_2O^+, H_2O^-, CO_2, and FeO.

The analyses were distributed among three main analytical laboratories in the U. S. Geological Survey located in Reston, Virginia, Denver, Colorado, and Menlo Park, California. They were performed over a 3-year period between 1979 and 1982. The precision and accuracy of the various types of chemical analyses are dependent on several variables: 1) type of analysis performed, 2) number of locations where analyses were performed (i.e. not all performed in the same laboratory), 3) who performed the analyses, 4) sample preparation technique utilized to prepare the samples prior to analysis, 5) the concentration at which the elements were analyzed, and 6) the standards used.

The same element is often analyzed by several methods. Generally, X-ray spectroscopy and neutron activation are more accurate and precise than the emission spectroscopy method.

The concentration of elements analyzed for is a variable that is often overlooked. Precision estimates are often reported in fixed percent rather than relative percent. The precision is a function of the amount of a given element present and approaches 50% by definition as the detection limit is approached. For a given element reported as a fixed amount, the precision is reported differently if the element is specified as a minor constituent of the sample versus a trace constituent, even if the amount present is the same in both cases. This is because different sample preparation techniques are used to prepare samples for major element analysis versus minor element analysis.

The standards used comprise a significant variable. For example, if different standards are used in different runs for a given type of analysis, the corresponding results cannot be compared with confidence.

X-ray Spectroscopy: X-ray spectroscopy was performed on three sets of samples. The first two sets, one from Amlia Island and one from Atka Island (Tables 5 and 6) were analyzed in the Menlo Park lab using a Diano 8600 wavelength-dispersive sequential X-ray spectrometer. For precision and accuracy of this method see Fabbi et al. (1976). The third set (from Atka Island, Table 6) was analyzed in the Denver, Colorado lab using a Phillips PW1600 wavelength-dispersive simultaneous X-ray spectrometer, according to the method of Taggart et al. (1981). The Denver spectrometer was calibrated with 42 worldwide rock standards, with the intent of accepting the world's bias on these standards as the bias for the Denver X-ray project. To insure that the calibration remains constant, 9 of the 42 standards were selected on the basis of quality and appropriate elemental abundances and are used to periodically recalibrate the instrument with a computer controlled recalibration program. An in-house standard (Basalt, BB-1) is periodically prepared and then counted every tenth sample to insure adherence to the original calibration. The samples in Table 6 analyzed by this method were all counted on the same day, and correspond to the precision and accuracy summarized in Table 7 for BB-1. Since all samples presented to the X-ray spectrometer are 91% lithium tetraborate, the statistics for this basalt are, to a spectrometer, reasonably similar to all the rock types covered by this study.

U.S. Geological Survey standards used at the Menlo Park analytical lab were QLO-1 (latite) for the major oxides and BCR-1 (basalt) for Sr and Ni. Data for these standards run with our samples are presented in Table 8.

Instrumental Neutron Activation Analysis: INAA was performed for selected Rare Earth Elements (REE) plus other elements for the three sets of samples (Tables 9 and 10). For the samples analyzed at Reston (Table 8) sample aliquots of 0.1 gm each were irradiated (Irr. No. 646 and 647) for two hours at the Georgia Tech. Research Reactor on November, 10, 1979 and November 14, 1979. The samples were counted on November 16, 1979 and January 1, 1980 on the low energy photon detector, and on November 18, 1979, December 3, 1979, and January 18, 1980 on Ge(Li) spectrometers. Four replicates of U.S.G.S. Standard Rock AGV-1 (andesite) were analyzed as controls. For the analytical method used and precision and accuracy of the method used, see Baedecker (1979).

The method used in Denver differs in only minor points from that described in Baedecker (1979). Ongoing comparison of the results between the two labs yields strong agreement regarding their precision and accuracy. Table 11 presents the data in Table 9 normalized for chondrites.

Emission Spectroscopy: Emission spectroscopy was performed for selected minor and trace elements for all three sets of rocks (Tables 12 and 13). Quality control samples are run at the beginning, middle, and end of each set of samples. In this study our largest job consisted of 26 samples, so no more than 13 samples were run between quality control checks. Maximum job size is 40 so no more than 20 samples would be run between quality control checks. Pooled standard deviation for 35 elements by direct-reading optical emission spectroscopy is 10% (relative standard deviation).

Wet Chemistry and Loss on Ignition (LOI): FeO is determined by wet chemistry (Peck, 1964). Total iron (in the form of Fe_2O_3) is analyzed by X-ray spectroscopy, as described earlier. The actual amount of iron present as Fe_2O_3 is calculated by difference. LOI is determined for H_2O^+, H_2O^- (Kolthoff et al., 1969; Penfield, 1894), and CO_2 (Tillman, 1977) in order to determine freshness of the rock and total carbon content of the rock. A LECO WR-12 carbon determinator was used to analyze for total carbon as CO_2. These analyses were done on all three sets of rocks (Tables 5 and 6). The accuracy of the determinations for FeO, H_2O^+, and H_2O^- is ±1% of the amount reported; for CO_2 it is ±2%.

Discussion

We have presented data on the chemistry of rocks from Atka and Amlia Islands, discussed the methods used to perform the chemical analyses, and provided information regarding the accuracy and precision of the methods.

The igneous rocks from Amlia and Atka Islands include most types that are found in intraoceanic island arcs, from basalt to rhyolite and gabbro to quartz diorite. SiO_2 contents range from 45.67% to 71.53% (uncorrected for volatiles) and K_2O ranges from 0.20% to 4.71%. The rocks are metamorphosed and/or weathered which means that some ion mobility has occurred.

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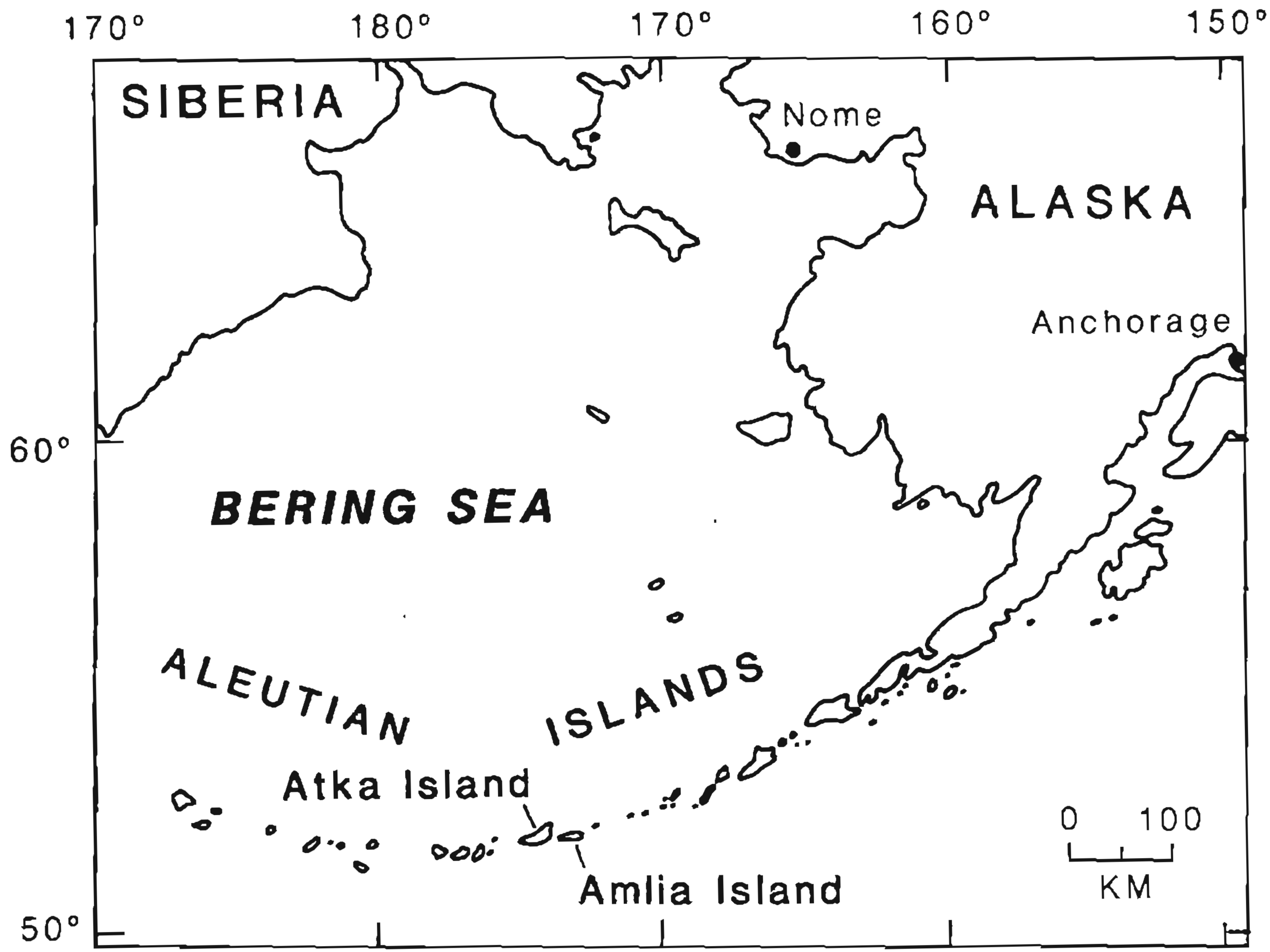

Figure 1. Location map showing Atka and Amlia Islands.

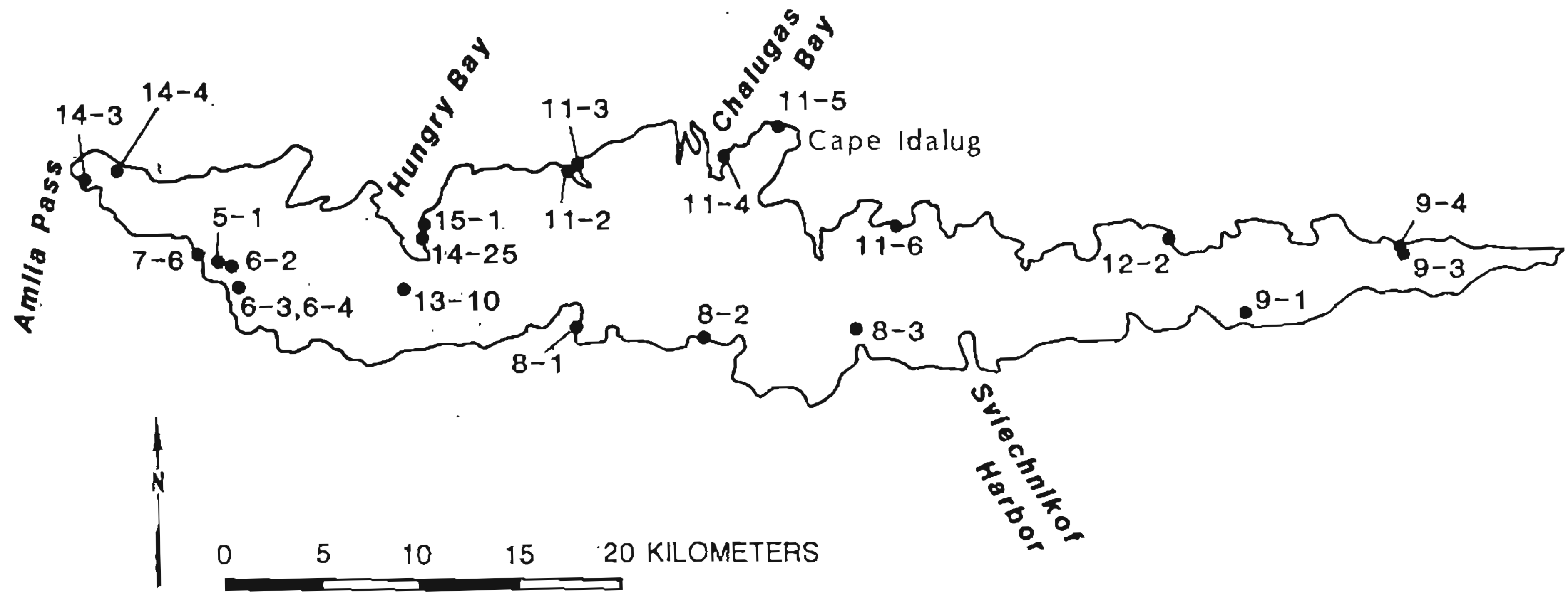

Figure 2. Amlia Island showing sample locations.

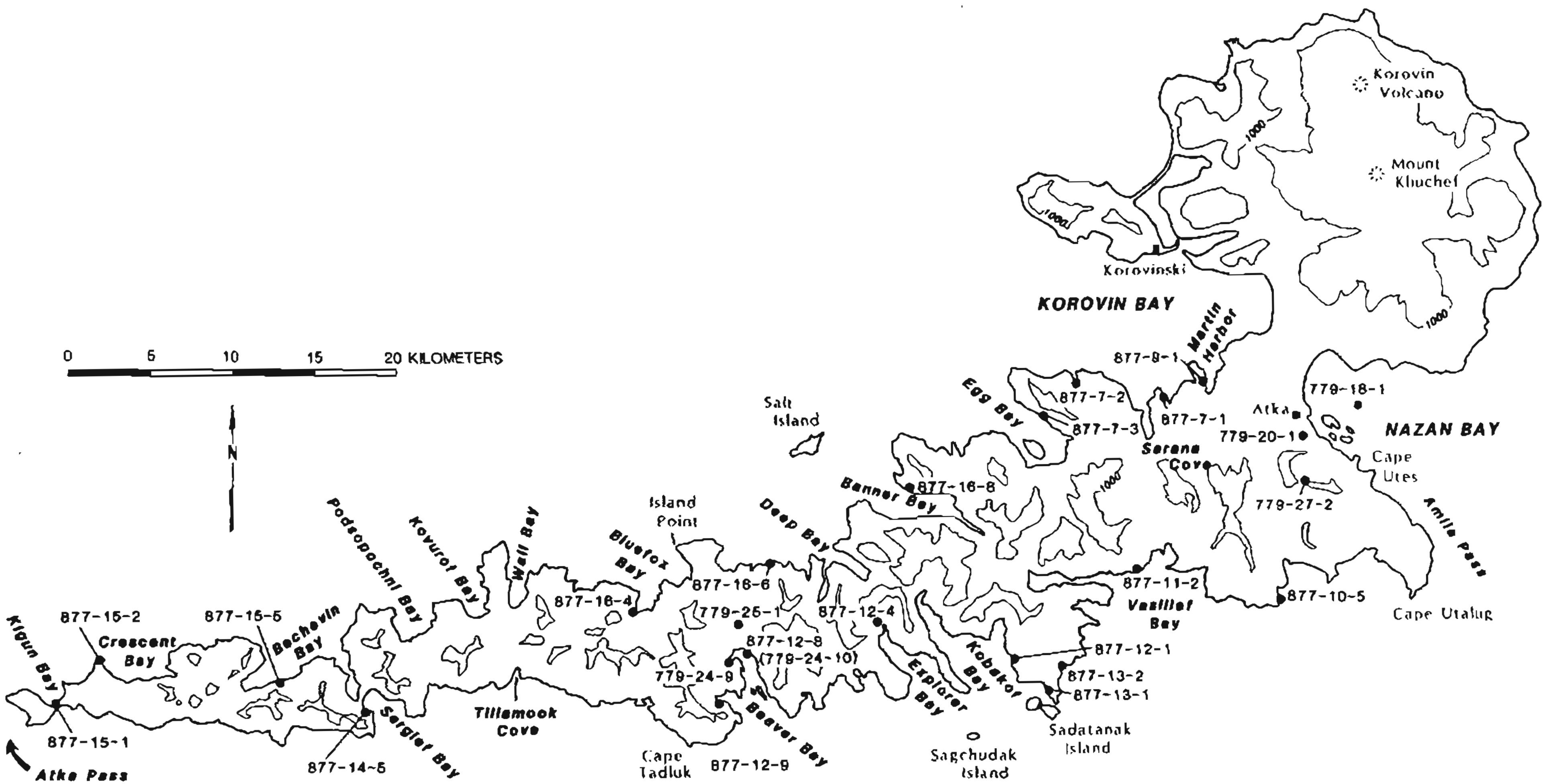

Figure 3. Atka Island showing sample locations.

Table 1. Rock names and analyses performed on igneous rocks from Amlia Island. Rocks are arranged by increasing SiO_2 content and setting (1-4 are intrusives; 5-28 are flows). Analyses are P, petrography; X, x-ray spectroscopy; N, neutron activation; A, K-Ar age; S, Sr^{87}/Sr^{86} isotopes; O, other chemistry (H_2O, CO_2, FeO).

No.	Sample	Name	Texture	% SiO_2	% K_2O	Analyses
1	779-14-25A	Gabbro	PG	48.61	0.54	P,X,N,O,S
2	779-11-2	Gabbro	HG	50.05	0.68	P,X,N,O
3	779-8-2B	Tonalite	PG	64.28	2.53	P,X,N,O,S
4	779-8-2C	Tonalite	PG	64.67	2.97	P,X,N,O
5	779-13-10D	Basalt	I	44.77	0.22	P,X,N,O
6	779-12-2A	Basalt	In to I	46.61	0.20	P,X,N,O
7	779-7-6B	Basalt	S to I	47.14	0.28	P,X,N,O
8	779-11-4A	Basalt	In	47.53	0.82	P,X,N,O,S
9	779-15-1C	Basalt	I	48.67	0.54	P,X,N,O
10	779-14-3A	Basalt	I	48.73	0.52	P,X,N,O
11	779-11-3	Basalt	In	50.62	0.80	P,X,N,O
12	779-9-1B	Basalt	I	51.19	0.41	P,X,N,O
13	779-9-1A	Basalt	I	51.65	1.30	P,X,N,O,S
14	779-14-4A	Basalt	I	51.68	1.52	P,X,N,O
15	779-8-3C	Basaltic and.	In	52.61	1.19	P,X,N,O,A
16	779-6-4	Basaltic and.	I	52.81	3.02	P,X,N,O
17	779-5-1	Basaltic and.	I	53.71	0.64	P,X,N,O,S
18	779-6-2	Andesite	H	59.04	2.50	P,X,N,O
19	779-8-3A	Andesite	In	60.31	1.16	P,X,N,O,S
20	779-6-3C	Andesite	H	60.47	2.21	P,X,N,O
21	779-8-1B	Andesite	H	60.72	2.36	P,X,N,O
22	779-9-4A	Dacite	In	66.59	4.71	P,X,N,O,A
23	779-8-1A	Rhyolite	H	69.00	1.69	P,X,N,O
24	779-11-6D	Rhyolite	H	69.64	1.62	P,X,N,O
25	779-11-6A	Rhyolite	H	70.01	1.93	P,X,N,O,S
26	779-12-2B	Rhyolite	H	71.05	2.18	P,X,N,O
27	779-9-3B	Rhyolite	H	71.33	1.37	P,X,N,O,S
28	779-11-5A	Rhyolite	H	71.53	1.01	P,X,N,O

Textures: H, hyalopilitic; HG, hypidiomorphic granular; I, intersertal; In, intergranular; PG, porphyritic granular; S, subophitic.

Table 2. Rock names and analyses performed on igneous rocks from Atka Island. Rocks are arranged by increasing SiO_2 content and setting (intrusives comprising the first group of 23, flows the remaining 8). Analyses are P, petrography; X, x-ray spectroscopy; N, neutron activation; A, K-Ar age; U, uranium-lead age; O, other chemistry (H_2O, CO_2, FeO); S, emission spectroscopy.

No.	Sample	Name	Texture	%SiO_2	%K_2O	Analyses
1	877-16-4A	Norite	H	45.67	0.31	P,X,N,O,S
2	877-7-2	Gabbro	H	46.65	0.51	P,X,N,O,S
3	779-24-10A	Bio-Hbl-Norite	H	47.80	1.76	P,X,N,O,S
4	877-13-1A	Gabbro	H	49.66	0.54	P,X,N,O,S
5	877-13-2 IV	Diabase	-	50.09	1.10	X,N,O,S
6	877-12-9A	Hbl-Norite	H	50.12	0.90	P,X,N,O,S
7	877-14-5 III	Diabase	DB	50.15	0.49	P,X,N,O,S
8	877-12-1	Diabase	PD	50.82	1.11	P,X,N,O,S
9	877-14-5 VI	Diabase	-	50.88	0.63	X,N,O,S
10	877-13-2 I	Diabase	PD	51.00	1.02	P,X,N,O,S
11	779-24-10B	Hbl-Norite	H	51.90	0.75	P,X,N,O,S
12	877-11-2	Diabase	PD	52.38	0.92	P,X,N,O,S
13	877-16-8B	Meladiorite	H	52.57	1.24	P,X,N,O,S
14	877-12-8	Meladiorite	H	52.60	0.74	P,X,N,O,A,S
15	877-13-2	Diabase	PD	53.17	1.13	P,X,N,O,S
16	877-15-1	Meladiorite	H	53.70	0.28	P,X,N,O,S
17	877-15-2	Diorite	H	57.37	1.89	P,X,N,O,S
18	877-12-9	Quartz diorite	-	59.02	1.26	X,N,O,A,S
19	779-24-9	Quartz diorite	H	59.50	1.86	P,X,N,O,S
20	877-14-5 II	Quartz diorite	H	60.02	2.08	P,X,N,O,A,S
21	779-20-1	Quartz diorite	PG	61.10	2.50	P,X,N,O,S
22	779-25-1	Quartz diorite	H	61.10	2.52	P,X,N,O,U,S
23	877-16-6	Quartz diorite	H	65.10	2.71	P,X,N,O,S
24	877-7-1	Basalt	PX	46.15	0.37	P,X,N,O,S
25	877-10-5B	Basalt	PX	48.51	0.70	P,X,N,O,S
26	877-9-1	Basalt	PX	50.08	0.75	P,X,N,O,A,S
27	779-27-2	Basalt	PI	50.80	0.98	P,X,N,O,S
28	877-15-5B	Basalt	PI	51.32	1.24	P,X,N,O,A,S
29	779-18-1A	Basaltic and.	PF	53.20	0.25	P,X,N,O,S
30	877-7-3	Andesite	PV	58.10	1.19	P,X,N,O,S
31	877-12-4	Andesite	PI	58.45	0.29	P,X,N,O,S

Textures: B, Porphyroblastic; H, hypidiomorphic granular; P, porphyritic; D, diabasic; G, intergranular; F, felty; I, intersertal; X, pilotaxitic; V, variolitic.
Rock names: Classified by SiO_2 content, mineralogy, and texture (see text).

Table 3. Major minerals, primary and secondary, in igneous rocks from Amelia Island determined by thin section and x-ray diffraction (x) analyses. Order shows relative abundance as determined from thin section analysis.

No.	Sample	Name	Primary Minerals	Secondary Minerals	Remarks
1	779-14-25A	Gabbro	Pl, Cpx, Gl, Opx(?), O	Chl, Am, Ze, Hm, Sm, S(?), L	
2	779-11-2	Gabbro	Pl, Cpx, Opx, O, Ap, Qtz	K, Sm, S(?), Am	Cpx peripherally amphibolized and includes microlites of Ap
3	779-8-2B	Tonalite	Pl, Qtz, O, Opx(?), Cpx	K, C, S(?), Ze	
4	779-8-2C	Tonalite	Pl, Qtz, Cpx, O, Opx(?)	Pu(?), K, C, Ze, S(?), L	
5	779-13-10D	Basalt	Pl, Cpx, Gl, O, Opx(?)	Ze, An, Sm, K, Chl, Pu(?), S(?)	
6	779-12-2A	Basalt	Pl, Cpx, Gl, O, Opx(?)	Chl, Ep, K, M(?), S(?), L	
7	779-7-6B	Basalt	Pl, Gl, Cpx, O, Opx(?)	Sm, Ca, S(?)	
8	779-11-4A	Basalt	Pl, Cpx, Gl, O, Opx(?), Qtz	Chl, Ca, An(?), L, S(?), N(?), K	
9	779-15-1C	Basalt	Pl, Gl, Cpx, Qtz, Pl, O, Opx(?)	Sm, L, Ca	
10	779-14-3A	Basalt	Pl, Gl, Cpx, O	C, K, Chl, Ze, S(?)	Pl rimmed with fresher feldspars
11	779-11-3	Basalt	Pl, Cpx, Gl, O, Qtz, Opx(?), Ap	Sm, C, Chl, K, S(?), Am	Matrix Pl includes rare microlite of Ap
12	779-9-1B	Basalt	Pl, Gl, Cpx, O, Qtz	Sm	
13	779-9-1A	Basalt	Pl, Gl, Cpx, O, Qtz, Opx(?)	C, Ze, S(?), Hm	
14	779-14-4A	Basalt	Pl, Gl, Cpx, O, Opx(?), Ol(?)	C, Pu(?), Ze, Ca, K	
15	779-8-3C	Basaltic and.	Pl, Cpx, Gl, O	Hm, Chl, Pu, N(?), S(?)	Matrix ore totally altered to Hm
16	779-6-4	Basaltic and.	Pl, Or(?), Cpx, Gl, O, Qtz, Opx(?)	Chl, Ze, Pu(?), L, Bio(?), S(?)	
17	779-5-1	Basaltic and.	Pl, Gl, Cpx, O, Opx	Sm, Chl, Ca	
18	779-6-2	Andesite	Gl, Pl, Qtz, Cpx, Or(?), O, Opx(?)	Chl, Ze, Sm, K, Ep, Pu(?), Ca, Hm	Gl highly altered and Qtz-charged
19	779-8-3A	Andesite	Pl, Gl, Cpx, Qtz, Opx(?), O	Sm, K, Ze, S(?), Hm, Pu(?)	
20	779-6-3C	Andesite	Gl, Pl, Cpx, O, Opx(?)	Sm, Ze, Qtz, S(?)	
21	779-8-1B	Andesite	Gl, Pl, Cpx, Opx, O, Or(?)	Ze, Sm, S(?)	
22	779-9-4A	Dacite	Gl, Pl, Qtz, Or(?), Cpx, O, Opx	Pu, Ze, Hm, L	Ore highly altered
23	779-8-1A	Rhyolite	Gl, Qtz, Pl, Cpx, O, Or(?), Ap, Opx(?)	Ze, Sm, S(?), K, Pu(?)	Ap in matrix
24	779-11-6D	Rhyolite	Gl, Qtz, Pl, Cpx, O, Or(?)	Ze, Sm, Hm, Qtz, Pu(?), K, L, C	Ap observed as inclusions in Cpx
25	779-11-6A	Rhyolite	Pl, Gl, Qtz, Cpx, O, Opx(?), Ap	C, Ze, K, Hm, Pu(?), S(?)	Both phyric and matrix ores highly altered
26	779-12-2B	Rhyolite	Gl, Qtz, Pl, Cpx, O, Or(?)	Qtz, Pu(?), Hm, Sm, K, Ze, Ep	Highly altered Gl charged with Hm dust
27	779-9-3B	Rhyolite	Gl, Pl, Cpx, Qtz, O, Opx	Ze, Hm, Sm, G	Gl (somewhat altered) charged with Hm dust
28	779-11-5A	Rhyolite	Pl, Gl, Qtz, Cpx, O, Opx(?)	Sm, C, Hm, Qtz, K, S(?), Pu(?), Ep	Ore displays evidence of resorption and alteration to hematite. Matrix ore highly altered.

Am, amphibole; An, analcime; Ap, apatite; Bio, biotite; C, chlorophaeite; Ca, calcite; Chl, chlorite; Cpx, clinopyroxene; Ep, epidote; G, goethite; Gl, glass; Hm, hematite; K, kaolinite; L, leucoxene; M, magnetite; N, natrolite; O, ore; Ol, olivine; Or, orthoclase; Opx, orthopyroxene; Pl, plagioclase; Pu, pumpellyite; Qtz, quartz; S, sericite; Sm, smectite; Ze, zeolites. From Friesen, 1981.

Table 4. Major minerals, primary and secondary, in igneous rocks from Atka Island determined by thin section and x-ray diffraction (x) analyses. Order shows relative abundance as determined from thin section analyses.

No.	Sample	Name	Primary Minerals	Secondary Minerals	Remarks
1	877-16-4A	Norite	P, Cpx, Opx, Ox, H	Act, Chl, Ca, Pr, Ct(x), Or(x)	Thin section 16-4
2	877-7-2	Gabbro	P, Cpx, Ol(?), H, Opx, Ox	Ep, Sp, Act, Chl, Ca, Or(x)	Many mafic minerals replaced Could be a hornfelsed diabase
3	779-24-10A	Bio-Hbl-Norite	P, Bio, H, Opx, Ox	Ca	Border zone to 24-10B, no Cpx
4	877-13-1A	Gabbro	P, Cpx, Ox, Opx	Act, Chl, Pr, Qtz, Or(x)	Metagabbro
5	877-13-2 IV	Diabase	P, Cpx, Ox	Act, Chl, Qtz, Or(x), Ze(?)	Hornfelsed diabase
6	877-12-9A	Hbl-Norite	P, H, Opx, Bio, Cpx, Ox	Ct(x)	Similar to xenoliths from Koniuji
7	877-14-5 III	Diabase	P, Ox	Act, Bio, Chl, Qtz, An(x)	Hornfelsed diabase (high-grade)
8	877-12-1	Diabase	P, Cpx, Ox	Chl, Pr, Ca, Hm, Qtz(x), Ze(?)	Metadiabase (low-grade)
9	877-14-5 VI	Diabase	no thin section available		
10	877-13-2 I	Diabase	P, Cpx, Ox	Act, Pr, Ep, Ze, Qtz(?)	Substitute 13-2 thin section
11	779-24-10B	Hbl-Norite	P, H, Opx, Bio, Ox, Cpx	Chl	Fresh, essentially unaltered
12	877-11-2	Diabase	P, Cpx, Ox	Act, Chl, Qtz, Pr, Hm, Ze(?)	Metadiabase (low-grade)
13	877-16-8B	Meladiorite	P, Ox, Qtz, Or(?)	Act, Ep, Pr, Sp, Chl	Cpx replaced by Act
14	877-12-8	Meladiorite	P, H, Bio, Ox, Opx	Act, Chl, Sp	Relatively unaltered
15	877-13-2	Diabase	no thin section available		
16	877-15-1	Meladiorite	P, Qtz, Cpx, H, Ox	Act, P, Ep, Chl, Sp, Ze(?)	Typical albite granite
17	877-15-2	Diorite	P, H, Qtz, Bio, Ox, Opx	Act, Chl, Ep, Sp, Hm, Ca	
18	877-12-9	Quartz diorite	no thin section available		
19	779-24-9	Quartz diorite	P, H, Bio, Cpx, Ox, Opx, Qtz	Act	Relatively fresh
20	877-14-5 II	Quartz diorite	P, Cpx, Opx, Bio, Qtz, H, Ox	Act	Relatively fresh
21	779-20-1	Quartz diorite	P, Cpx, H, Qtz, Ox, Opx, Bio	Chl, Act, Ep, Pr, Qtz, Ze(?), Sp	
22	779-25-1	Quartz diorite	P, Bio, H, Qtz, Cpx, Ox, Opx	Act	Fresh, relatively unaltered
23	877-16-6	Quartz diorite	P, Qtz, Bio, H, Opx, Cpx	Act, Chl, Pr, Ep, Ca, Sp	Trondhjemite - quartz-rich
24	877-7-1	Basalt	P, Ox	Ca, Chl, Ze, Ep	Mafic minerals replaced; amyg.
25	877-10-5B	Basalt	P, Cpx, Ol, Ox	Sm, Ca, An(x), He(x)	Abundant zeolites
26	877-9-1	Basalt	P, Cpx, Ox, Gl, H, Opx	Ca, Sm, Ze, Hm, Chl	Clean Cpx, probably best basalt sample
27	779-27-2	Basalt	P, Cpx, Ox, Gl	Sm, Ze, Qtz, P	Glass almost totally replaced by Sm
28	877-15-5B	Basalt	P, Cpx, Ox	Pr, Act, Py(x), Ct(x), Chl, Sm, Qtz	Greatly altered, prehnite-pumpellyite
29	779-18-1A	Basaltic and.	P, Ox	Ep, He(x), Chl, Hm, Qtz, Sm	Greatly altered
30	877-7-3	Andesite	P, Cpx, Ox	Chl, Ze, Ca, Qtz, Sp	Variolitic Cpx
31	877-12-4	Andesite	P, Ox, Gl	Chl, Sm, Ca, Ep, Pr, Sp	Most glass replaced by chlorite

Act, actinolite; An, analcime; Bio, biotite; Ca, calcite; Chl, chlorite; Cpx, clinopyroxene; Ct, clinoptilolite; Ep, epidote; Gl, glass; H, hornblende; He, heulandite; Hm, hematite; Ol, olivine; Or, orthoclase; Opx, orthopyroxene; Ox, Fe-Ti oxides; Pl, plagioclase; Pr, prehnite; Qtz, quartz; Sm, smectite; Sp, sphene; Ze, zeolites.
Name: original rock type; many should have "meta" prefix.

Table 5. Major, minor, and trace oxide compositions of igneous rocks from Amlia Island.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
SiO_2 (%)	48.61	50.05	64.28	64.68	44.77	46.61	47.14	47.53	48.67	48.73	50.62	51.19	51.65	51.68
Al_2O_3	19.50	19.62	15.34	14.90	18.27	18.59	17.35	18.79	15.12	17.60	17.01	14.50	15.47	15.79
Fe_2O_3	2.42	3.82	2.88	2.29	3.69	3.64	6.93	2.48	7.24	3.40	3.03	6.07	6.60	4.30
FeO	5.20	5.18	2.92	3.32	5.40	5.99	4.24	6.88	5.02	5.57	6.18	7.00	5.39	4.53
MgO	4.40	3.70	1.70	1.53	5.21	4.37	5.39	4.78	4.91	4.20	5.64	4.48	3.75	4.93
CaO	11.28	10.41	2.32	2.69	8.85	10.43	10.96	9.93	10.26	8.83	9.39	8.69	7.81	7.69
Na_2O	3.38	3.60	4.92	4.48	3.79	3.94	3.22	3.42	2.84	4.25	3.04	3.32	3.98	3.33
K_2O	0.55	0.68	2.53	2.97	0.22	0.20	0.28	0.82	0.54	0.52	0.80	0.41	1.30	1.52
TiO_2	0.77	0.95	0.76	0.75	0.91	0.93	1.01	0.83	1.22	0.87	0.76	1.33	1.24	0.74
P_2O_5	0.14	0.17	0.24	0.23	0.17	0.15	0.18	0.15	0.20	0.17	0.16	0.16	0.23	0.14
MnO	0.133	0.129	0.132	0.106	0.144	0.132	0.242	0.145	0.202	0.113	0.147	0.174	0.173	0.139
H_2O^+	3.14	1.86	1.16	1.56	5.47	4.68	0.83	3.35	1.13	3.17	2.25	0.69	1.41	1.58
H_2O^-	0.75	0.46	0.83	0.62	2.39	0.73	3.36	0.49	2.43	2.09	0.45	2.12	1.99	2.88
CO_2	0.04	0.08	0.06	0.07	0.40	0.05	0.20	0.46	0.43	0.06	0.04	0.04	0.05	0.17
Total	100.31	100.71	100.07	100.20	99.68	100.44	101.33	100.06	100.21	99.57	99.52	100.17	100.24	99.42
Ni (ppm)	16	8	<8	<8	39	16	31	24	16	24	31	16	16	31
Sr	372	423	169	186	431	600	372	490	271	431	381	279	279	304
Rock Type	Gabbro	Gabbro	Tonalite	Tonalite	Basalt	Basalt	Basalt	Basalt	Basalt	Basalt	Basalt	Basalt	Basalt	Basalt

Table 5 (cont.)

	15	16	17	18	19	20	21	22	23	24	25	26	27	28
SiO_2 (%)	52.61	52.81	53.71	59.04	60.31	60.47	60.72	66.59	69.00	69.64	70.01	71.05	71.33	71.53
Al_2O_3	14.49	16.57	15.22	15.54	15.03	15.54	13.93	14.72	13.63	13.95	13.21	11.94	12.32	12.33
Fe_2O_3	5.76	3.06	5.19	2.81	4.38	3.12	2.51	3.85	2.17	2.29	2.86	3.25	2.59	3.22
FeO	6.83	4.35	6.21	4.83	3.21	4.80	2.94	1.21	2.66	1.85	1.41	1.46	2.46	1.80
MgO	3.82	4.49	3.76	3.62	2.88	3.02	1.74	1.31	1.31	1.05	1.24	1.05	1.10	0.82
CaO	6.32	5.41	6.90	4.13	3.89	3.77	5.84	1.44	1.83	1.78	1.46	1.57	2.67	1.54
Na_2O	4.88	4.41	4.07	4.08	6.08	4.78	3.47	4.81	4.97	5.29	4.66	4.46	4.13	5.26
K_2O	1.19	3.02	0.64	2.50	1.16	2.21	2.36	4.71	1.69	1.62	1.93	2.18	1.37	1.01
TiO_2	1.20	1.11	1.33	0.91	0.85	0.89	0.72	0.90	0.83	0.68	0.64	0.73	0.82	0.77
P_2O_5	0.20	0.23	0.28	0.26	0.26	0.25	0.24	0.24	0.17	0.13	0.13	0.20	0.22	0.19
MnO	0.205	0.145	0.184	0.138	0.152	0.128	0.126	0.188	0.141	0.097	0.088	0.173	0.193	0.184
H_2O^+	2.13	2.83	1.33	1.86	1.39	1.49	2.92	0.59	0.95	1.03	1.20	0.72	0.77	0.70
H_2O^-	0.96	1.15	2.17	1.28	0.83	0.75	2.88	0.57	1.19	0.64	0.56	0.69	0.80	0.41
CO_2	0.06	0.05	0.12	0.18	0.04	0.10	0.04	0.06	0.06	0.08	0.04	0.08	0.04	0.06
Total	100.66	99.64	101.11	101.18	100.46	101.32	100.44	101.19	100.60	100.13	99.44	99.55	100.81	99.82
Ni (ppm)	8	16	8	24	16	24	<8	<8	<8	<8	<8	<8	<8	<8
Sr	144	364	279	194	85	178	211	25	110	93	161	42	169	42
Rock Type	Basaltic andesite	Basaltic andesite	Basaltic andesite	Andesite	Andesite	Andesite	Andesite	Dacite	Rhyolite	Rhyolite	Rhyolite	Rhyolite	Rhyolite	Rhyolite

All analyses performed at Menlo Park analytical lab. 10 major oxides + Ni and Sr analyzed on a Diano 8600 wavelength-dispersive sequential X-ray spectrometer by L. Espos. FeO analyzed by wet chemistry, total iron by X-ray spectroscopy and Fe_2O_3 by difference. H_2O^+ and H_2O^- measured gravimetrically. Total carbon measured as CO_2 using a LECO WR-12 carbon determinator. FeO, H_2O^+, H_2O^-, and CO_2 analyzed by P. Klock. Rock types are from Friesen, 1981. Sample numbers correspond with those in Tables 1 and 2.

Table 6. Major, minor, and trace oxide compositions of igneous rocks from Atka Island.

	1[2]	2[2]	3[1]	4[2]	5[2]	6[2]	7[2]	8[2]	9[2]	10[2]	11[1]	12[2]	13[2]	14a[1]	14b[2]	15[2]
SiO_2 (%)	45.67	46.65	47.8	49.66	50.09	50.12	50.15	50.82	50.88	51.00	51.9	52.38	52.57	51.7	52.60	53.17
Al_2O_3	22.30	21.97	17.7	15.61	16.62	14.84	14.74	16.48	15.83	16.98	19.2	14.84	20.81	20.1	19.17	17.36
Fe_2O_3	3.35	3.37	5.70	4.06	3.91	4.69	4.16	4.31	4.57	3.51	2.96	4.57	3.91	3.33	2.92	3.71
FeO	5.13	2.72	6.49	7.62	5.81	5.71	6.55	5.30	6.56	6.32	4.03	7.49	3.12	3.62	3.94	5.40
MgO	5.80	6.20	7.96	6.00	5.40	7.20	7.00	5.50	5.40	4.80	5.27	4.10	2.90	4.95	5.20	3.30
CaO	10.50	13.23	5.82	9.41	8.97	10.99	10.43	8.10	9.54	8.06	8.10	8.00	8.44	8.64	8.62	7.47
Na_2O	2.62	2.76	3.68	3.49	4.01	3.66	3.09	4.28	4.05	4.30	4.82	3.91	4.20	4.39	4.33	4.41
K_2O	0.31	0.51	1.76	0.54	1.10	0.90	0.49	1.11	0.63	1.02	0.75	0.92	1.24	0.73	0.74	1.13
TiO_2	0.28	0.30	0.85	1.17	1.00	0.63	0.89	0.94	0.95	1.04	0.84	1.41	0.77	0.60	0.86	1.05
P_2O_5	0.09	0.09	0.14	0.20	0.19	0.18	0.17	0.18	0.18	0.20	0.18	0.24	0.20	0.23	0.25	0.21
MnO	0.088	0.00	0.34	0.156	0.130	0.233	0.166	0.136	0.163	0.155	0.21	0.184	0.142	0.1	0.084	0.108
H_2O^+	1.51	1.53	0.97	1.76	2.15	0.67	1.12	2.39	1.04	2.26	0.97	1.76	0.97	0.95	1.25	2.28
H_2O^-	0.28	0.97	0.13	0.88	0.67	0.14	0.13	0.74	0.16	0.59	0.10	0.59	0.32	0.07	0.16	0.53
CO_2	0.15	0.38	0.17	0.12	0.10	0.30	0.18	0.35	0.09	0.11	1.19	0.19	0.18	0.10	0.05	0.11
Total	98.08	100.78	99.51	100.68	100.15	100.26	99.27	100.64	100.04	100.35	100.52	100.58	99.77	99.51	100.17	100.24
Ni (ppm)	39	31	<79	31	24	55	63	39	31	24	<79	<16	<8	<79	47	<8
Sr	609	347	254	313	338	457	355	347	389	330	592	304	981	676	820	389
Rock Type	Norite	Gabbro	Norite	Gabbro	Diabase	Norite	Diabase	Diabase	Diabase	Diabase	Norite	Diabase	Mela-diorite	Mela-diorite	Mela-diorite	Diabase

Table 6 (cont.)

	16[2]	17[2]	18[2]	19[1]	20[2]	21[1]	22[1]	23[2]	24[2]	25[2]	26[2]	27[1]	28[2]	29[1]	30[2]	31[2]
SiO_2 (%)	53.70	57.37	59.02	59.5	60.02	61.1	61.1	65.10	46.15	48.51	50.08	50.8	51.32	53.2	58.10	58.45
Al_2O_3	16.00	17.74	18.42	16.9	16.02	17.0	16.1	15.93	15.34	14.40	16.94	19.9	12.77	21.2	13.10	15.47
Fe_2O_3	2.59	3.46	2.36	1.52	2.31	2.82	1.52	1.33	3.63	3.89	3.20	5.74	2.59	3.54	3.85	4.45
FeO	2.40	3.33	2.54	3.30	2.87	2.51	3.02	1.92	5.53	4.35	4.63	2.59	5.81	3.83	3.73	4.20
MgO	5.70	3.10	2.70	4.47	4.40	2.26	4.04	2.20	6.50	7.50	5.60	3.37	10.30	1.12	3.50	3.70
CaO	11.35	6.20	6.58	6.20	6.28	5.26	5.44	3.95	7.96	11.57	11.13	7.46	9.97	8.95	5.84	3.22
Na_2O	4.99	3.95	4.26	3.76	4.11	3.83	3.61	4.10	4.62	4.31	3.52	3.54	2.50	3.26	3.96	5.46
K_2O	0.28	1.89	1.26	1.86	2.08	2.50	2.52	2.71	0.37	0.70	0.75	0.98	1.24	0.25	1.19	0.29
TiO_2	0.87	0.73	0.57	0.60	0.58	0.56	0.63	0.42	1.20	0.66	0.87	0.54	0.56	0.84	0.77	0.96
P_2O_5	0.31	0.22	0.18	0.14	0.15	0.16	0.14	0.13	0.23	0.14	0.17	0.18	0.16	0.13	0.14	0.17
MnO	0.077	0.124	0.081	0.08	0.098	0.12	0.07	0.037	0.230	0.171	0.142	0.18	0.182	0.33	0.184	0.145
H_2O^+	0.73	1.46	1.10	0.83	0.56	0.85	0.85	0.90	3.95	2.11	0.30	2.64	1.62	2.75	3.06	3.10
H_2O^-	0.29	0.67	0.18	0.09	0.50	0.11	0.10	0.37	0.96	2.02	0.83	1.73	0.29	0.41	1.21	0.63
CO_2	1.08	0.36	0.91	0.18	0.09	0.08	0.46	0.65	4.96	0.82	1.90	0.95	0.17	0.04	1.52	0.37
Total	100.37	100.60	100.16	99.43	100.07	99.16	99.60	99.75	101.63	101.15	100.06	100.60	99.48	99.85	100.15	100.62
Ni (ppm)	16	16	<8	<79	71	<79	<79	16	204	71	31	<79	196	<79	39	24
Sr	414	541	719	507	474	254	423	499	271	161	474	507	330	676	372	161
Rock Type	Mela-diorite	Diorite	Quartz Diorite	Quartz Diorite	Quart Diorite	Quartz Diorite	Quartz Diorite	Quartz Diorite	Basalt	Basalt	Basalt	Basalt	Basalt	Basaltic andesite	Andesite	Andesite

[1]10 major oxides analyzed in Denver on a Phillips PW 1600 wavelength-dispersive simultaneous X-ray spectrometer, J.S. Wahlberg, A. Bartel, and J. Baker, analysts. Ni and Sr analyzed in Menlo Park on a Diano 8600 wavelength-dispersive sequential X-ray spectrometer, and on a Kevex energy dispersive X-ray spectormeter. B. King, analyst.

[2]10 major oxides + Ni and Sr analyzed in Menlo Park on a Diano 8600 wavelength-dispersive sequential X-ray spectrometer and on a Kevex energy dispersive X-ray spectrometer. L. Espos, analyst.

For all samples FeO analyzed by wet chemistry, total iron by X-ray spectroscopy, and Fe_2O_3 by difference. H_2O^+ and H_2O^- measured gravimetrically. Total carbon measured as CO_2 using a LECO WR-12 carbon determinator. FeO, H_2O^+, and H_2O^- measured in Menlo Park, [1]M. Cremer and [2]M. Taylor analysts.
Sample numbers correspond to those in Tables 7 and 8.

Table 7. Statistics on in-house Baker Basalt Standard quality control sample counted 62 times over a 6-month period of time. Error limit is 1 sigma. First column is ±the standard deviation. Second column shows relative error. X-ray project, Denver, Colorado analytical laboratory.

Oxide	Result (%)	Relative error (%)
SiO_2	52.8 ± .19	0.36
Al_2O_3	16.7 ± .05	0.30
Fe_TO_3	9.35 ± .02	0.21
MgO	3.54 ± .06	1.7
CaO	6.60 ± .02	0.30
Na_2O	3.20 ± .07	2.2
K_2O	4.38 ± .03	0.68
TiO_2	0.88 ± .01	1.1
P_2O_5	0.60 ± .01	1.6
MnO	0.18 ± .01	5

Table 8. X-ray spectroscopy results of U.S. Geological Survey standards QLO-1 (latite) and BCR-1 (basalt) run with samples in Menlo Park analytical lab. QLO-1 was analyzed for 10 major oxides. BCR-1 was analyzed for SrO and NiO.

Oxide	Reference Value	Result	Relative error (%)
SiO_2	65.93	66.33 ± 0.2	0.27
Al_2O_3	16.37	16.50 ± 0.06	0.36
Fe_2O_3	4.29	4.41 ± 0.01	0.19
TiO_2	0.62	0.62 ± 0.002	0.38
MgO	1.04	1.29 ± 0.08	6.6
Na_2O	4.23	4.22 ± 0.14	3.3
CaO	3.24	3.26 ± 0.01	0.35
K_2O	3.63	3.63 ± 0.013	0.38
P_2O_5	0.26	0.26 ± 0.004	1.6
MnO	0.09	0.091 ± 0.004	4.5
SrO	0.039	0.039 ± 0.002	4
NiO	0.002	0.002 ± 0.0002	13

All analyses were performed on a Diano 8600 wavelength-dispersive simultaneous X-ray spectrometer. L. Espos and B. King, analysts. Reference values are from Flanagan, F.J., 1976, Descriptions and analyses of eight new U.S.G.S. rock standards: U.S. Geological Survey Prof. Paper 840, 192 p.

Table 9. Instrumental neutron activation analysis of igneous rocks from Amlia Island.

	1	2	3	3	4	4	5	6	7	7	8	9	10	11	12	12	13	13	14	15	15	16	16
Ba	<300	130	758	743	872	801	<300	<300	<300	<300	200	130	230	160	160	190	385	416	410	270	240	612	696
σ	(1)	28 (1)	3 (3)	3 (3)	3 (3)	3 (3)	(1)	(1)	(1)	(1)	17 (2)	29 (1)	13 (2)	17 (2)	23 (1)	29 (1)	7 (3)	7 (3)	10 (3)	15 (1)	12 (3)	6 (3)	4 (3)
Co	23.0	25.8	10.0	9.7	10.2	9.8	33.8	26.5	35.8	37.2	32.6	35.1	30.7	32.4	32.7	32.4	29.1	27.9	33.1	32.7	32.6	23.5	23.9
σ	1 (3)	1 (3)	1 (3)	1 (3)	1 (3)	1 (3)	1 (3)	1 (3)	1 (3)	1 (3)	1 (3)	1 (3)	1 (3)	1 (3)	1 (3)	1 (3)	1 (3)	1 (3)	1 (3)	1 (3)	1 (3)	1 (3)	1 (3)
Cr	36.2	25.1	2.2	3.3	2.2	2.2	51.8	34.1	42.0	41.2	30.4	28.6	34.5	63.0	12.0	12.3	4.9	6.1	29.0	4.2	4.4	36.5	37.6
σ	1 (3)	2 (3)	26 (1)	11 (2)	18 (2)	16 (2)	1 (3)	2 (3)	2 (3)	2 (3)	2 (3)	2 (3)	2 (3)	1 (3)	5 (2)	4 (2)	10 (2)	9 (2)	2 (3)	16 (2)	12 (2)	1 (3)	1 (3)
Cs	<2.0	<2.0	<2.0	<2.0	0.8	0.7	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	1.0	<2.0	<2.0	<2.0	<2.0
σ	(1)	(1)	(1)	(1)	18 (1)	15 (2)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	19 (1)	(1)	(1)	(1)	(1)
Hf	1.0	1.4	6.1	6.0	6.3	6.0	1.0	0.9	1.1	1.2	1.4	1.4	1.4	1.5	1.4	1.2	2.1	2.1	1.6	2.1	2.0	3.2	3.4
σ	6 (3)	3 (3)	1 (3)	2 (3)	1 (3)	1 (3)	4 (3)	7 (3)	5 (3)	5 (3)	5 (3)	4 (3)	5 (3)	4 (3)	5 (3)	5 (3)	3 (3)	3 (3)	4 (3)	3 (3)	3 (3)	2 (3)	2 (3)
Rb	<30	<40	64	63	69	60	<40	<30	<40	<40	21	<40	<30	<30	<40	<40	6	<40	25	29	32	51	47
σ	(1)	(1)	4 (2)	3 (2)	4 (2)	4 (2)	(1)	(1)	(1)	(1)	20 (2)	(1)	(1)	(1)	(1)	(1)	99 (1)	(1)	10 (2)	14 (2)	15 (2)	7 (2)	6 (2)
Sb	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<3.0	<2.0	<2.0	<3.0	<2.0	<3.0	<2.0	<2.0	<3.0	<3.0	<2.0	<2.0	<2.0	<2.0	<3.0	<2.0	<2.0
σ	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)
Ta	<1.00	<2.00	0.70	0.48	0.66	0.42	<2.00	<2.00	<2.00	<2.00	<1.00	<2.00	<2.00	<2.00	<2.00	<2.00	<2.00	<2.00	<1.00	<2.00	<2.00	1.07	1.20
σ	(1)	(1)	51 (1)	24 (1)	43 (1)	25 (2)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	8 (3)	6 (3)
Th	0.5	0.5	4.5	4.2	4.7	4.2	0.6	0.4	0.4	0.4	0.5	0.5	0.5	1.0	0.7	0.5	1.0	1.3	0.9	1.3	1.1	3.6	3.5
σ	12 (2)	19 (2)	3 (3)	2 (3)	3 (3)	2 (3)	21 (2)	30 (2)	16 (2)	15 (2)	22 (2)	21 (2)	10 (2)	11 (2)	19 (2)	14 (2)	7 (2)	11 (3)	8 (2)	8 (3)	13 (2)	2 (3)	4 (3)
U	<2.0	<2.0	2.1	2.3	2.7	2.7	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	0.9	<2.0	<2.0	<2.0	<2.0	2.0	2.1
σ	(1)	(1)	8 (2)	8 (1)	7 (2)	7 (1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	21 (1)	(1)	(1)	(1)	(1)	9 (1)	9 (2)
Zn	65	69	46	45	45	43	90	68	118	83	68	118	84	74	114	88	111	112	89	118	112	71	80
σ	2 (3)	2 (3)	2 (3)	2 (3)	3 (3)	2 (3)	2 (3)	4 (1)	4 (1)	3 (2)	2 (3)	2 (2)	3 (2)	2 (3)	2 (2)	2 (3)	2 (3)	2 (3)	2 (3)	2 (3)	2 (3)	2 (3)	2 (3)
Zr	<708	<800	360	350	260	<500	<800	<700	<800	<900	<700	<900	<800	<700	<800	<900	<700	<900	<800	<800	<900	370	<600
σ	(1)	(1)	45 (1)	14 (1)	24 (1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	22 (1)	(1)
Sc	28.80	30.10	14.60	14.50	14.60	13.60	34.40	32.60	38.50	37.90	31.90	46.80	32.70	31.70	40.50	39.20	32.50	31.20	31.30	33.90	32.60	22.40	23.50
σ	1 (3)	1 (3)	1 (3)	1 (3)	1 (3)	1 (3)	1 (3)	1 (3)	1 (3)	1 (3)	1 (3)	1 (3)	1 (3)	1 (3)	1 (3)	1 (3)	1 (3)	1 (3)	1 (3)	1 (3)	1 (3)	1 (3)	1 (3)
La	3	5	17	16	17	15	4	3	4	4	4	5	4	5	3	3	6	6	5	8	7	14	15
σ	3 (1)	2 (1)	1 (1)	1 (1)	1 (1)	1 (1)	3 (1)	3 (1)	2 (1)	3 (1)	2 (1)	3 (1)	2 (1)	2 (1)	3 (1)	4 (1)	2 (1)	3 (1)	2 (1)	2 (1)	2 (1)	1 (1)	1 (1)
Ce	8	12	35	35	38	34	9	7	11	9	9	11	10	11	10	8	15	15	12	18	18	27	30
σ	4 (5)	3 (5)	2 (5)	1 (5)	1 (5)	2 (5)	5 (5)	4 (4)	4 (5)	3 (5)	4 (5)	3 (5)	3 (5)	3 (5)	3 (5)	5 (5)	3 (5)	5 (5)	3 (5)	3 (5)	3 (5)	2 (5)	2 (5)
Nd	7	9	28	27	29	24	9	4	8	8	8	13	9	11	8	7	12	13	10	16	12	17	17
σ	12 (1)	11 (1)	7 (3)	8 (2)	7 (3)	5 (3)	12 (1)	33 (1)	12 (1)	11 (1)	12 (1)	24 (1)	11 (1)	30 (1)	13 (1)	12 (1)	8 (2)	9 (1)	10 (1)	7 (1)	9 (1)	7 (2)	13 (2)
Sm	1.9	2.5	6.3	5.8	6.5	5.5	2.3	1.8	2.3	2.2	2.3	2.8	2.4	2.3	2.5	2.4	3.7	3.6	2.6	3.6	3.5	3.8	4.1
σ	2 (2)	2 (2)	1 (2)	1 (2)	1 (2)	1 (2)	2 (2)	2 (2)	2 (2)	2 (2)	2 (2)	2 (2)	2 (2)	1 (2)	2 (2)	3 (2)	1 (2)	2 (2)	2 (2)	1 (2)	2 (2)	1 (2)	1 (2)
Eu	0.69	0.84	1.29	1.23	1.27	1.18	0.75	0.68	0.81	0.79	0.68	0.97	0.84	0.73	0.90	0.85	1.10	1.04	0.77	1.08	1.05	1.06	1.11
σ	2 (5)	2 (5)	1 (5)	2 (5)	1 (5)	2 (5)	2 (5)	4 (3)	2 (5)	2 (5)	3 (5)	2 (5)	2 (5)	2 (5)	2 (5)	2 (5)	2 (5)	2 (5)	2 (5)	2 (5)	2 (5)	2 (5)	2 (5)
Gd	<5.0	3.0	7.0	6.0	7.1	7.3	<6.0	-	<6.0	<6.0	<3.0	<6.0	2.6	<5.0	3.6	<6.0	2.7	4.3	<5.0	<6.0	4.5	5.1	<5.0
σ	(1)	58 (1)	18 (1)	11 (1)	10 (1)	9 (1)	(1)	-	(1)	(1)	(1)	(1)	23 (1)	(1)	16 (1)	(1)	25 (1)	15 (1)	(1)	(1)	14 (1)	14 (1)	(1)
Tb	0.41	0.48	0.75	0.76	1.13	1.07	0.37	0.40	0.44	0.45	0.52	0.65	0.51	0.41	0.53	0.62	0.70	0.70	0.48	0.54	0.58	0.68	0.69
σ	12 (1)	9 (3)	8 (2)	5 (2)	4 (3)	3 (2)	17 (1)	10 (3)	9 (3)	14 (1)	7 (2)	7 (2)	7 (1)	10 (3)	9 (3)	9 (2)	6 (3)	7 (2)	10 (2)	9 (3)	10 (2)	12 (2)	6 (3)
Ho	0.6	1.0	1.1	1.6	1.6	1.7	0.5	<2.0	0.5	0.7	0.6	0.9	0.6	0.7	1.1	<2.0	0.8	1.2	0.8	0.9	1.0	<1.0	0.6
σ	15 (1)	14 (1)	24 (1)	11 (1)	10 (1)	10 (1)	31 (1)	(1)	19 (1)	17 (1)	21 (1)	13 (1)	15 (1)	19 (1)	13 (1)	(1)	15 (1)	14 (1)	13 (1)	15 (1)	16 (1)	(1)	28 (1)
Tm	<0.50	<0.50	0.67	0.63	0.71	0.55	0.59	-	0.45	<0.50	<0.30	<0.60	<0.50	<0.50	0.68	0.56	0.69	0.53	<0.50	0.56	<0.60	0.49	0.37
σ	(1)	(1)	8 (1)	8 (1)	8 (1)	8 (1)	29 (1)	-	32 (1)	(1)	(1)	(1)	(1)	(1)	26 (1)	27 (1)	24 (1)	31 (1)	(1)	11 (1)	(1)	26 (1)	29 (1)
Yb	1.5	1.8	4.6	4.4	4.8	4.3	1.6	1.5	1.6	1.5	1.7	2.3	1.7	1.8	2.1	2.1	3.0	3.0	1.8	2.4	2.4	1.6	1.7
σ	3 (2)	2 (2)	1 (2)	1 (2)	1 (2)	3 (2)	3 (2)	3 (2)	3 (2)	4 (2)	3 (2)	3 (2)	3 (2)	4 (2)	2 (2)	3 (2)	2 (2)	2 (2)	3 (2)	2 (2)	3 (2)	3 (2)	3 (2)
Lu	0.27	0.28	0.66	0.68	0.70	0.66	0.24	0.23	0.27	0.32	0.25	0.36	0.30	0.31	0.34	0.32	0.45	0.49	0.32	0.49	0.46	0.25	0.25
σ	6 (1)	3 (2)	1 (2)	2 (2)	1 (2)	2 (2)	8 (1)	3 (2)	3 (2)	6 (1)	3 (2)	6 (1)	5 (1)	2 (2)	2 (2)	7 (1)	2 (2)	4 (1)	5 (2)	4 (2)	4 (1)	6 (1)	3 (2)

Table 9 (cont.)

	17	17	18	18	19	19	20	20	AGV-1	AGV-1	AGV-1	AGV-1	21	21	22	23	23	24	25	26	27	28
Ba	230	270	447	435	306	287	441	416	1220	1160	1190	1140	388	437	518	451	417	403	631	579	342	256
σ	12 (3)	10 (3)	6 (3)	5 (3)	8 (3)	9 (3)	5 (3)	6 (3)	2 (3)	2 (3)	2 (3)	2 (3)	5 (3)	5 (3)	5 (3)	5 (3)	5 (3)	4 (5)	3 (3)	4 (3)	6 (3)	8 (3)
Co	27.5	27.0	19.3	19.1	19.3	18.4	19.9	19.8	14.2	14.0	14.6	14.3	8.7	8.6	4.3	3.6	3.5	4.6	4.5	5.9	3.1	4.2
σ	1 (3)	1 (3)	1 (3)	1 (3)	1 (3)	1 (3)	1 (3)	1 (3)	1 (3)	1 (3)	1 (3)	1 (3)	1 (3)	1 (3)	2 (3)	2 (3)	3 (3)	2 (5)	2 (3)	2 (3)	2 (3)	2 (3)
Cr	5.2	4.8	59.6	59.2	37.4	37.2	61.7	66.8	7.3	7.8	8.1	6.6	2.3	3.1	<4.0	<4.0	2.7	<3.0	1.0	1.4	<3.0	<4.0
σ	10 (2)	10 (2)	1 (3)	1 (3)	1 (3)	1 (3)	1 (3)	1 (3)	5 (3)	5 (3)	5 (2)	5 (2)	19 (2)	18 (1)	(1)	(1)	22 (1)	(1)	50 (1)	46 (1)	(1)	(1)
Cs	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	1.3	1.4	1.1	1.2	0.9	1.2	<2.0	<2.0	<2.0	<2.0	0.9	<2.0	<2.0	<2.0
σ	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	7 (3)	7 (3)	9 (3)	8 (3)	10 (3)	9 (3)	(1)	(1)	(1)	(1)	11 (3)	(1)	(1)	(1)
Hf	2.9	2.9	5.3	5.3	4.9	4.8	5.3	5.4	4.6	4.6	4.8	4.5	6.0	5.7	4.1	4.6	4.4	5.2	4.8	4.0	3.4	3.8
σ	2 (3)	2 (3)	1 (3)	1 (3)	1 (3)	2 (3)	1 (3)	2 (3)	1 (3)	1 (3)	2 (3)	2 (3)	1 (3)	2 (3)	2 (3)	1 (3)	1 (3)	1 (5)	1 (3)	2 (3)	2 (3)	2 (3)
Rb	<40	<40	46	53	22	21	26	37	65	65	67	63	30	27	37	29	23	28	45	27	<30	21
σ	(1)	(1)	6 (2)	5 (2)	16 (2)	14 (2)	29 (2)	7 (2)	5 (2)	5 (2)	4 (2)	3 (2)	10 (2)	8 (2)	9 (2)	8 (2)	11 (2)	5 (4)	7 (2)	8 (2)	(1)	14 (2)
Sb	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	4.0	3.6	3.8	4.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
σ	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	4 (3)	4 (3)	4 (3)	4 (3)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)
Ta	<2.00	<2.00	<0.90	0.77	<0.90	<0.90	<0.90	<0.90	0.91	0.87	0.74	0.97	<0.80	0.30	<0.90	<0.70	<0.80	<0.70	0.57	0.59	<0.70	<0.80
σ	(1)	(1)	(1)	39 (1)	(1)	(1)	(1)	(1)	9 (3)	7 (3)	9 (3)	6 (3)	(1)	73 (1)	(1)	(1)	(1)	(1)	23 (1)	47 (1)	(1)	(1)
Th	1.6	1.6	3.5	3.6	3.4	3.4	3.5	3.6	5.6	5.7	5.8	5.8	4.3	4.2	2.0	2.4	2.4	2.7	2.7	2.5	1.8	1.9
σ	8 (2)	8 (2)	4 (3)	3 (3)	3 (3)	3 (3)	4 (3)	3 (3)	2 (3)	2 (3)	2 (3)	2 (3)	3 (3)	2 (3)	4 (3)	4 (3)	3 (3)	2 (5)	4 (3)	4 (3)	5 (3)	5 (3)
U	1.3	1.7	2.4	2.1	1.4	1.5	2.0	1.7	1.2	1.5	1.9	2.2	2.3	1.9	1.0	1.3	1.5	1.4	1.4	1.2	0.9	1.6
σ	14 (1)	12 (1)	9 (1)	9 (1)	12 (2)	13 (1)	9 (2)	11 (1)	15 (1)	17 (2)	11 (1)	9 (1)	7 (2)	10 (1)	21 (1)	10 (2)	12 (1)	14 (1)	14 (1)	26 (1)	19 (1)	13 (1)
Zn	82	83	81	86	93	86	221	210	78	79	78	75	71	70	96	88	81	53	70	83	89	106
σ	2 (3)	2 (3)	2 (3)	2 (3)	2 (3)	2 (3)	1 (3)	1 (3)	2 (3)	2 (3)	2 (3)	2 (3)	2 (3)	2 (3)	2 (3)	2 (3)	2 (3)	2 (5)	2 (3)	2 (3)	2 (3)	2 (3)
Zr	<700	<800	<600	<600	<600	<700	<600	400	290	280	330	260	290	280	<500	<500	<500	260	180	<500	<500	<500
σ	(1)	(1)	(1)	(1)	(1)	(1)	(1)	17 (1)	15 (1)	20 (1)	18 (1)	23 (1)	19 (1)	23 (1)	(1)	(1)	(1)	21 (1)	31 (1)	(1)	(1)	(1)
Sc	31.10	31.10	22.00	21.70	21.70	20.70	21.00	21.20	11.10	10.90	11.40	10.90	13.70	13.70	16.40	14.10	14.00	11.40	11.00	13.20	13.60	13.20
σ	1 (3)	1 (3)	1 (3)	1 (3)	1 (3)	1 (3)	1 (3)	1 (3)	1 (3)	1 (3)	1 (3)	1 (3)	1 (3)	1 (3)	1 (3)	1 (3)	1 (3)	1 (5)	1 (3)	1 (3)	1 (3)	1 (3)
La	9	9	14	14	14	13	14	14	38	38	39	37	16	15	11	11	11	12	12	11	10	10
σ	1 (1)	2 (1)	1 (1)	1 (1)	1 (1)	1 (1)	1 (1)	1 (1)	1 (1)	1 (1)	1 (1)	1 (1)	1 (1)	1 (1)	1 (1)	1 (1)	2 (1)	1 (1)	1 (1)	1 (1)	1 (1)	1 (1)
Ce	23	22	32	31	32	30	31	32	61	60	66	63	36	36	25	27	26	27	25	27	23	23
σ	2 (5)	3 (5)	2 (5)	2 (5)	2 (5)	2 (5)	2 (5)	2 (5)	1 (5)	1 (4)	1 (5)	1 (5)	2 (5)	2 (5)	2 (5)	2 (5)	2 (5)	2 (6)	2 (4)	2 (5)	3 (5)	3 (4)
Nd	17	17	22	23	25	20	23	20	31	31	32	33	22	22	20	21	22	22	20	16	21	20
σ	7 (2)	7 (1)	11 (3)	10 (2)	10 (2)	6 (3)	10 (3)	6 (3)	6 (3)	4 (3)	6 (3)	6 (3)	5 (3)	5 (3)	6 (3)	11 (2)	9 (3)	7 (5)	5 (3)	12 (3)	10 (3)	10 (3)
Sm	4.9	4.4	5.6	5.5	5.5	5.0	5.3	5.1	6.2	5.5	5.8	5.5	6.2	6.0	6.0	6.1	5.6	5.7	5.2	5.2	5.4	5.5
σ	1 (2)	1 (2)	1 (2)	1 (2)	1 (2)	2 (2)	1 (2)	1 (2)	1 (2)	1 (2)	1 (2)	1 (2)	1 (2)	1 (2)	1 (2)	1 (2)	1 (2)	1 (2)	1 (2)	1 (2)	1 (2)	2 (2)
Eu	1.35	1.35	1.18	1.19	1.19	1.11	1.18	1.17	1.43	1.40	1.43	1.38	1.23	1.17	1.64	1.44	1.44	1.20	1.21	1.24	1.41	1.37
σ	2 (5)	2 (5)	2 (5)	1 (5)	2 (5)	2 (5)	2 (5)	2 (5)	1 (5)	2 (4)	1 (5)	1 (5)	1 (5)	1 (5)	1 (5)	1 (5)	1 (5)	1 (6)	2 (4)	2 (5)	1 (5)	2 (4)
Gd	6.1	5.4	6.2	5.7	5.8	5.2	6.0	3.9	4.0	-	4.3	4.7	7.1	5.9	6.7	6.8	5.7	-	-	5.5	4.7	-
σ	15 (1)	16 (1)	13 (1)	11 (1)	14 (1)	14 (1)	13 (1)	18 (1)	19 (1)	-	15 (1)	13 (1)	10 (1)	12 (1)	24 (1)	11 (1)	13 (1)	-	-	13 (1)	18 (1)	-
Tb	0.89	0.84	0.88	0.87	0.70	0.78	0.88	0.75	0.60	0.59	0.62	0.65	0.71	0.60	1.13	1.10	0.97	0.87	0.85	0.70	0.99	0.95
σ	4 (3)	5 (2)	4 (3)	5 (2)	6 (3)	6 (2)	4 (3)	6 (2)	5 (3)	5 (3)	6 (2)	6 (2)	7 (2)	9 (2)	3 (3)	3 (3)	4 (2)	2 (5)	4 (3)	6 (2)	3 (3)	3 (3)
Ho	1.0	1.2	1.3	1.4	1.2	1.6	1.5	1.5	<2.0	<2.0	0.6	<2.0	1.6	1.7	1.8	1.7	1.7	1.7	1.9	1.5	1.8	1.7
σ	12 (1)	12 (1)	11 (1)	10 (1)	12 (1)	11 (1)	10 (1)	11 (1)	(1)	(1)	24 (1)	(1)	10 (1)	10 (1)	10 (1)	9 (1)	10 (1)	12 (1)	11 (1)	9 (1)	10 (1)	12 (1)
Tm	0.45	0.58	0.62	0.57	0.71	0.70	0.54	0.57	0.39	-	<0.40	0.37	0.58	0.66	0.73	0.89	0.77	-	-	0.53	0.67	-
σ	29 (1)	11 (1)	10 (1)	9 (1)	19 (1)	19 (1)	19 (1)	10 (1)	12 (1)	-	(1)	26 (1)	9 (1)	8 (1)	8 (1)	15 (1)	7 (1)	-	-	10 (1)	8 (1)	-
Yb	3.4	3.4	4.0	4.0	3.9	3.6	3.8	3.8	1.5	1.6	1.9	1.5	4.6	4.4	5.2	5.3	5.2	5.2	4.9	3.9	4.8	4.7
σ	1 (2)	2 (2)	1 (2)	3 (2)	1 (2)	2 (2)	1 (2)	1 (2)	2 (2)	2 (2)	9 (2)	3 (2)	1 (2)	1 (2)	1 (2)	1 (2)	1 (2)	1 (4)	1 (2)	1 (2)	1 (2)	1 (2)
Lu	0.53	0.48	0.64	0.59	0.58	0.59	0.56	0.58	0.24	0.27	0.29	0.28	0.66	0.64	0.76	0.77	0.72	0.74	0.72	0.60	0.70	0.72
σ	1 (2)	3 (2)	2 (2)	3 (1)	1 (2)	3 (1)	1 (2)	3 (1)	2 (2)	5 (2)	4 (2)	4 (2)	1 (2)	2 (2)	1 (2)	1 (2)	2 (2)	1 (4)	2 (2)	2 (1)	1 (2)	2 (2)

All values are in ppm. σ is in %. Error limits are one standard deviation based on counting statistics alone. Numbers in parantheses are numbers of individual results, based on repetitive counts, averaged to yield expressed results. "-" means not reported due to instrumental problems. U. S. Geological Survey standard andesite AGV-1 was run as a control. Gd and Tm data are not reported for 4 samples due to instrumental problems on the second LEPD count.

Samples were irradiated at the Georgia Tech Research Reactor and were counted on a coaxial Ge(Li) detector and an intrinsic germanium planar low-energy photon detector. Data processing was carried out on a Honeywell series 60, level 68 computer that operates in the multics operating system. Samples were analyzed through Reston analytical lab, L. J. Schwartz, analyst. Sample numbers correspond with those in Tables 1 and 2.

Table 10. Instrumental neutron activation analysis of igneous rocks from Atka Island.

	1[2]	2[2]	3[1]	4[2]	5[2]	6[2]	7[2]	8[2]	9[2]	10[2]	11[1]	12[2]	13[2]	14a[1]	14b[2]	15[2]
Cs	0.313	0.328	0.785	0.137	0.460	0.555	0.423	0.524	0.309	0.656	0.147	0.173	0.277	0.246	0.239	<0.349
cv	1.	9.	4.	14.	2.	10.	6.	3.	7.	3.	6.	19.	7.	10.	6.	*
Rb	<10.00	<10.00	34.90	<10.00	21.00	22.80	10.30	16.50	13.10	19.60	<10.00	13.20	11.80	<10.00	<10.00	25.10
cv	0.	0.	3.	0.	8.	8.	14.	9.	9.	5.	0.	2.	5.	0.	0.	11.
Ba	<100.00	<100.00	501.0	134.0	128.0	110.0	128.0	225.0	132.0	438.0	202.0	202.0	395.0	194.0	178.0	130.0
cv	0.	0.	1.	6.	7.	11.	6.	5.	7.	4.	3.	2.	1.	4.	5.	9.
Sr	599.0	399.0	306.0	306.0	305.0	399.0	366.0	335.0	366.0	311.0	659.0	266.0	948.0	654.0	800.0	361.0
cv	1.	12.	0.	2.	5.	3.	3.	1.	4.	6.	1.	10.	2.	2.	6.	3.
Th	0.233	<0.100	0.266	0.780	0.755	1.760	1.090	1.160	1.230	0.974	0.110	1.140	1.100	0.252	0.423	1.100
cv	9.	0.	2.	5.	9.	1.	3.	1.	5.	3.	1.	2.	6.	4.	0.	0.
U	0.220	0.140	0.120	0.430	0.440	0.820	0.690	0.630	0.570	0.470	0.120	0.500	0.950	0.140	0.310	0.660
cv	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
La	2.130	0.954	4.730	5.020	4.820	9.780	5.290	6.450	5.770	5.770	4.880	6.780	10.10	7.710	12.30	7.870
cv	2.	1.	1.	1.	1.	1.	1.	0.	1.	1.	1.	1.	1.	1.	1.	0.
Ce	4.84	2.350	9.990	12.00	11.30	22.30	13.30	14.50	14.60	14.20	12.60	13.60	21.60	17.50	30.10	16.90
cv	7.	12.	5.	3.	3.	0.	4.	5.	2.	8.	0.	1.	4.	3.	2.	2.
Nd	3.66	<1.560	5.850	10.40	8.750	14.10	9.470	10.70	11.10	11.20	10.30	12.80	15.10	11.00	19.70	13.00
cv	15.	*	4.	7.	6.	6.	8.	14.	8.	6.	0.	1.	3.	1.	5.	6.
Sm	0.951	0.679	1.480	2.720	2.520	3.310	3.120	2.780	3.270	3.130	2.640	3.430	3.480	2.580	4.560	3.340
cv	1.	1.	0.	1.	0.	1.	0.	1.	0.	1.	1.	0.	0.	0.	2.	0.
Eu	0.499	0.368	0.641	0.956	0.920	0.865	0.981	0.886	1.080	1.060	0.933	1.220	1.230	1.020	1.350	1.100
cv	2.	2.	2.	2.	2.	2.	1.	2.	1.	2.	2.	2.	1.	6.	1.	1.
Gd	0.720	0.781	1.260	3.840	3.650	3.210	3.500	3.340	4.060	3.600	3.180	3.840	3.400	2.180	4.330	3.690
cv	1.	24.	1.	1.	4.	0.	13.	7.	0.	1.	3.	0.	8.	3.	5.	2.
Tb	0.150	0.139	0.235	0.569	0.533	0.469	0.564	0.549	0.596	0.656	0.469	0.749	0.539	0.418	0.000	0.657
cv	4.	5.	12.	2.	8.	8.	2.	5.	5.	3.	6.	4.	4.	1.	2.	9.
Dy	0.880	1.240	1.620	3.670	3.440	2.970	3.390	3.320	3.490	3.800	2.750	4.350	3.240	2.500	3.560	4.500
cv	21.	12.	18.	12.	4.	25.	1.	7.	26.	9.	6.	3.	6.	2.	11.	5.
Yb	0.636	0.547	1.190	2.120	2.170	1.350	2.120	2.040	2.280	2.360	1.600	2.740	1.920	1.360	1.650	2.570
cv	4.	6.	2.	3.	5.	1.	5.	2.	5.	7.	3.	1.	1.	2.	1.	3.
Lu	0.108	0.100	0.201	0.351	0.337	0.231	0.341	0.336	0.373	0.386	0.253	0.443	0.292	0.196	0.258	0.436
cv	25.	4.	3.	8.	5.	6.	8.	5.	7.	5.	7.	3.	1.	1.	6.	5.
Ta	0.017	<.0209	0.0322	0.192	0.129	0.0455	<0.140	0.111	0.057	0.177	0.103	0.187	0.110	.0713	0.142	0.188
cv	11.	*	6.	16.	14.	7.	*	13.	12.	14.	17.	3.	5.	3.	7.	6.
Zr	0.000	0.000	41.20	<76.50	76.50	35.20	72.90	47.90	85.10	0.000	69.70	108.00	73.60	42.80	60.50	89.10
cv	0.	0.	*	*	17.	16.	28.	20.	7.	0.	15.	16.	7.	20.	10.	11.
Hf	0.388	0.325	0.985	1.460	1.540	1.500	1.360	1.700	1.680	1.810	1.820	2.120	2.140	1.070	1.350	2.100
cv	1.	3.	4.	1.	1.	*	5.	2.	1.	0.	4.	0.	4.	6.	3.	1.
Sb	0.228	<0.098	0.000	0.000	0.125	0.255	0.433	0.198	0.550	0.161	0.000	0.182	0.0481	0.0558	0.000	<0.213
cv	6.	*	0.	0.	28.	12.	0.	23.	2.	5.	0.	23.	8.	27.	0.	*
Sc	9.380	32.40	29.60	41.90	34.70	38.00	41.80	32.30	37.30	34.60	20.40	35.20	16.10	15.80	22.10	27.50
cv	2.	1.	0.	2.	0.	1.	0.	1.	1.	0.	0.	0.	1.	0.	0.	1.
Cr	10.70	35.50	36.50	63.00	56.60	256.0	260.0	77.00	80.0	56.60	84.60	1.500	6.440	72.10	88.80	4.340
cv	2.	1.	0.	1.	2.	2.	1.	1.	5.	2.	2.	6.	4.	2.	2.	0.
Co	36.10	30.40	37.80	38.40	31.40	27.00	31.90	30.50	28.10	30.10	21.20	28.80	18.30	17.80	17.20	22.20
cv	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.

Table 10 (cont.)

	16[2]	17[2]	18[2]	19[1]	20[2]	21[1]	22[1]	23[2]	24[2]	25[2]	26[2]	27[1]	28[2]	29[1]	30[2]	31[2]
Cs	0.807	1.350	0.546	1.490	0.974	1.450	2.050	2.090	1.040	1.590	0.209	0.138	0.999	0.896	0.331	0.117
cv	2.	2.	3.	1.	2.	2.	1.	1.	8.	4.	8.	6.	1.	4.	8.	12.
Rb	<10.00	31.80	21.20	30.20	35.20	60.70	44.90	59.10	<10.00	11.20	11.30	20.60	22.80	<10.00	15.80	<10.00
cv	0.	2.	4.	2.	4.	1.	1.	1.	0.	5.	8.	2.	2.	0.	1.	0.
Ba	142.0	436.0	366.0	257.0	431.0	793.0	388.0	470.0	<100.00	319.0	220.0	423.0	178.0	115.0	452.0	<100.00
cv	6.	4.	3.	4.	3.	2.	2.	1.	0.	3.	5.	2.	5.	13.	3.	0.
Sr	439.0	530.0	696.0	587.0	477.0	375.0	501.0	491.0	195.0	129.0	452.0	472.0	259.0	634.0	323.0	145.0
cv	6.	2.	4.	1.	2.	1.	1.	2.	9.	16.	3.	0.	5.	2.	4.	8.
Th	1.600	3.930	1.440	2.600	3.060	6.050	3.720	5.570	0.633	0.263	0.892	1.770	1.310	0.975	1.560	1.290
cv	7.	2.	3.	2.	2.	2.	0.	1.	4.	10.	0.	2.	1.	1.	2.	3.
U	0.570	1.640	1.060	1.440	1.870	2.220	2.120	2.450	0.450	0.160	0.580	0.750	0.670	0.560	0.730	1.060
cv	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
La	7.220	13.30	9.080	9.840	10.60	15.50	13.00	11.30	6.210	2.120	5.750	8.580	7.730	6.130	8.870	7.450
cv	1.	1.	1.	1.	1.	1.	0.	0.	0.	3.	3.	1.	1.	1.	0.	0.
Ce	21.30	29.70	21.20	21.30	22.00	32.20	27.90	23.40	13.10	4.960	13.50	17.60	18.30	13.60	17.30	18.50
cv	1.	1.	0.	2.	1.	1.	1.	3.	13.	2.	4.	1.	1.	6.	1.	1.
Nd	16.40	18.20	13.90	13.20	11.60	17.60	16.60	12.20	10.80	5.920	11.30	14.20	13.90	9.550	14.10	13.20
cv	3.	1.	6.	8.	2.	2.	5.	3.	7.	12.	2.	6.	1.	2.	3.	2.
Sm	5.110	4.280	2.780	3.060	2.990	3.760	3.600	2.510	2.870	1.530	2.770	2.940	3.110	2.450	3.470	3.890
cv	0.	2.	1.	2.	0.	2.	1.	1.	0.	2.	0.	1.	0.	1.	0.	1.
Eu	1.170	1.150	0.886	0.885	0.894	0.959	0.920	0.711	1.020	0.581	1.010	0.944	0.793	0.826	0.965	1.050
cv	1.	1.	1.	1.	2.	0.	1.	1.	2.	2.	1.	1.	2.	1.	1.	2.
Gd	6.390	3.600	2.610	2.900	3.020	3.410	3.080	2.380	3.520	2.240	2.400	2.720	2.600	2.750	3.920	4.650
cv	4.	7.	11.	1.	7.	3.	1.	8.	6.	8.	3.	4.	1.	2.	13.	2.
Tb	0.950	0.617	0.364	0.400	0.425	0.575	0.447	0.339	0.503	0.325	0.413	0.455	0.451	0.493	0.624	0.781
cv	19.	12.	6.	3.	3.	3.	2.	5.	5.	6.	6.	3.	7.	7.	4.	2.
Dy	0.000	3.770	2.620	2.360	2.700	3.700	2.620	2.000	3.220	1.950	2.560	3.060	3.080	2.650	4.000	5.040
cv	1.	1.	1.	1.	9.	5.	1.	5.	4.	6.	2.	12.	2.	8.	9.	7.
Yb	3.320	2.030	1.420	1.230	1.360	2.330	1.500	1.090	1.860	1.170	1.470	1.700	1.730	1.770	2.530	3.390
cv	3.	5.	4.	4.	2.	0.	2.	3.	2.	6.	6.	2.	5.	1.	3.	4.
Lu	0.538	<0.470	0.224	0.180	0.247	0.355	0.222	0.175	0.279	0.194	0.2440	0.261	0.273	0.266	0.397	0.557
cv	5.	*	8.	4.	19.	4.	2.	4.	20.	17.	3.	4.	1.	4.	3.	8.
Ta	0.122	0.255	0.230	0.241	0.180	0.247	0.329	0.313	0.182	0.0366	0.0671	0.0817	0.126	0.094	0.258	0.252
cv	7.	5.	6.	1.	4.	4.	3.	2.	2.	14.	3.	7.	5.	2.	4.	5.
Zr	115.0	147.00	105.0	100.00	0.000	162.0	181.0	127.0	<93.20	44.30	44.40	76.10	80.60	72.10	82.60	0.000
cv	11.	4.	6.	10.	0.	9.	4.	3.	*	23.	17.	22.	11.	17.	12.	0.
Hf	2.120	3.860	2.700	3.070	3.260	0.000	5.330	3.670	1.690	0.751	1.740	1.920	2.000	1.840	2.080	3.370
cv	2.	0.	0.	5.	5.	0.	4.	2.	2.	6.	5.	2.	2.	2.	0.	0.
Sb	0.320	0.274	0.132	0.166	0.165	0.199	0.168	0.122	3.930	0.000	0.082	0.115	0.303	55.20	0.224	0.280
cv	24.	11.	6.	6.	15.	3.	19.	10.	0.	0.	9.	4.	11.	0.	20.	8.
Sc	32.60	17.30	9.680	15.20	17.50	11.20	13.60	7.530	34.90	46.8	35.00	13.70	34.50	21.20	23.30	25.80
cv	1.	1.	0.	0.	1.	1.	0.	1.	1.	1.	0.	1.	1.	1.	1.	1.
Cr	86.50	20.10	7.550	112.0	189.0	11.60	119.0	31.10	499.0	383.0	149.0	10.60	914.0	10.10	48.90	33.80
cv	6.	2.	2.	1.	1.	2.	0.	1.	1.	2.	1.	4.	1.	1.	2.	0.
Co	16.40	18.70	13.00	16.90	18.10	11.70	16.00	8.00	41.90	42.10	25.50	18.90	37.10	20.20	21.50	23.00
cv	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	1.	0.	1.	1.	1.

All values are in ppm. cv is coefficient of variation and is in %. (CV = $\frac{\sigma}{\text{mean}}$ X 100). "<" means below empirical detection limit (usually due to unidentified interference). "*" means cv exceeds 30%; < value is 3X standard deviation of measured value. Sample numbers correspond with those in Tables 7 and 8. Analysis performed in Denver analytical lab.

[1] D. McKown and R. Knight analysts.

[2] J. Budahn and D. McKown, analysts.

Table 11. Rare earth element compositions of igneous rocks from Amlia Island, normalized for chondrites.

Sample No.	La	Ce	Nd	Sm	Eu	Gd	Tb	Ho	Tm	Yb	Lu
Chondrites*	0.33	0.88	0.60	0.18	0.07	0.25	0.05	0.07	0.03	0.20	0.03
1	9.24	8.78	12.33	10.33	10.03		8.72	9.00		7.30	7.94
2	14.24	13.07	15.33	13.81	12.22	12.05	10.32	13.71		9.15	8.29
3	51.52	39.77	46.33	34.64	18.70	28.11	15.96	15.71	22.20	22.85	19.53
3	49.70	40.00	45.67	32.27	17.83	24.10	16.11	22.86	20.97	22.00	19.88
4	50.91	43.18	48.17	35.80	18.41	28.51	24.04	22.86	23.53	23.90	20.65
4	45.15	38.64	39.17	30.55	17.10	29.48	22.77	24.29	18.33	21.50	19.44
5	11.45	10.14	14.83	12.43	10.88		7.87	7.71	19.67	7.95	7.09
6	7.70	7.53	6.83	10.06	9.81		8.51			7.45	6.82
7	12.03	12.05	12.50	12.76	11.80		9.36	6.86	15.00	8.10	8.03
7	11.97	10.67	14.00	12.21	11.45		9.57	10.00		7.45	9.44
8	12.03	10.27	12.83	12.54	9.86		11.09	9.00		8.30	7.44
9	13.82	12.50	21.67	15.47	14.04		13.91	13.43		11.25	10.65
10	13.06	11.82	14.67	13.54	12.12	10.44	10.89	9.14		8.25	8.74
11	15.97	12.95	18.33	12.65	10.59		8.72	10.29		9.25	9.09
12	10.55	11.07	12.50	13.81	13.07	14.46	11.34	15.71	22.67	10.65	9.91
12	10.06	9.43	12.33	13.20	12.38		13.23		18.67	10.25	9.56
13	18.15	17.27	20.33	20.33	15.94	10.84	14.98	11.86	23.00	14.85	13.24
13	18.64	17.16	21.17	19.78	15.07	17.27	14.81	17.14	17.67	14.80	14.32
14	14.52	13.52	16.00	14.14	11.22		10.21	10.86		9.15	9.50
15	23.06	20.91	26.17	19.89	15.65		11.49	12.14	18.67	12.15	14.32
15	22.12	20.23	20.50	19.45	15.22	18.07	12.34	13.86		12.15	13.44
16	43.94	33.86	28.33	22.65	16.09		14.57	9.00	12.33	8.65	7.47
16	41.82	30.57	28.17	21.22	15.36	20.48	14.47		16.33	8.15	7.44
17	27.52	25.57	27.83	26.80	19.57	24.50	18.89	14.29	15.00	16.85	15.56
17	27.67	24.43	27.83	24.25	19.57	21.69	17.89	17.14	19.33	17.25	14.00
18	43.03	35.91	36.67	30.94	17.10	24.90	18.83	18.57	20.67	19.80	18.94
18	40.91	35.23	38.33	30.61	17.25	22.89	18.49	20.00	18.97	19.80	17.38
19	43.64	36.70	41.67	30.17	17.25	23.29	14.96	17.14	23.67	19.75	17.09
19	40.61	34.20	32.50	27.79	16.09	20.88	16.55	22.86	23.33	17.95	17.44
20	41.52	35.68	38.33	29.34	17.10	24.10	18.74	21.43	18.00	19.20	16.50
20	41.82	35.80	32.50	28.12	16.96	15.66	15.98	21.43	19.00	19.05	17.15
AGV-1	115.76	69.09	52.17	34.42	20.72	16.06	12.79		13.00	7.75	7.09
Do.	115.15	68.64	51.00	30.39	20.29		12.51			7.95	8.09
Do.	118.48	74.66	52.50	31.93	20.72	17.27	13.09	9.00		9.45	8.59
Do.	110.91	71.25	54.50	30.50	20.00	18.88	13.79		12.33	7.65	8.29
21	49.09	40.68	37.17	34.42	17.83	28.51	15.13	22.86	19.30	23.15	19.29
21	46.06	41.14	36.67	33.15	16.96	23.69	12.70	24.29	22.17	21.90	18.76
22	33.03	28.86	32.50	33.26	23.77	26.91	24.04	25.71	24.20	26.15	22.29
23	34.24	30.57	35.00	33.65	20.87	27.31	23.40	24.43	29.67	26.65	22.79
23	34.55	29.89	36.83	31.05	20.87	22.89	20.53	24.29	25.77	25.95	21.18
24	35.15	30.11	36.33	31.27	17.39		18.47	24.29		25.80	21.88
25	36.67	28.86	32.50	28.73	17.54		18.09	27.14		24.45	21.15
26	34.24	30.23	26.67	28.73	17.97	22.09	14.98	21.43	17.67	19.75	17.62
27	29.45	25.57	35.00	29.89	20.43	18.88	21.13	25.71	22.37	23.90	20.47
28	30.00	25.57	33.33	30.17	19.86		20.21	24.29		23.35	21.26

* from Haskin et al., 1968.

AGV-1, U.S. Geological Survey standard andesite, used as control.
Samples were irradiated at the Georgia Tech Research Reactor and counted on a coaxial Ge(Li) detector and an intrinsic germanium planar low-energy photon detector. Data processing was carried out on a Honeywell series 60, level 68 computer that operates in the multics operating system. Samples were analyzed through Reston analytical lab, L. J. Schwartz, analyst.

Table 12. Trace element composition of igneous rocks from Amlia Island*. All results are in ppm.

No.	B	Cu	Pb	V	Y	Ga	No.	B	Cu	Pb	V	Y	Ga
1	<4.	37.	<14.	210.	15.	13.	15	29.	200.	<14.	380.	39.	29.
2	<4.	34.	<14.	380.	28.	34.	16	5.	150.	23.	210.	26.	29.
3	8.	13.	14.	65.	55.	18.	17	17.	230.	<14.	270.	55.	25.
4	18.	18.	<14.	71.	53.	19.	18	5.	60.	25.	94.	52.	20.
5	<4.	80.	<14.	240.	17.	13.	19	9.	94.	32.	130.	51.	18.
6	<4.	57.	<14.	290.	17.	19.	20	12.	79.	38.	87.	38.	14.
7	<4.	200.	<14.	370.	29.	22.	21	23.	28.	23.	59.	64.	19.
8	22.	240.	<14.	360.	31.	34.	22	7.	21.	26.	47.	66.	18.
9	<4.	110.	<14.	350.	21.	15.	23	13.	18.	18.	25.	53.	12.
10	<4.	68.	<14.	180.	15.	12.	24	<4.	14.	43.	24.	38.	10.
11	<4.	130.	<14.	310.	27.	29.	25	22.	18.	28.	31.	57.	21.
12	<4.	310.	<14.	570.	50.	31.	26	<4.	15.	<14.	49.	29.	8.
13	16.	240.	46.	360.	58.	31.	27	21.	13.	<14.	24.	55.	20.
14	<4.	61.	<14.	180.	18.	11.	28	<4.	15.	<14.	30.	54.	18.

Other elements were scanned, but are below the limits of detection (listed in parentheses in ppm); Ag (4.0); As (200.); Au (14.); Be (1.4), 4 samples have detectable amounts of Be - 4 and 19, 1.4 ppm, 15, 1.8 ppm, and 24, 1.7 ppm; Bi (14.); Cd (30.); Mo (4.); Nb (20.); Sn (4.); W (20.); Ge (14.); In (3.); Re (14.); Tl (6.); Hg (20.). "<" indicates limits of detection for a particular element. Sample numbers correspond to those in Tables 1 and 2. Samples were analyzed using D-C arc direct reading optical emission spectroscopy, Menlo Park, analytical lab, C. Heropoulos, analyst.

* determined by direct reading optical emission spectroscopy.

Table 13. Trace elements from Atka Island. All values are in ppm.

No.	B	Be	Cu	Pb	V	Y	Zn	Ga	Pr	No.	B	Be	Cu	Pb	V	Y	Zn	Ga	Pr
1[2]	10.	<0.7	150.	<7.	150.	7.	70.	15.	N/A	16[2]	15.	<0.7	50.	<7.	200.	30.	50.	20.	N/A
2[2]	10.	<0.7	30.	<7.	150.	10.	70.	15.	N/A	17[2]	15.	1.	150.	30.	300.	20.	100.	20.	N/A
3[1]	<2.	<0.7	30.	<7.	200.	10.	150.	50.	N/A	18[2]	7.	1.	50.	<7.	150.	15.	100.	20.	N/A
4[2]	30.	<0.7	70.	<7.	300.	20.	100.	20.	N/A	19[1]	50.	1.5	100.	<7.	100.	15.	100.	30.	<20.
5[2]	20.	<0.7	30.	<7.	200.	20.	100.	30.	N/A	20[2]	10.	1.5	70.	20.	200.	15.	70.	20.	N/A
6[2]	20.	<0.7	100.	<7.	200.	10.	150.	20.	N/A	21[1]	7.	1.5	70.	15.	100.	20.	100.	30.	<20.
7[2]	15.	<0.7	50.	<7.	300.	20.	100.	20.	N/A	22[1]	20.	1.5	70.	20.	150.	15.	100.	30.	<20.
8[2]	20.	<0.7	20.	<7.	200.	15.	70.	20.	N/A	23[2]	10.	1.5	20.	<7.	150.	10.	50.	20.	N/A
9[2]	20.	1.	70.	<7.	300.	30.	100.	20.	N/A	24[2]	15.	<0.7	7.	20.	200.	20.	100.	15.	N/A
10[2]	30.	<0.7	70.	<7.	300.	30.	100.	30.	N/A	25[2]	10.	<0.7	70.	<7.	300.	15.	70.	15.	N/A
11[1]	<2.	0.7	70.	<7.	150.	15.	100.	30.	<20.	26[2]	15.	1.	100.	<7.	200.	15.	100.	20.	N/A
12[2]	20.	<0.7	70.	<7.	200.	30.	100.	20.	N/A	27[1]	3.	0.7	7.0	15.	150.	15.	100.	50.	<20.
13[2]	10.	1.	100.	30.	150.	15.	100.	30.	N/A	28[2]	10.	<0.7	50.	15.	150.	15.	100.	15.	N/A
14a[1]	<2.	1.	20.	<7.	150.	15.	70.	50.	<20.	29[1]	70.	<0.7	30.	20.	150.	15.	150.	50.	<20.
14b[2]	7.	<0.7	70.	<7.	150.	15.	70.	30.	N/A	30[2]	20.	1.5	70.	20.	200.	30.	100.	20.	N/A
15[2]	15.	<0.7	30.	<7.	200.	20.	70.	30.	N/A	31[2]	15.	<0.7	50.	<7.	150.	30.	70.	20.	N/A

Other elements were scanned but are below the limits of detection (listed in parentheses in ppm): Ag (0.2); As (150.); Au (7.); Bi (7.); Cd (7.); Mo (2.); Nb (10.); Pd (1.); Pt (5.); Sn (2.); Te (300.); W (10.); Ge (7.); In (1.5); Li (100); Re (7.); Tl (3.). "<" indicates limits of detection for a particular element. "N/A" means not analyzed. Sample numbers correspond to those in Tables 7 and 8. All samples were analyzed at Menlo Park analytical lab. Samples analyzed by D.C. arc optical emission spectroscopy, R. Lerner and J. Kent, analysts.