Potassium-argon ages from Tristan da Cunha, South Atlantic

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Summary. Potassium-argon ages measured on 11 volcanic rocks, mainly lavas, from Tristan da Cunha range from 0.21 ± 0.01 to 0.01 ± 0.02 Ma, and confirm the youthfulness of this volcano, which lies on the Walvis Ridge just to the east of the crest of the Mid Atlantic Ridge.

1. Introduction

The Tristan da Cunha group of volcanic islands is situated about 400 km east of the crest of the Mid Atlantic Ridge at longitude 12° 17′ W, latitude 37° 05′ S. The island group lies near the southwestern extremity of the Walvis Ridge where it merges with the Mid Atlantic Ridge, and is built upon oceanic crust of age approximately 20 Ma (Dingle & Simpson, 1976; Ladd, Dickson & Pitman, 1973). As shown by Baker *et al.* (1964) and Gass (1967) the principal islands comprising Tristan da Cunha itself (hereafter called Tristan), Inaccessible and Nightingale, are separate volcanoes rising from oceanic depths exceeding 2000 m. Tristan is a large nearly symmetrical, circular volcano about 12 km in diameter at sea level, rising to an altitude of 2600 m, showing relatively little erosion. In contrast Inaccessible and Nightingale islands have irregular form and are the erosional remnants of volcanoes.

In this paper we present new K-Ar age data on samples from Tristan. Miller (1964) reported K-Ar age results from samples from Tristan and the other islands of the group, and Gass (1967) referred to some unpublished K-Ar results. The poor precision of the ages given by Miller (1964) emphasizes the desirability of attempting to provide higher quality data. The visit by one of us (C. D. O.) to the islands to undertake geomorphological studies enabled sampling to be undertaken on Tristan.

2. Methods

All samples were carefully examined in thin section under the petrographic microscope, and only those that were essentially free of alteration were selected for isotopic dating. Most of the rocks are trachybasalt, trachyandesite or trachyte. The trachybasalts and trachyandesites commonly are quite richly phyric in clinopyroxene, with less common olivine, plagioclase and iron oxide set in a fine to very fine grained groundmass in which variable amounts of mesostasis or glass occur in some specimens. Provided that the mesostasis or glass appeared fresh, along with the rest of the components of the rock, the samples were used in the dating. The trachyte (T15) consisted of feldspar phenocrysts within a very fine grained groundmass composed mainly of feldspar, and was fresh and well crystallized.

Samples chosen for dating were crushed to 1.0–0.5 mm, an aliquant taken and crushed further to less than 0.14 mm for measurement of potassium by flame photometry. Argon analyses were done on the coarser fraction, using between 10 and 25 g for each extraction. Methods were described previously (McDougall & Schmincke, 1977) and involved fusion of the sample in a high vacuum extraction line with addition of an ^{38}Ar tracer. Following purification of the gas, its isotopic composition was determined in a substantially modified AEI MS10 mass spectrometer operated in the static mode. Data are taken digitally on-line with a computer, in which all data reduction is done immediately following analysis.

3. Results and discussion

Results are given in Table 1. Most samples were measured in duplicate for both potassium and argon. Precision of potassium measurement normally is better than 1%, but for radiogenic argon the precision varies considerably owing to the very low proportion of argon that is radiogenic. Judging from the replicate argon analyses, the reported precision from statistical assessment of the mass spectrometer data (McDougall, Polach & Stipp, 1969) in some cases is underestimated, often considerably. With such small proportions of radiogenic argon, usually less than 6% of the total argon, error magnification effects are large, and any variation in the mass discrimination of the mass spectrometer will cause systematic error in the calculated results. It should be noted that the replicates were measured several months apart, and although the mass discrimination was monitored regularly by analysis of atmospheric argon, small, but significant systematic errors undoubtedly occur. In addition the extrapolation of the peak height data from the mass spectrometer to zero time, to allow for memory effects, may be mathematically very precise, but again slight systematic error will be reflected in poor precision of replicates, although not in the formally calculated uncertainties.

Bearing these problems in mind we believe that the results given in Table 1 are satisfactory. Nevertheless caution must be exercised in the interpretation of the results so as not to read too much into apparent small differences in measured age.

The 11 samples measured from Tristan yield apparent K-Ar ages in the range 0.01 ± 0.02 Ma to 0.21 ± 0.01 Ma, and clearly confirm the conclusions of Gass (1967) that this volcano is very youthful, at least subaerially. Gass (1967) referred to an unpublished K-Ar age of less than 0.1 Ma, and Miller (1964) presented K-Ar data from about 20 samples, the majority of which are classified as Recent as the amount of radiogenic argon was less than one percent of the total argon, and the remainder generally have reported ages of the order of 1 ± 1 Ma. However, in a footnote Miller (1964) reported two ages on a single sample from the north coast of Tristan as 0.80 ± 0.10 and 1.10 ± 0.15 Ma. In the light of the present results, these ages would seem to be anomalously old, a conclusion previously reached by Gass (1967). Creer (1964) measured the direction of magnetization in nine samples from Tristan, and found all of them had normal polarity, consistent with the youthful ages determined in the present work.

Samples T6, T7, T8 and T9 are from the main cliffs adjacent to the northwest coast of Tristan near Settlement (Fig. 1), and clearly are from the main shield building stage of the volcano. Two samples, T6 and T7, from the cliffs behind Pigbite yielded concordant ages of 0.12 ± 0.03 and 0.11 ± 0.03 Ma respectively. Similarly samples T8 and T9 from Hottentot Gulch give ages that are indistinguishable from one another and from those obtained from Pigbite. The locations in Hottentot Gulch from which these samples were collected were mapped by Baker *et al.* (1967) as lying within a pyroclastic centre within the main lava sequence, but the size of this centre is exaggerated on the map and our samples come from the main flow sequence. These four results, which are essentially concordant (Table 1), suggest that the main sequence behind Settlement was erupted about 0.13 ± 0.02 Ma ago.

The trachybasalt (T13) from the southern valley of Flat Gulch on the western slopes of Tristan, just below the young cinder cone comprising Mates Hill, gives a relatively old age of 0.18 ± 0.01 Ma, and no doubt is from the main sequence.

The young age of 0.03 ± 0.03 Ma found for the trachyandesite sample (T12) from Gipsy's Gulch on the southwest flanks of Tristan suggests that this is probably a young lava of the kind described by Baker *et al.* (1964) under the classification of Recent trachyandesite eruptions.

Table 1. Potassium-argon age measurements on whole rock samples of volcanics from Tristan da Cunha

Lab. no.	Field no.	K (wt. %)	Radiogenic ^{40}Ar (10^{-12} mol/g)	100 Rad. ^{40}Ar / Total ^{40}Ar	Calculated age Ma ± 1 s.d.	Average age Ma ± 1 s.d.	Locality
77–760	T15	5.008, 5.014	0.145	3.5	0.017 ± 0.001	0.02	Trachytic dyke, Queen Mary's Peak (1980 m)
77–749	T4	2.446, 2.451	0.317 0.299	1.8 1.8	0.075 ± 0.011 0.070 ± 0.025	0.07 ± 0.02	South coast, East Beach
77–757	T12	3.469, 3.469	0.335 < 0.05	2.4 < 0.5	0.056 ± 0.006 < 0.01 ± 0.01	0.03 ± 0.03	Gipsy's Gulch, SW flanks (~ 650 m)
77–758	T13	1.800, 1.804	0.553 0.562	4.4 6.2	0.177 ± 0.010 0.180 ± 0.008	0.18 ± 0.01	Flat Gulch, SW flanks (~ 680 m)
77–746	T1	2.372, 2.381	0.864 0.859	5.8 5.7	0.210 ± 0.010 0.208 ± 0.010	0.21 ± 0.01	The Hardies, NW coast
77–747	T2	2.510, 2.508	0.062 < 0.010	0.3 < 0.3	0.014 ± 0.013 < 0.002 ± 0.014	0.01 ± 0.02	Runaway Beach, NW coast
77–748	T3	2.453, 2.451	0.500 0.326	2.7 2.0	0.117 ± 0.011 0.077 ± 0.011	0.10 ± 0.03	Darleys Hill, NW coast
77–754	T9	1.372, 1.370	0.338 0.354	5.2 6.5	0.142 ± 0.009 0.149 ± 0.006	0.15 ± 0.01	Main cliffs, Hottentot Gulch (~ 300 m)
77–753	T8	3.346, 3.316	0.947 0.531 0.578	8.3 5.0 5.4	0.164 ± 0.005 0.092 ± 0.006 0.100 ± 0.005	0.12 ± 0.04	Main cliffs, Hottentot Gulch (~ 180 m)
77–752	T7	1.932, 1.927	0.249 0.424 0.406	2.5 3.1 3.4	0.074 ± 0.008 0.127 ± 0.012 0.121 ± 0.009	0.11 ± 0.03	Main cliffs, Pigbite (~ 420 m)
77–751	T6	1.880, 1.878	0.342 0.460	4.1 3.9	0.105 ± 0.017 0.141 ± 0.010	0.12 ± 0.03	Main cliffs, Pigbite (~ 90 m)

$\lambda_e + \lambda_e' = 0.581 \times 10^{-10}\ a^{-1}$ $\lambda_\beta = 4.962 \times 10^{-10}\ a^{-1}$ $^{40}K/K = 1.167 \times 10^{-4}$ mol/mol.

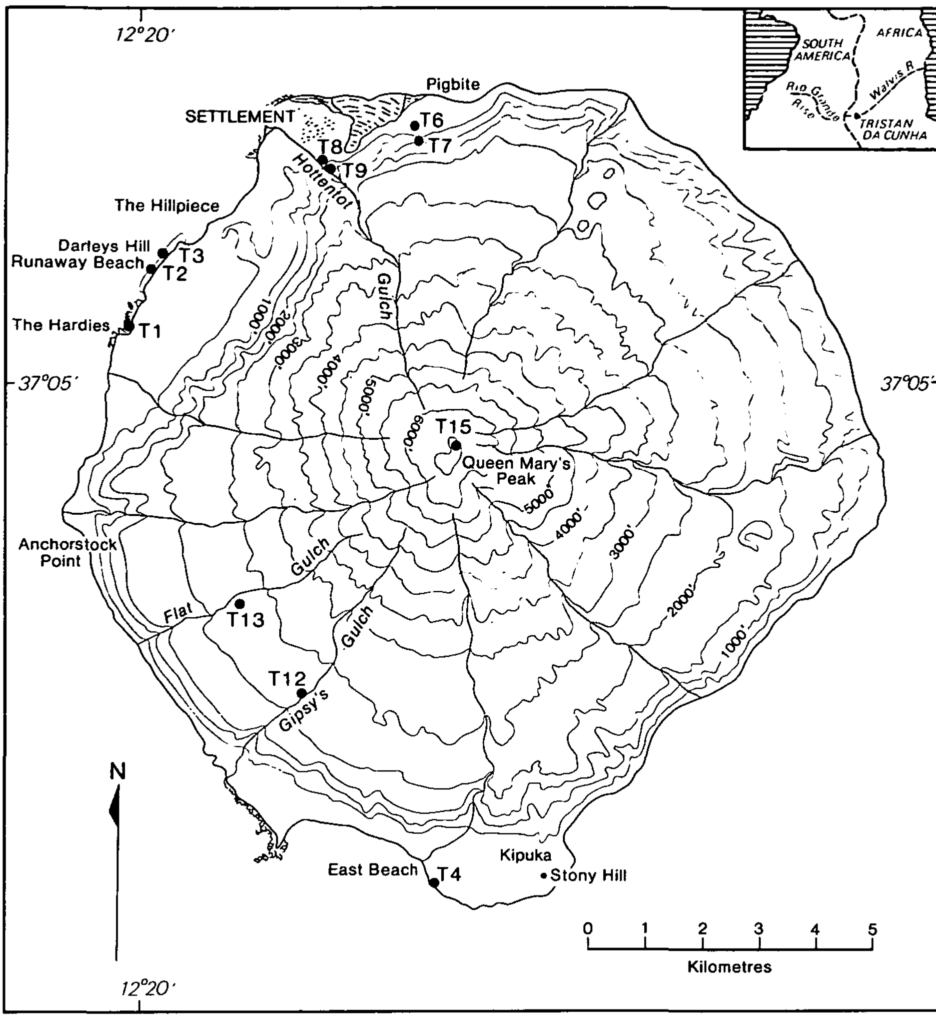

Figure 1. Map of Tristan da Cunha with contours in feet showing location of samples used in the dating. Inset shows location of Tristan in the South Atlantic.

An intermediate age of 0.07 ± 0.02 Ma was obtained on a sample (T4) from a lava at East Beach on the south coast. On field evidence this is from a flow older than the youthful-looking flows from Kipuka and Stony Hill.

A sample (T15) from a trachytic dyke near the summit of Tristan at Queen Mary's Peak yields an age of about 0.02 Ma, providing an estimate for the time of cessation of activity in the summit area.

The sample (T1) from the coast at the Hardies southwest of the settlement has an apparent age of 0.21 ± 0.01 Ma, and sample T3 from Darleys Hill has a measured age of 0.10 ± 0.03 Ma. This suggests that these lavas are related to the main sequence, rather than to young parasitic centres such as the Hillpiece about a kilometre to the northeast. However the extremely youthful age of 0.01 ± 0.02 Ma for sample T2 from Runaway Beach indicates that this is probably a lava erupted from one of these young centres. These results are of interest because of the implications they have for the structure and geomorphic history of Tristan.

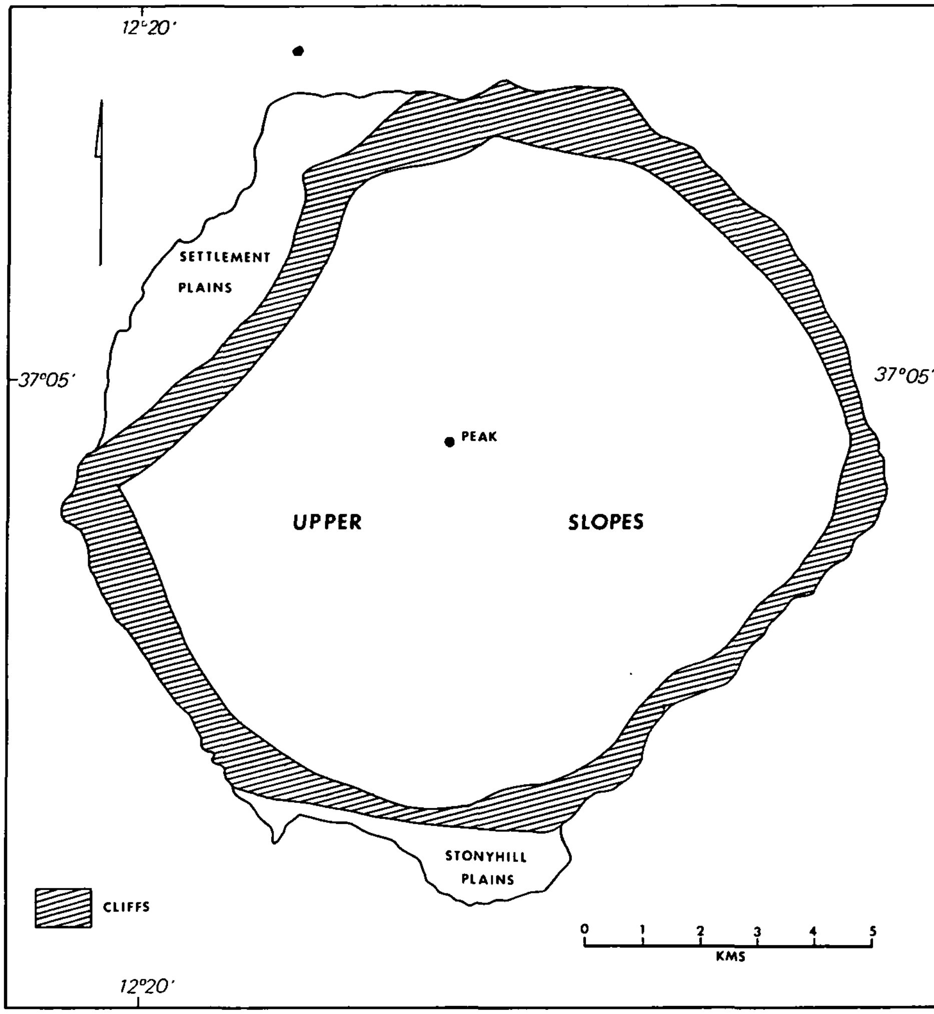

Figure 2. Map of Tristan da Cunha showing the main physiographic elements.

Figure 2 shows the main physiographic elements of Tristan – the upper slopes of the volcano, the bounding cliffs, and plains at the south and northwest. The island without the plains looks much more rectangular than the simple circular impression gained from an outline map.

It seems that marine erosion has attacked the main volcano of Tristan, producing cliffs over 600 m high, but the island shape is modified by the two low level plains of the Settlement and Stony Hill. The simplest explanation for these is that they result from younger eruptions near sea level, similar to the eruption of 1961. Every worker seems to agree that this is correct for the southern plain, and Baker *et al.* (1964) suggested it is also the mechanism for the northern plain. Earlier Dunne (1941) had suggested that the cliffs backing the Settlement Plain might be a fault scarp on the dubious grounds that the lavas exposed in the small sea cliffs bounding the Settlement Plain 'correspond petrographically rather closely to those around the 1000 m level'. This is still possible, but we prefer to think that the Settlement Plain is an erosional shelf cut across the main sequence (and backed by marine cliffs), upon which younger volcanoes have erupted.

Much of the Settlement Plain is obscured by younger volcanics and huge alluvial fans and outwash, but seawards the plain is terminated by basalt cliffs 5 to 15 m high. The relatively old age of 0.10 ± 0.03 Ma measured on basalt sample T3 from the cliffs indicates that these lavas are likely to be part of the main volcano. Thus it is suggested that a plain of marine erosion runs from the coastal clifftop, under the younger deposits, to the base of the high cliffs.

If the Settlement Plain is interpreted correctly as a marine erosion surface, it follows that as the plain is now a little above sea level, there has been some uplift of Tristan relative to sea level since formation of the plain. Assuming that the backing cliffs, like all the other main cliffs around Tristan, result from marine erosion, it appears that most erosion took place on the northwest of the island, with resistant promontories at Anchorstock and near Hottentot Gulch and a slightly concave coast between.

Overall the K-Ar ages from rocks from Tristan appear to be consistent with the known geology and suggest that the volcano was active subaerially from at least 0.2 Ma ago until virtually the present time. Where samples were obtained in known stratigraphic relation to one another from Hottentot Gulch and Pigbite in the main cliffs, the ages are concordant, and provide confidence that these estimates are geologically realistic. The youthful ages are consistent with the conclusions of Gass (1967) from the geomorphology that the island is indeed young. In addition the results indicate that it is unlikely that the lavas contain significant amounts of excess radiogenic argon, that is radiogenic argon remaining in the lavas at the time of their crystallization. Such excess argon would cause the measured K-Ar ages to be older than the true age of eruption.

4. Conclusion

The K-Ar age data demonstrate that the accessible lavas of the main shield building phase of Tristan volcano were erupted between about 0.2 and 0.1 Ma ago, with activity continuing intermittently until the present time, as exemplified by the eruption of 1961 (Baker *et al.* 1964). Although the very limited erosion of the volcano probably means that the oldest lavas have not been sampled, it is unlikely that any part of the volcano above sea level has an age exceeding 0.5 Ma. These results serve to emphasize that Tristan had a main shield building phase of activity that was very short-lived, a characteristic of many oceanic volcanoes (McDougall, 1964; McDougall & Schmincke, 1977; McDougall & Duncan, 1980).

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