K-Ar CHRONOLOGY OF BYERS PENINSULA, LIVINGSTON ISLAND, SOUTH SHETLAND ISLANDS

By R. J. PANKHURST, S. D. WEAVER,* M. BROOK† *and* A. D. SAUNDERS*

ABSTRACT. K-Ar ages within the range 132–73 Ma are reported from 18 whole-rock samples and one mineral separate from the igneous rocks of Byers Peninsula, Livingston Island. The ages obtained suggest that the unfossiliferous "younger unit" of Valenzuela and Hervé (1971) is in part a time correlative of the upper (non-marine) facies of the "older unit" which it overlies unconformably. Lava flows and intrusions in the main non-marine outcrop are of Lower Cretaceous age and igneous activity on Byers Peninsula concluded with dolerite plugs and sills in Upper Cretaceous times.

BYERS PENINSULA (lat. 62°38′S, long. 61°05′W) forms the western end of Livingston Island and consists of a low-lying area of about 45 km². It is the largest area of summer rock exposure in the South Shetland Islands.

A reconnaissance geological survey of Byers Peninsula was carried out by Hobbs (1968), who recognized agglomerates near Start Point (Fig. 1) and andesite lavas with interbedded sediments on the northern shores of New Plymouth. On lithological grounds, Hobbs equated the rocks of Byers Peninsula with those of the supposed mid-Tertiary successions of King George Island (Barton, 1965).

The presence of Mesozoic rocks on Byers Peninsula was first demonstrated by González-Ferrán and others (1970), who reported an ammonite fauna in sediments on the south-western part of the peninsula. Subsequently, Valenzuela and Hervé (1971) provided the first detailed geological description of Byers Peninsula. These authors described an "older unit" composed of fossiliferous marine sediments and interbedded volcanic rocks, which passes up into non-marine sediments and volcanic rocks. A "younger unit", composed mostly of agglomerates, overlies unconformably the "older unit".

The geological map (Fig. 1) and the description that follows are based on field work carried out in February 1975 by A. D. Saunders and S. D. Weaver.

Marine shales and sandstones on the west coast of Byers Peninsula pass rapidly upwards into a non-marine sequence of sandstones, conglomerates, pyroclastic rocks and lavas, which occupies the central and eastern parts of the peninsula. Along the west coast, opposite Rugged Island, the marine beds dip moderately to the east and are cut by a large number of dolerite and andesite sills, plugs and dykes. Judging by their extensive zeolitization, these intrusions were probably emplaced into wet sediments. The unconsolidated nature of the sediments at the time of intrusion is confirmed by irregular outcrops of basalt–shale breccia, south-west of Chester Cone, and in which large sediment clasts show highly contorted bedding. Because of the extensive alteration, no igneous rocks could be found from within the marine sedimentary sequence that were suitable for K-Ar dating. By contrast, most of the intrusions and interbedded lavas in the non-marine epiclastic-pyroclastic sedimentary sequence are relatively fresh.

The prominent rounded hill known as Chester Cone is an andesite plug or volcanic dome. At the margin on the south side, the andesite contains numerous amphibole megacrysts up to 10 cm in length. The dolerite intrusion west-north-west of Vietor Rock and the cylindrical plug of Negro Hill are prominent features and exhibit spectacular columnar jointing. Lavas are predominantly basalt or andesite but a series of rhyolite and ignimbrite flows crops out in the vicinity of Chester Cone.

On the north-west of Byers Peninsula (Fig. 1), thick agglomerates rest uncomformably above marine shales and sandstones. It is these former beds which were termed the "younger unit" by

* Department of Geological Sciences, University of Birmingham, Birmingham B15 2TT.
† Geochemical Division, Institute of Geological Sciences, 64–78 Gray's Inn Road, London WC1X 8NG.

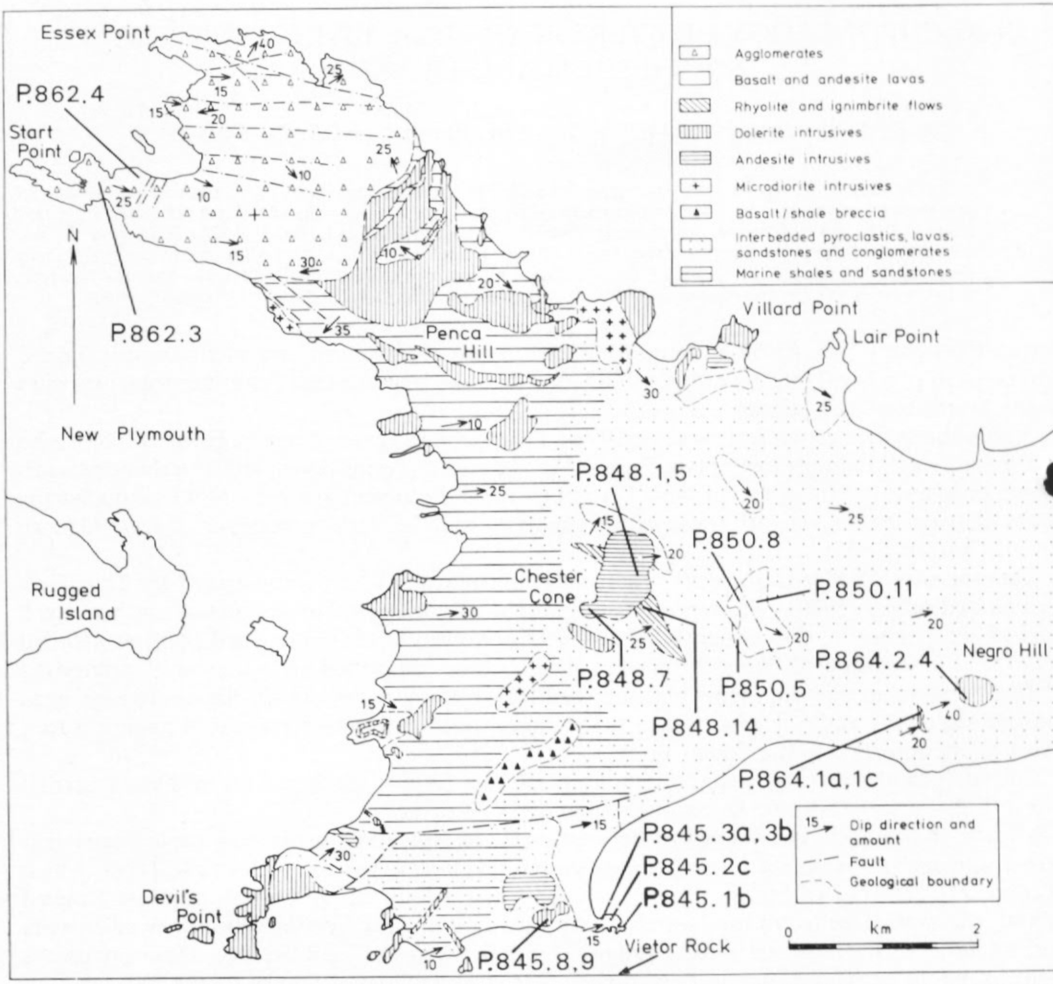

Fig. 1. Geological sketch map of Byers Peninsula, Livingston Island, South Shetland Islands. The localities of the dated samples are indicated.

Valenzuela and Hervé (1971) by contrast with the "older" marine and non-marine sequences which crop out over the remainder of the peninsula.

Palaeontological Evidence

According to Tavera (1971), the invertebrate marine fauna indicates an uppermost Jurassic to Lower Cretaceous age (Tithonian to Barremian). A detailed study by Covacevich (1976) yielded a more restricted stratigraphical range of Tithonian to Valanginian. Plant fossils from the non-marine deposits near Negro Hill have been assigned to the Barremian by Hernández and Azcárate (1971, p. 15–20).

The absolute age of the Jurassic–Cretaceous boundary has been given by Harland and others (1964, p. 260–62) as 136 Ma, the top of the Valanginian as 124 Ma and the top of the Barremian as 112 Ma, but Lambert (1971) has emphasized the large degree of uncertainty in these figures. For comparison with the dates given here, which have been calculated with the atomic constants recommended by the International Union of Geological Sciences, Sub-commission on Geochronology (1977), these time-scale boundaries should each be increased by 3 Ma.

Analytical Methods

Samples were collected from the localities indicated in Fig. 1. The freshest material available was selected for dating. Feldspars in all the dated samples were unaltered but, in most rocks containing olivine, this mineral was partly replaced by "iddingsite" and serpentine.

With the exception of the hornblende megacrysts from Chester Cone, all dating was performed on jaw-crushed whole-rock samples treated subsequently in one of two ways. Either a fine size fraction (denoted by F in Table I) was separated by sieving between 35 and 80 ASTM screens and used directly for both potassium and argon determinations, or a coarse fraction (1–3 mm mesh, denoted by C in Table I) was taken for Ar extraction and a sub-sample of this ground to powder for potassium analysis. These procedures were followed to assess the effects of sample inhomogeneity.

Potassium was determined in duplicate or triplicate by flame photometry using Li as an internal standard (reproducibility about 1% standard deviation). Standard addition experiments showed that matrix effects were mostly less than 1% of the amount determined. Argon was extracted by a conventional vacuum-fusion technique and isotope dilution with an ^{38}Ar-enriched spike using an AEI MS10 mass-spectrometer. All results are given in Table I.

Rather high and variable atmospheric argon contents were found, even after pre-baking overnight at 200° C. Nevertheless, all duplicate analyses agree to within the quoted 2σ errors. The fine fractions on the whole contain less atmospheric Ar, indicating that this is incorporated in very fine-grained minerals, possibly alteration products, rather than adsorbed on the surfaces of grains. There is no systematic difference in age between the fine and coarse size fractions.

Discussion of Results

Samples P.845.1b, 2c, 3a and b are from a sequence of three lava flows with interbedded tuffs on the coast north of Vietor Rock. Samples P.845.3a and b are from the oldest of these flows and P.845.1b is from the youngest. Samples P.845.8 and 9 are from the dolerite intrusion about 500 m to the west which cuts tuffaceous sediments underlying the lavas. Two of the flows and the intrusion yield concordant ages averaging 108 Ma. Both samples from the oldest flow give discordant ages of 86 and 74 Ma, clearly indicating argon loss, although the grain-size and degree of alteration are similar to those of the other flows.

Two samples, P.848.1 and 5, from the Chester Cone intrusions yield mean ages of 110 and 113 Ma. An age of 109 Ma is obtained for the nearby rhyolite flow, P.848.14. The flow is cut by the plug but it is probably not significantly older, as the group of silicic flows surrounding Chester Cone appears to be chemically related to the intrusion (unpublished data of S. D. Weaver). Ages determined for rocks of the Chester Cone area are therefore in good agreement with those obtained from the coastal area north of Vietor Rock, with the exception of the apparently discordant ages obtained from the oldest flow. However, the amphibole megacrysts separated from the Chester Cone andesite give a reproducible age of 132 Ma, raising the possibility that *all* the dates mentioned so far have been re-set owing to argon loss. In view of the consistency of the whole-rock results (with the exception of P.845.3) and the fact that the amphibole date would be significantly older than the top of the Valanginian (127 Ma), we are more inclined to accept the whole-rock age determinations. In thin section, it is clear that the hornblende is in a state of magmatic resorption and is breaking down to magnetite. Subsequent loss of potassium might offer a reasonable explanation for the apparent high age, since the K content of the amphibole is rather low at 0.29 wt %.

Samples P.850.5, 8 and 11 are from a sequence of lavas stratigraphically younger than those on the coast north of Vietor Rock and near Chester Cone, and older than that part of the

Table I. K-Ar ages of rock samples from Byers Peninsula, Livingston Island

Sample number	*Rock type*	*Size**	*Wt % K*	^{40}Ar *rad* (nl/g)	% *atmospheric Ar*	*Age* (Ma)
Vietor Rock area						
P.845.1b	Basalt lava	F	0.532	2.302	65	108±4
P.845.1b	Basalt lava	C	0.525	2.162	45	103±4
P.845.2c	Basaltic andesite	F	0.990	4.217	35	107±4
P.845.2c	Lava	C	1.018	4.427	40	109±4
P.845.3a	Basaltic andesite	F	0.490	1.674	38	86±3
P.845.3a	Lava	F	0.490	1.781	58	91±4
P.845.3a	Lava	C	0.483	1.560	49	82±3
P.845.3b	Basaltic andesite	F	0.397	1.163	59	74±3
P.845.3b	Lava	C	0.397	1.139	52	73±3
P.845.8	Dolerite plug	C	0.257	1.110	40	108±4
P.845.9	Dolerite plug	C	0.271	1.180	53	109±4
Chester Cone area						
P.848.1	Andesite plug	F	0.926	4.350	64	116±5
P.848.1	Andesite plug	F	0.926	3.959	23	107±4
P.848.1	Andesite plug	C	0.947	4.024	39	107±4
P.848.5	Andesite plug	F	0.789	3.501	15	111±4
P.848.5	Andesite plug	C	0.817	3.625	29	116±4
P.848.5	Andesite plug	C	0.817	3.647	31	112±4
P.848.14	Rhyolite lava	C	4.96	21.624	9	109±4
P.848.7	Amphibole	F	0.290	1.540	23	132±5
P.848.7	Amphibole	F	0.290	1.539	20	132±5
Eastern area of peninsula						
P.850.5	Basalt sill	F	0.220	0.645	66	74±3
P.850.5	Basalt sill	C	0.222	0.675	76	77±4
P.850.8	Basalt lava	F	0.195	0.715	30	92±3
P.850.8	Basalt lava	C	0.194	0.751	82	97±6
P.850.11	Basalt lava	F	0.293	0.902	36	78±3
P.850.11	Basalt lava	C	0.297	0.955	79	81±5
P.864.1a	Basalt sill	F	0.495	1.511	61	77±3
P.864.1a	Basalt sill	F	0.495	1.524	39	78±3
P.864.1a	Basalt sill	C	0.509	1.489	42	74±3
P.864.1c	Basalt sill	F	0.532	1.547	45	74±3
P.864.1c	Basalt sill	C	0.532	1.542	57	73±3
P.864.2	Dolerite plug	C	0.191	0.675	72	89±4
P.864.4	Dolerite plug	C	0.194	0.736	76	95±5
P.862.3	Andesite dyke	C	1.531	7.937	15	129±4
P.862.3	Andesite dyke	C	1.531	7.830	13	127±4
P.862.4	Basalt sill	C	0.417	2.155	41	127±7
P.862.4	Basalt sill	C	0.417	1.994	47	119±4

* C — 1–3 mm chips for Ar determination.
F — 35–80 mesh ASTM.

$\lambda_\beta = 4.962 \times 10^{-10}\ a^{-1}$, $\lambda_e = 0.581 \times 10^{-10}\ a^{-1}$.
$^{40}K/K = 0.01167$ atomic %; atomic weight of K = 39.098.
USGS basalt standard BCR–1 gave 1.405% K.

succession cut by the Negro Hill plug. Samples of the plug itself (P.864.2 and 4) are the freshest collected from the peninsula and their mean age of 92 Ma provides the most reliable limit for the age of the top of the lava succession. Sample P.850.8 from a basalt lava flow gives an age of 95 Ma, which seems reasonable, but the result for P.850.11, a sample from the succeeding flow, seems too young at 80 Ma. Three further samples (P.850.5, 864.1a and c) from the eastern area of the peninsula are from basalt sills and consistently yield the youngest ages obtained, averaging 75 Ma. This appears to represent the last igneous activity on Byers Peninsula, during which the K-Ar systems of samples P.845.3 and 850.11 may well have been thermally re-set.

The final two samples are from the "younger" agglomeratic unit of Valenzuela and Hervé (1971) on Start Point peninsula. Sample P.862.4 is from what is probably a sill near the base of this sequence, whereas P.862.3 is from a dyke which cuts the agglomerates. Both yield the same age of about 126 Ma, the oldest obtained in the present study apart from the questionable result for the Chester Cone amphibole. Thus the agglomerates at Start Point are at least as old as the non-marine part of the succession which they overlie, and the unconformity with the marine beds cannot represent any great interval of time. Alternatively, disconformities may occur within the marine transition. In either case, the geochronological data confirm the age of the marine beds as pre-Hauterivian, in good agreement with the assignment of Covacevich (1976).

Conclusions

Whole-rock K-Ar age determinations on volcanic and intrusive rocks from Byers Peninsula range from about 126 Ma to about 75 Ma. They require some modifications to the geological history suggested by Valenzuela and Hervé (1971). Marine sediments and lavas of Tithonian to Valanginian age in the western part of the peninsula were rapidly and unconformably overlain by the Start Point agglomerates at the end of this period. The facies transition from marine to non-marine beds is clearly diachronous, younging eastward, so that volcanic agglomerates near the base of the non-marine part of the succession south of Villard Point may be laterally equivalent to the much thicker exposures of the Start Point area.

According to the geochronological data, non-marine sediments and interbedded lava flows were deposited during post-Barremian times with the formation of the Chester Cone andesite intrusion about 110 Ma ago. The non-marine succession was completed by the time of the Negro Hill intrusion about 92 Ma ago (possibly Cenomanian according to the late Cretaceous time-scale of Obradovich and Cobban (1975)). The final event recognized was a period of sill intrusion about 75 Ma ago which caused some local re-heating of the volcanic succession. However, ages obtained for lavas (P.845.1b, 2c and 850.8), lying stratigraphically below the plant-bearing beds exposed near Negro Hill, are not compatible with the provisional assignment by Hernández and Azcárate (1971) of a Barremian age (121–115 Ma) to these fossils. The geochronological results suggest a probable Cenomanian age for the plants. Should the Barremian age be further substantiated, the possibility is raised that all of the lava samples dated in this study have lost argon and that their apparent ages are too young.

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