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CONVENTIONAL K-AR AND ^{40}AR/^{39}AR AGES OF THE MIOCENE SUBMARINE ROCKS OF THE CAPE VERDE ISLANDS

E. K. AGYEI
Department of Physics, University of Ghana, Legon, Ghana

Summary

Conventional K-Ar and argon-40/argon-39 stepwise heating age determinations have been performed on eight whole rock basaltic samples from four sites on the island of Maio in the Cape Verde Group of Islands. Thin sections of these samples collected from the Mesozoic igneous rock complex indicate that they are unlike the overlying sequence of Pliocene basaltic volcanics and are known to be of Miocene ages. Results of this work confirm the Miocene ages and indicate that most probably these young ages were due to later metamorphic events that reoccurred at the four different sites at various times between 8 and 15 Ma ago.

Introduction

On the island of Maio in Cape Verde group of islands, there is a a collection of rocks that geologists regard as submarine volcanics of Upper Crataceous and late Jurassic age. These are overlain by major sequence of Pliocene basalt volcanics that have extensive distribution and most probably cover the entire Archipelago. The Mesozoic age of the old igneous complex is based on fossil evidence in the limestone. However, few conventional K-Ar datings for the older rocks have given Miocene ages.

The question arises as to whether these younger ages are due to the major argon loss from the older Mesozoic rocks during the main Pliocene volcanic phase or they represent later sill intrusions. A combined radiometric and paleomagnetic study should clarify the situation, especially the use of conventional K-Ar and the step wise heating ^{40}Ar/^{39}Ar procedure should be very useful.

Experimental

Eight block samples from the island of Maio collected from among the Mesozoic submarine rocks have ben provided by Dr J. G. Mitchell, School of Physics, University of Newcastle-Upon-Tyne, United Kingdom. Thin sections of these rocks show that they are characterized by relatively large phenocrysts of brown hornblende and pyroxene and are quite unlike the over-lying major sequence of the Pliocene basalt volcanics and must be the Miocene rocks. Conventional K-Ar and step-heating ^{40}Ar/^{39}Ar studies are performed on these samples.

The eight samples come from four different sites as follows:

Site A - H1/7885, H2/7886, H3/7887
Site B - H4/7888,
Site C - H6/7889, H7890
Site D - H8/7891, H9/7892

Fresh piece of each block sample was cut, cleaned, crushed down in a jaw crusher to 60-100 mesh, divided into two and one half further pulverized in a ball mill. The conventional K-Ar analysis was performed using exactly the same technique and the same equipment previously employed by the author in dating basalts and trachytes from the King's Trough in the Mid-Atlantic sea floor. (Agyei, 1982).

In the ^{40}Ar/^{39} Ar method, samples of 60-100 mesh H3/7887, H7/7890, H9/7892, five samples of a biotite standard Bi 133 of accurately known age of 10^9 years and 10 other unknown samples which are not related to this work were inserted in a sample holder at known geometric positions. The monitor was distributed in between the unknowns. The samples, about 0.1-0.5 g each were loaded in glass phials plugged with glass wool and wrapped in aluminium foils. They were then arranged in pairs in a row and the whole package wrapped once more in aluminium foil before inserting into the sample holder which was then irradiated for 1.44 days.

Irradiation facilities were provided at the Adermaston Reactor at the Atomic Weapons Research Establishment in Britain. The sample holder with the long axis vertical was rotated through 180^0 about the vertical axis at half time during the irradiation to correct for any flux changes in the horizontal direction.

On return from the irradiation, the samples were loaded in the 'christmas tree' just as in the conventional method. Each of the unknowns, after dropping into the molybdenum crucible, was heated in turns, in incremental steps, the argon purified and the relative argon isotopes 40, 39, 37, 36 measured at each step. In the case of the monitor the heating was once and total for each sample. The corresponding apparent K-Ar age at each step was calculated using the following expression derived by Dalrymple & Lanphere (1971) using Mitchell's (1968) formulation

$t = 1 \ln [F.J + 1]$

where λ is the decay constant of $^{40}K = 5.543 \times 10^{-10}$ yr^{-1}

F = ratio of the radiogenic argon-40 to K-derived argon-39 in the unknown ($^{40}Ar_{rad}/^{39}Ar_{K}$)

J is a function of the age of the monitor and of the integrated fast neutron flux and is given by

$$J = \frac{e^{tm - 1}}{^{40}Ar_{rad} / ^{39}Ar_{Km}}$$

where $^{40}Ar_{rad}/^{39}Ar\,K_m = F_m$ = the ratio of the radiogenic argon-40 to K-derived argon-39 in the monitor.

The F's were calculated by using the expression

$$F = \frac{A - C_1 B + C_1 C_2 D - C_3}{1 - C_4 D}$$

where A, B, D were computed from the measured relative argon isotopes as follows:

$A = {}^{40}Ar/^{39}Ar$

$B = {}^{36}Ar/^{39}Ar$

$D = {}^{37}Ar/^{39}Ar$ (corrected for the decay of ^{37}Ar).

$C_1 = ({}^{40}Ar/^{36}Ar)$ atmospheric = 295.5

$C_2 = ({}^{36}Ar/^{37}Ar)$ calcium $= (2.72 \pm 0.1) \times 10^{-4}$

$C_3 = ({}^{40}Ar/^{39}Ar)$ potassium $= (5.9 \pm 0.4) \times 10^{-3}$

$C_4 = {}^{39}Ar/^{37}Ar)$ calcium $= (6.33 \pm 0.4) \times 10^{-4}$

The J's for the monitor samples were calculated and plotted against position. The J's for the unknown were found by interpretation. (See for example Mitchell, 1968). Using the J-values thus determined and the measured relative argon isotopes, the apparent K-Ar age against percentage cumulative argon-39 was then plotted for each of these samples.

Results and discussion

Table 1 indicates the results of the conventional K-Ar measurements. All the errors indicated are one standard deviation of the mean. Fig. 1 shows the graph of the J-values against relative geometric positions. The biotite monitors occupied geometric positions 1, 6, 9, 14, and 17 and the samples H3/7887, H7/7890 and H9/7892, the positions 3,1 and 4 respectively. From the graph the J-values for the samples were 7.815 x 10^{-3}, 7.600 x 10^{-3} and 7.815 x 10^{-3} respectively.

Fig. 2, 3, and 4 show graphs of apparent K-Ar ages against percent cumulative argon-39 for the three whole rock samples from the Cape Verde Islands H3/7887, H7/7890 and H9/7892.

The conventional K-Ar results in Table 1 confirm the Miocene ages of the whole rock basaltic samples from the Island of Maio of the Cape Verde Islands. Ages from the same site agree fairly well, as indicated in Table 2 .

The miocene ages of the block samples range from 8.1 ± 0.4 to 14.4 ± 0.4 Ma.

TABLE 1

Potassium-argon ages of Mid-Atlantic basalts and trachytes

Sample No.	*Rock type*	*K_2O (%)*	*Radiogenic content 10^{-2} $mm^{-3}g^{-1}$*	*Atmospheric contamination (%)*	*Age (Ma)*
D9564-105	Basalt	0.215±0.001	0.108 ± 0.002	62.9 ± 0.5	149± 2
			0.117 ± 0.002	61.1 ± 0.3	161± 2
D9564-109	Basalt	0.188±0.004	0.033 ± 0.004	96.9 ± 0.3	53 ± 6
			0.033 ± 0.004	96.8 ± 0.4	53 ± 6
			0.032 ± 0.003	96.6 ± 0.4	52 ± 5
D9562-19	Trachyte	9.17±0.08	0.98 ± 0.01	26.3 ± 0.3	32.7 ± 0.4
			1.00±0.01	20.3±0.5	33.3±0.5
			0.97±0.01	27.4±0.3	32.3±0.3
D9562-20	Trachyte	9.56±0.08	1.04±0.01	25.2±0.2	33.3±0.4
			0.99±0.01	23.5±0.3	32.3±0.4
			0.99±0:01	27.3±0.4	31.7±0.3
D9562-26	Trachyte	11.1±0.1	1.18±0.01	22.5±0.2	32.7±0.4
			1.25±0.01	24.2±0.2	34.6±0.5
			1.13±0.01	22.1±0.4	31.1±0.4
			1.18±0.01	25.1±0.4	32.7±0.3
D9562-30	Trachyte	9.72±0.05	1.04±0.01	24.7±0.2	32.8± 0.4
			0.99±0.01	24.2±0.2	31.0±0.7
			0.98±0.01	23.5±0.2	30.9±0.4
D9562-31	Trachyte	9.7±0.1	0.649±0.007	27.5±0.2	34.7±0.7
			0.646±0.007	28.9±0.3	34.6±0.7
			0.675±0.008	26.2±0.2	36.2±0.8
D9562-32	Trachyte	11.1±0.1	1.22±0.01	20.8±0.3	33.5±0.4
			1.24±0.01	21.6±0.2	34.1±0.5
			1.24±0.01	22.4±0.4	34.2±0.5

$\lambda_\beta = 4.962 \times 10^{-10}$ yr^{-1}; $\lambda_e = 0.581\times10^{-10}$ yr^{-1}; $^{40}K/ = 1.1167\times10^{-2}$ atoms %

Fig. 3, 4, and 5 follow the theoretical argon release patterns for a sample with lognormal distribution of grain radii with almost 100 per cent argon loss, published by Turner (1968) and reproduced by Faure (1977). The high dates obtained in this work for the first fractions of the gas may have resulted form a small amount of radiogenic argon-40 that diffused from the crystal lattice to non-lattice sites from where it was readily removed at low temperatures.

The results for H7/7890 and H9/7892 give plateau ages of about 11 and 14 Ma which agree fairly well with the conventional K-Ar ages. It is not possible yet to explain the discrepancy between the plateau age and the conventional K-Ar age of H3/7887. It is interesting, however, to note that among the group of samples from site A it has the lowest conventional K-Ar age.

If the same metamorphic event caused a 100 per cent loss in argon from all the samples, the Miocene ages for all the sites should give a better agreement than what is indicated by the results. It appears, therefore, that whatever volcanic action or later intrusion that occurred in the Mesozoic igneous complex it must have reoccurred at the different sites studied at different times between 8 and 15 Ma age.

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