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Pitcairn Island—another Pacific hot spot?

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The volcanic Pitcairn Island, which has surface lavas with apparent ages between 0.45 and 0.93 Myr, may be the youngest member of another NW–SE trending volcanic lineament in the Pacific Ocean.

PITCAIRN Island, in the south-eastern Pacific Ocean (24°04′S, 130°06′W), is built entirely of volcanic rock[1]. Unlike the majority of volcanic islands in the Pacific basin, which are grouped in distinctive linear chains (see Fig. 1), Pitcairn is isolated from its nearest neighbours, Oeno, Ducie and Henderson (all coralline islands) by 160 km, and it is 600 km from its closest volcanic neighbour, Mangareva in the Gambier Islands. Easter Island lies approximately 2,100 km to the east, near the summit of the East Pacific Rise. The position and youth of Pitcairn Island beg explanation by one or another of the rapidly proliferating theories of nonorogenic volcanism.

Pitcairn Island is built up from the seafloor, a depth of at least 3,500 m (ref. 2). The age of the oceanic crust on which

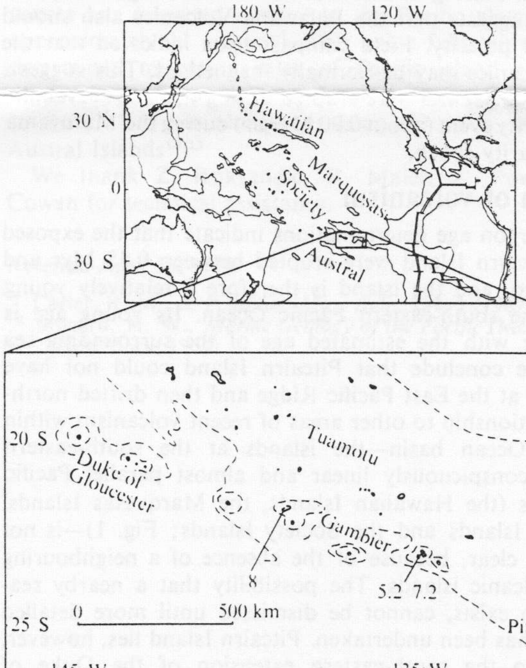

Fig. 1 Pitcairn Island is situated in the Pacific Basin, possibly the SE end of the Duke of Gloucester–Gambier Islands volcanic lineament which is parallel to other well known Pacific Island chains (Hawaiian, Marquesan, Society and Austral). The Duke of Gloucester Islands are all coral atolls at sealevel. Numbers indicate K–Ar ages × 10⁶ yr. Bathymetry in the Pacific Basin denoted by the 4,000 m contour; in the inset by the 4,000 m and 2,000 m contours (dotted lines).

the island is constructed is not known with any great precision but magnetic anomaly studies[3] predict an age close to 30 Myr (anomalies 7–9). Basal sediments from Deep Sea Drilling Project (DSDP) site 75, 1,200 km NNW of Pitcairn (and roughly the same distance from the East Pacific Rise), have been assigned a lower Oligocene age (35–40 Myr)[4].

The island is approximately elliptical, measuring 4 km by 2 km and is cliffed on all sides, rising to an altitude of 347 m (Fig. 2). Volcanic rocks of two types—lavas and pyroclastics—predominate. Structurally, the island seems to be the remnant of a single shield volcano, its dissected caldera rim forming a prominent annular ridge which opens to the north. Four units have been discriminated: the Tedside Volcanics—gently dipping flows exposed near the west coast; the Christians Cave Formation—an agglomeratic tuff generally overlaying the Tedside Volcanics with erosional unconformity; the overlying Adamstown Volcanics—horizontal flows which fill the central basin; and the Pulawana Volcanics—a sequence of lava flows at the western extremity of the island, which may be coeval with the Adamstown Volcanics, as their lithology suggests. There are also some dykes, mainly within the Tedside Volcanics.

Petrologically, the lavas range from alkali olivine basalts through hawaiites and mugearites to minor trachytes. The basalts contain phenocrysts of plagioclase feldspar, olivine and augite. The hawaiites and mugearites exhibit trachytic texture and contain fewer phenocrysts than the basalts. A common additional groundmass phase in these samples is biotite. The alkaline character of the trachytes is evident in phenocrysts of alkali feldspar, aegirine augite and fayalitic olivine. Almost all of the rocks contain interstitial alkali feldspar, the amount increasing in the sequence olivine basalt to trachyte. Chemical analyses of hawaiites, mugearites and trachytes from Pitcairn Island have been presented by Lacroix[5] who finds them comparable to the petrological association in the Marquesas Islands[5,6]. New analyses from this Pitcairn collection will be published elsewhere.

Geochronology

The samples selected for dating in this study are primarily hawaiites and mugearites. All four lithological units are represented in the age determinations.

Of the 17 selected samples, 12 were chosen for K–Ar age determination, on the basis of thin section examination. Only those specimens which were devoid of any alteration of the K-bearing phases were selected. Generally, they were holocrystalline and nonvesicular.

Measurements were taken following the techniques previously described by McDougall[7–9]. Constants used in the calculations are: $\lambda_e = 0.585 \times 10^{-10}$ yr^{-1}; $\lambda_\beta = 4.72 \times 10^{-10}$ yr^{-1}; $^{40}K/K = 1.19 \times 10^{-2}$ atom %.

Table 1 presents the analytical data for 20 K–Ar age determinations on the 12 whole rock samples. Generally, the duplicate analyses on 8 of the samples show agreement to within experimental error. The samples are grouped according to the formations defined by Carter[1]. Localities and ages are shown in Fig. 2.

The calculated ages fall into at least two groups. Ages for four samples from the Tedside Volcanics, stratigraphically the oldest unit exposed on Pitcairn, form a group distinctly older than the rest, averaging 0.85 Myr and spanning the period

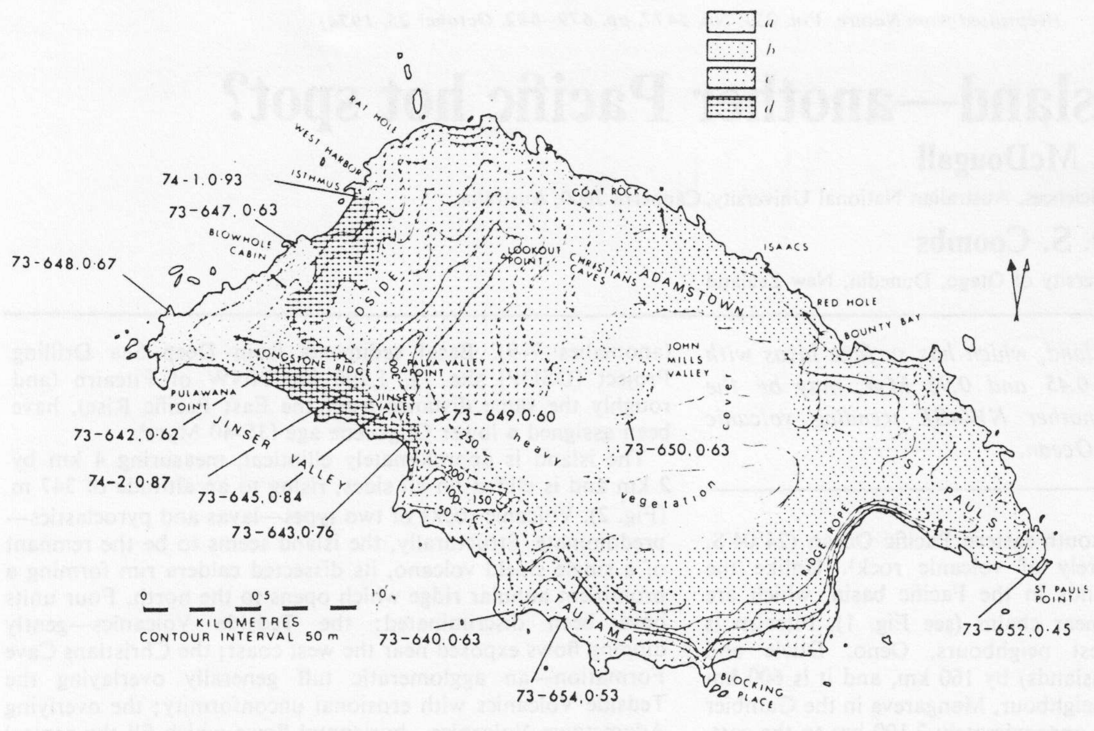

Fig. 2 Generalised geology of Pitcairn Island (after Carter[1]). *a*, Pulawana Volcanics; *b*, Adamstown Volcanics; *c*, Christian Cave Formation; *d*, Tedside Volcanics. Arrows indicate the generalised direction of lava flows. Observed geological contacts indicated by solid line; inferred contacts, dashed line. Numbers after commas, K–Ar ages ($\times 10^6$ yr) of samples indicated. Contours at 50 m intervals.

0.76–0.93 Myr. The oldest apparent age was obtained on sample 74–1 from the north-west coast (near sealevel), about 1 km from the other three Tedside collecting localities which were in Jinser Valley. The three Jinser Valley samples are from nearly horizontal lavas. Samples 74–2 and 73–645 are from approximately the same stratigraphical horizon and give nearly identical ages, averaging 0.86 Myr. The third sample (73–643), stratigraphically lower in the sequence, yields a significantly younger age of 0.76 $\pm$ 0.01 Myr. (Because minor intersertal glass occurs in this sample it is possible that some radiogenic argon has been lost from it, resulting in a younger apparent age.) These data suggest that much of the exposed Tedside Volcanics were erupted over a short interval of time between about 0.85 Myr and 0.93 Myr ago.

The samples from the Christians Cave Formation, and the Adamstown and Pulawana Volcanics all yield younger K–Ar ages—from 0.46–0.63 Myr—consistent with their stratigraphically younger age. A block from an agglomerate of the Christians Cave Formation yields an age of 0.60 Myr, indistinguishable from the apparent age of 0.62 Myr for sample 73–650 from the overlying Adamstown Volcanics. The Christians Cave formation can thus be interpreted as contemporaneous with an early phase of the Adamstown Volcanics. Sample 73–640 gives a similar age (0.63 $\pm$ 0.01 Myr) and was collected from the south coast. The radiometric age supports its inclusion in the Adamstown Volcanics as tentatively suggested by Carter[1]. The two remaining samples from the Adamstown Volcanics have measured ages that are significantly younger (0.53 Myr and 0.45 Myr). Sample 73–654 is from a biotite mugearite flow, from which samples were taken by early Polynesians to manufacture artefacts. The Pulawana Volcanics, which overlie stratigraphically the Tedside Volcanics, near to the west coast, give concordant K–Ar ages of 0.62–0.63 Myr on two samples. A trachyte dyke (73–648) cutting the Pulawana Volcanics near the western tip of the island gives a slightly older age of 0.67 $\pm$ 0.01 Myr. These ages are indistinguishable from the older ages found for the Adamstown Volcanics, which supports the suggestion[1] that the two formations are in part equivalent.

We interpret these data as indicating that the Tedside volcanics, regarded as a relic of a dome building phase, were erupted between about 0.8 Myr and 0.9 Myr ago. Following a hiatus of about 0.2 Myr, during which time caldera subsidence occurred, the Christians Cave Formation, the Adamstown Volcanics (which filled the caldera), and the extracaldera flows of the Pulawana Volcanics, were erupted about 0.62 Myr ago, with volcanism continuing until at least about 0.45 Myr ago. The volcano was therefore active for a period of 0.5 Myr during the younger part of the Pleistocene.

The Adamstown Volcanics and Christians Cave Formation are normally magnetised[1], which is consistent with their geochronological placing in the Brunhes normal magnetic epoch. This study suggests that the Pulawana Volcanics also should have normal polarity. Field compass texts indicated that the Tedside Volcanics may be normally magnetised. This suggests that Tedside Volcanics were erupted during the short Jaramillo normal polarity event (about 0.90 Myr BP) during the Matuyama reversed polarity epoch.

Migration of volcanism

Potassium–argon age determinations indicate that the exposed lavas on Pitcairn Island were erupted between 0.45 Myr and 0.93 Myr ago, and the island is therefore a relatively young feature in the south-eastern Pacific Ocean. Its young age is incompatible with the estimated age of the surrounding sea floor and we conclude that Pitcairn Island could not have been formed at the East Pacific Ridge and then drifted north-west. Its relationship to other areas of recent volcanism within the Pacific Ocean basin—the islands at the south-eastern end of the conspicuously linear and almost parallel Pacific island chains (the Hawaiian Islands, the Marquesas Islands, the Austral Islands and the Society Islands; Fig. 1)—is not immediately clear, because of the absence of a neighbouring chain of volcanic islands. The possibility that a nearby seamount chain exists, cannot be dismissed until more detailed bathymetry has been undertaken. Pitcairn Island lies, however, very near to the south-eastern extension of the Duke of Gloucester Islands–Gambier Islands lineament, which is also approximately parallel to the Pacific island chains. Potassium-argon age determinations on volcanic samples from the Gambier Islands[10] suggest that the tholeiitic and alkali olivine basalt lavas which form the islands of Mangareva, Aukena and Makapu, cooled between 5.2 Myr and 7.2 Myr ago. Winterer[11] has reported an age of 8 Myr (D. Krummenacher, personal communication) for basalt from a drill hole at Mururoa Atoll at the north-western end of the Gambier Islands. Thus, there is the suggestion of a NW–SE migration of volcanism, which supports other geochronological studies of linear Pacific island chains[12–15].

Table 1 K–Ar ages on whole rock samples from Pitcairn Island

Laboratory No.	Otago University No.	Rock Type	K (weight %)	rad.^{40}Ar 10^{-8} cm^3 NTP g^{-1}	$\frac{100 \text{ rad.}^{40}\text{Ar}}{\text{Total }^{40}\text{Ar}}$	Calculated age ± 2 s.d. (Myr)	Approximate altitude (m)	Locality
Pulawana Volcanics								
73–647	18815	Hawaiite	1.694; 1.696	4.27	32.5	0.63 ± 0.01	25	Cabin Cave, NW coast
73–642	18740	Hawaiite	2.183; 2.169	5.42 5.41	28.8 28.9	0.62 ± 0.01 0.62 ± 0.02	10	Jinser Valley, SW coast
73–648	18823	Trachyte	3.826; 3.828	10.28	34.8	0.67 ± 0.01	10	Dyke, W coast
Adamstown Volcanics								
73–652	18878	Hawaiite	1.537; 1.535	2.80 2.78	20.8 16.7	0.46 ± 0.01 0.45 ± 0.02	30	St Pauls Point, Eastern tip of island
73–654	18888	Biotite mugearite	1.718; 1.736	3.75 3.61	9.0 18.0	0.54 ± 0.04 0.52 ± 0.02	110	Artefact site, Tautama, adjacent to south coast
73–650	18825	Olivine mugearite	2.315; 2.311	5.63 5.96	26.0 36.7	0.61 ± 0.02 0.64 ± 0.02	200	Western side of John Mills Valley, centre of island
73–640	18730A	Mugearite	2.024; 2.036	5.11	31.7	0.63 ± 0.01	20	Western end Tautama, southern coast; possibly Adamstown Volcanics
Christians Cave Formation								
73–649	18824	Hawaiite	1.274; 1.286	3.04	19.5	0.60 ± 0.02	270	Block in agglomerate, Palva Ridge
Tedside Volcanics								
74–1	18755	Basalt	1.429; 1.418	5.41 5.23	40.5 38.3	0.95 ± 0.02 0.92 ± 0.02	10	Water Valley
74–2	18731	Hawaiite	1.960; 1.964	7.03 6.65	16.2 51.3	0.90 ± 0.03 0.85 ± 0.01	150	Jinser Valley
73–645	18764	Hawaiite	1.491; 1.496	5.01 5.01	46.0 47.3	0.84 ± 0.01 0.84 ± 0.01	130	Jinser Valley
73–643	18753	Basalt	1.065; 1.067	3.23 3.28	42.1 34.5	0.76 ± 0.01 0.77 ± 0.02	30	Jinser Valley

If Pitcairn Island is a more recent manifestation of the source which produced volcanism in the Gambier Islands (and earlier, presumably, in the Duke of Gloucester Islands), then that source has migrated relative to the Pacific plate at a rate of approximately 11 cm yr^{-1}. This value falls within previously determined migration rates of Pacific island chains, which range from 15 cm yr^{-1} in the Hawaiian Islands[15], through 10 cm yr^{-1} in the Marquesas Islands[12], to 9 cm yr^{-1} in the Austral Islands[13,14].

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