

The Determination of a Series of Ages of Hawaiian Volcanoes by the Potassium-Argon Method¹

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GEOLOGICALLY SPEAKING, the Hawaiian Islands are perhaps the most thoroughly studied group of oceanic islands in the world. Because of their relative petrological and structural simplicity, they constitute an example where an intensive application of the techniques of geology and geophysics may be expected to yield significant results particularly relevant to volcanology. An example of a thorough effort of this type was reported by McDougall (1964) who measured the relative ages of the surface lavas of most of the older volcanoes of the islands using the potassium-argon method of geochronology. We would like to report additional age measurements obtained by the same method, with a concentration of our effort on the Waianae Volcano on the island of Oahu. A scattering of measurements made on samples from other sites also is tabulated.

METHODS AND RESULTS

The argon measurement equipment and techniques developed by the Berkeley group (Evernden and Curtis, 1965) were employed in the work. Ultrahigh vacuum methods were necessary for measurements on these young materials of relatively low potassium content. Potassium was analyzed by flame photometry.

The results of the potassium-argon age work on Hawaiian extrusive rocks are given in Table 1. The over-all precision of the ages reported herein is estimated to be approximately 11%

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(standard deviation). The uncertainty for each age is based on the experimental errors and the effect of the correction necessary for air argon contamination.

The ages of the different members of the Waianae Range are in general agreement with those of McDougall (1964). However, this investigator reported an age of 8.36 my for a biotite fraction separated from the Mauna Kuwale rhyodacite. This age appears to be abnormally high in view of the present work which indicates that Mauna Kuwale is contemporaneous with the upper member of the Waianae volcanic series. A possible cause of this discordance relating to included excess radiogenic argon has been discussed elsewhere (Funkhouser, Barnes, and Naughton, 1966).

DISCUSSION

The results obtained from HK-123, a vesicular olivine basalt classified as Lower Waianae, are clearly anomalous. The high degree of air argon contamination for this specimen contributes to the large uncertainty; however, this does not fully explain the wide variation in the results. Thin-section examination as well as microscopic inspection of hand samples and granular fractions indicated no abnormal mineral components or alteration products. The basalt contains a large number of very small vesicles which probably contain entrapped air. This is substantiated by the lower air argon correction for HK-123-3 which was ground to 100-180 mesh while the other two samples were analyzed as 10-16 mesh fractions. Of course, this sample could be 7-12 my old, but there is no confirmation from geological field evidence or other potassium-argon dates. The ages obtained for HK-142, a Lower Waianae olivine basalt, also show a range greater than that predicted from experimental uncertainties and the atmospheric argon correction.

TABLE 1
 POTASSIUM-ARGON AGES OF HAWAIIAN EXTRUSIVE ROCKS

SAMPLE,* ROCK TYPE OR MINERAL, AND LOCATION	K, %	Ar ⁴⁰ (RADIOGENIC), cc/gm × 10 ⁻⁷	Ar ⁴⁰ (AIR), % of Total Ar	AGE × 10 ⁶ yrs
UPPER WAIANAE				
HK-121. Mauna Kuwale rhyodacite (average of 11 determinations of minerals and whole rock)	1.32-6.03	1.32-10.5	75-89	2.3 ± 0.4
HK-119-1. Dike through HK-121	1.43	1.71	49	3.3 ± 0.2
HK-119-2. Dike through HK-121	1.43	1.90	50	3.0 ± 0.2
HK-143-1. Feldspar from flow overlying HK-121	0.206	0.348	91	4.3 ± 1.1
HK-122-3. Flow underlying HK-121	0.885	0.810	88	2.3 ± 0.5
HK-122-4. Flow underlying HK-121	0.885	1.081	84	3.1 ± 0.5
HK-122-5. Flow underlying HK-121. Calcite removed	0.911	0.838	91	2.3 ± 0.6
HK-124-1. Whole rock	1.07	1.22	38	2.9 ± 0.1
HK-126-1. Feldspar	0.272	0.235	80	2.2 ± 0.2
HK-126-2. Whole rock less feldspar	0.970	1.019	37	2.7 ± 0.1
HK-132-1. Feldspar	0.238	0.207	65	2.2 ± 0.1
HK-132-2. Whole rock	0.697	0.717	42	2.6 ± 0.1
B-1. Whole rock	1.02	1.12	47	2.8 ± 0.1
MIDDLE WAIANAE				
HK-145-1. Whole rock	0.512	0.735	80	3.7 ± 0.4
HK-145-2. Whole rock	0.512	0.712	77	3.5 ± 0.3
HK-146-1. Whole rock	1.11	1.33	39	3.0 ± 0.1
HK-146-2. Whole rock	1.11	1.26	39	2.9 ± 0.1
LOWER WAIANAE				
HK-123-1. Whole rock	0.441	2.82	97	16.1 ± 13.6
HK-123-2. Whole rock	0.441	1.09	98	6.2 ± 6.2
HK-123-3. Whole rock. Fine powder. Zeolite removed	0.435	1.94	93	11.2 ± 3.9
HK-142-1. Whole rock	0.209	0.360	83	4.3 ± 0.6
HK-142-2. Whole rock	0.209	0.409	82	4.9 ± 0.6
HK-142-4. Whole rock. Treated with HF	0.264	0.332	83	3.2 ± 0.4
HK-144-1. Ewa drill core. Whole rock	0.522	0.820	88	4.0 ± 0.8
HK-144-2. Ewa drill core. Whole rock	0.522	0.722	90	3.5 ± 0.8
B-2. Whole rock	0.70	1.49	45	5.4 ± 0.3
SAMPLES FROM OTHER HAWAIIAN SITES				
HK-127-1. Whole rock. Nihoa Island	0.416	1.25	56	7.5 ± 0.4
HK-107-1. Whole rock. Necker Island	1.04	4.66	57	11.3 ± 0.6
B-3. Whole rock nepheline basalt. Moiliili, Oahu	1.02	0.35	88	0.9 ± 0.5
B-5. Dike edge. Glass. Koolau Volcano, Oahu	1.52	1.79	76	2.2 ± 0.3
B-4. Whole rock. Trachyte. Puuwaawaa, Hawaii	4.18	0.64	79	0.4 ± 0.3
B-5. Whole rock hawaiite. Laupahoehoe, Mauna Kea, Hawaii	1.89	0.43	73	0.6 ± 0.3
B-6. Phlogopite mica from B-5	5.50	6.34	44	2.8 ± 0.1

* Samples prefixed by "B" were analysed at Brookhaven National Laboratory, New York, and previously reported as an abstract (Naughton and Schaeffer, 1962).

The basaltic dike (HK-119) cutting through the rhyodacite (HK-121) yields a high age relative to its host formation. The low air argon contamination in this specimen precludes any convenient overlap of ages within experimental error. The single determination on the feldspar (HK-143) from the flow overlying the rhyodacite should also be less than 2.3 ± 0.4 my. The feldspar phenocrysts were hand-picked from a weathered specimen and treated with hydrofluoric acid to remove the more easily soluble altered layers. Microscopic examination of these indicated pure plagioclase crystals with no alteration or contamination evident. The high atmospheric argon correction creates a large potential uncertainty in the 4.3 my date, and it is possible that an even greater error than acknowledged exists due to alteration not revealed by examination. It is also possible that these samples (HK-119 and HK-143) contain an "excess" of radiogenic argon. Damon, Laughlin, and Percious (1967) noted 0.56×10^{-7} std. cc/g excess argon in large plagioclase phenocrysts from a very young basalt, and 2.3×10^{-7} std. cc/g excess argon from the chilled border of a young basaltic dike. It is believed that the discordance in age shown between whole-rock sample B-7 and its constituent mica, B-8, is an example of mica giving an anomalously older age due to excess radiogenic argon present in inclusions, as in the samples from the Mauna Kuwale rhyodacite noted above.

HK-144, a sample from a core taken from the 1081-foot level of the Ewa I drill hole at Barber's Point, Oahu, is listed as a Lower Waianae sample, although H. T. Stearns has stated, on topographic grounds, that it might come from a flow from Koolau Volcano, the other major volcano of the island of Oahu.

The variability in the degree of air argon contamination among the different samples is worth noting. Bake-out temperatures and time cannot be correlated with the quantity of air argon in each sample. A relatively large amount of air argon was present in the apparatus during the initial gas extractions but any corrections for this would lower the atmospheric correction of HK-121 (whole rock) to a minimum of approximately 80%. In general, certain minerals have been found to hold inherently less air

than others. This phenomenon apparently holds true for different whole-rock samples as well, and is probably related to the degree of micro-vesiculation of the basalts. The differences between feldspar separates and whole-rock samples is mostly attributable to the residual air argon in the extraction system which would predominate when smaller total quantities of radiogenic argon are released.

The two specimens in which feldspar and whole-rock ages can be compared indicate a possible loss of radiogenic argon from the plagioclase, yet Evernden and James (1964), and Livingston, Damon, Manger, Bennett, and Laughlin (1965) have reported that volcanic feldspars are quite retentive, especially for young rocks. It is most probable that during the 23–28 hours of bake-out at 210°–240°C some of the radiogenic argon was lost by diffusion, or that the lower ages are coincidental and result from experimental error.

Nihoa (Bird) Island is approximately 150 miles west-northwest of Kauai while Necker Island is about 180 miles beyond Nihoa. The ages of 7.5 my and 11.3 my, respectively, for these island remnants are not surprising considering the progression of age of the islands (McDougall, 1964).

The paucity of data and the uncertainty in the age determinations preclude any generalizations regarding the duration of island growth or volcanism except to note that volcanic activity of the Waianae Volcano appears to have spanned well over two million years.

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