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Geochronology of volcanic rocks from the Irish Shelf

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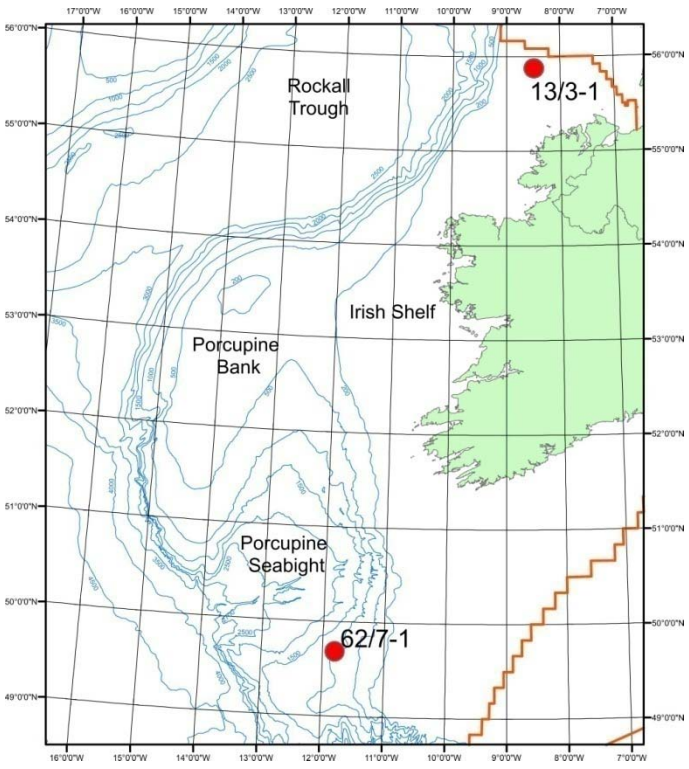

Report to the Petroleum Affairs Division, Department of Communications, Energy and Natural Resources, Dublin, Ireland.

Based on samples provided by PAD.

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BRITISH GEOLOGICAL SURVEY

MARINE GEOSCIENCE PROGRAMME

COMMISSIONED REPORT CR/09/018

Geochronology of volcanic rocks from the Irish Shelf

Darren Mark[1], Ian L Millar[2], Kenneth Hitchen[3]

[1] NERC Argon Isotope Facility, Scottish Universities Environmental Research Centre, Rankine Avenue, Scottish Enterprise Technology Park, East Kilbride, G75 0QF, Scotland, UK

[2] NERC Isotope Geosciences Laboratory, Keyworth, Nottingham, NG12 5GG, UK

[3] British Geological Survey, Murchison House, West Mains Road, Edinburgh, EH9 3LA, UK

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Front cover

Location map of the two wells sampled on the Irish Shelf

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British Geological Survey offices

BGS Central Enquiries Desk

Tel 0115 936 3143 Fax 0115 936 3276

email enquiries@bgs.ac.uk

Kingsley Dunham Centre, Keyworth, Nottingham NG12 5GG

Tel 0115 936 3241 Fax 0115 936 3488

email sales@bgs.ac.uk

Murchison House, West Mains Road, Edinburgh EH9 3LA

Tel 0131 667 1000 Fax 0131 668 2683

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Tel 01392 445271 Fax 01392 445371

Maclean Building, Crowmarsh Gifford, Wallingford OX10 8BB

Tel 01491 838800 Fax 01491 692345

Geological Survey of Northern Ireland, Colby House, Stranmillis Court, Belfast BT9 5BF

Tel 028 9038 8462 Fax 028 9038 8461

www.bgs.ac.uk/gsni/

Parent Body

Natural Environment Research Council, Polaris House, North Star Avenue, Swindon SN2 1EU

Tel 01793 411500 Fax 01793 411501

www.nerc.ac.uk

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Contents

Summary

This report contains the results of Ar-Ar geochronological analysis of a sample of igneous rock from well 62/7-1, drilled to the south-west of Ireland. An average age of 93.8 ± 1.0 Ma was derived from the weighted mean of the two plateau ages for this sample. The report also documents an unsuccessful attempt to date an igneous sample from well 13/3-1, to the north of Ireland, using U-Pb methods. Both samples were provided by the Irish Petroleum Affairs Division, Dublin.

The results presented here complement a larger confidential study of the igneous evolution of the UK Atlantic Margin undertaken by BGS and Rockall Consortium.

1. Introduction

Six samples of igneous rocks from wells and boreholes from the Irish Shelf were examined with the intention of carrying out a programme of Ar-Ar geochronology. Unfortunately, suitable separates of fresh plagioclase feldspar were obtained from only one sample (from well 62/7-1). In addition, U-Pb/Pb-Pb isochron dating of one further sample (from well 13/3-1) was attempted.

2. Ar-Ar geochronology

2.1 METHODOLOGY

Basalt samples recovered from well 62/7-1 were screened by petrographic examination. The samples were crushed and sieved and plagioclase feldspar was concentrated using magnetic separation and heavy fluid separation. Splits were leached in dilute HNO_3 to remove alteration products (e.g. clay) and pristine crystals of plagioclase were hand-picked using a binocular microscope for Ar-Ar dating. Two aliquots of plagioclase were prepared. Purified separates were loaded into Cu packets (packet 37 and 48), placed into a quartz vial and then loaded into an Al can for irradiation (EK54). Adjacent to both sample packets in the quartz vial we placed Al packets of the international standard Taylor Creek Rhyolite sanidine (TCR; 28.34 ± 0.16 Ma, Renne *et al.*, 1998) to permit characterization of the irradiation flux to the samples. The samples were irradiated in the Petten HFR reactor for 48 hours in the Cd lined facility (RODEO).

Samples were step heated using a resistively heated double-vacuum furnace over a temperature range from 500 to 1600 °C. Samples were heated for 5 minutes prior to 10 minutes cleanup. Extracted gases were cleaned using 3 GP50 SAES getters (two operated at 450 °C and one at room temperature). Furnace blanks were stable at less than 1.2×10^{-14} ^{40}Ar, 8.5×10^{-17} mol ^{39}Ar, 6.8×10^{-17} ^{38}Ar and ^{37}Ar, and 1.4×10^{-16} ^{36}Ar. Data were collected using an ARGUS multi-collector mass spectrometer at the NERC Argon Isotope Facility, SUERC. The ARGUS employs five high-gain, low-noise Faraday detectors with 10^{11} (^{40}Ar) and 10^{12} ($^{39-36}Ar$) ohm resistors for simultaneous collection of all five isotopes of Ar. The ARGUS has a sensitivity of 1.35×10^{-3} A/Torr.

Ar-Ar Calc (Koppers 2002) was used to regress and reduce age data. Isotope data are corrected for blank, radioactive decay, mass discrimination and interfering reactions. Ar-Ar ages also include a 0.5% error assigned to the J-parameter. J values and interference correction factors are presented below tabulated data (Tables 1 and 2).

2.2 DATA

Tables 1 and 2 summarise the geochronological Ar-Ar data and give age information for weighted plateaus (Figs. 1.1 and 1.3), total fusion ages and inverse isochron ages (Figs. 1.2 and 1.4). Inverse isochron plots are constructed using data which were included in the weighted plateau calculations for which the acceptance criteria are n = 3 for minimum number of contiguous steps, F = 0.60 (that is, ≥ 60% of ^{39}Ar released) and P = 0.05 for the probability of fit. The weighted plateau ages, total fusion ages and inverse isochron ages are all concordant within 2σ limits, and excess ^{40}Ar is not evident in either aliquot.

Given the high-degree of consistency between the Ar-Ar ages derived using different numerical techniques and the statistical testing of the data, we accept that the Ar-Ar ages are representative of crystallisation and not a secondary process such as re-heating or alteration. Our preferred age of 93.8 ± 1.0 Ma is derived from the weighted mean of the two plateau ages.

Table 1. Ar isotope data for sample 62/7-1 (packet 37)

62/7-1 [packet 37], 15.12 mg plagioclase, J = 0.0133815 ± 0.0000669, lab# 13004-13025

	Furnace power	Plateau steps	$^{36}Ar_{atm}$ (V)	$^{37}Ar_{Ca}$ (V)	$^{38}Ar_{Cl}$ (V)	$^{39}Ar_{K}$ (V)	$^{40}Ar^{*}$ (V)	$^{40}Ar^{*}/^{39}Ar_{K}$	Age (Ma)	2σ (Ma)	$^{40}Ar^{*}$ (%)	K/Ca	2σ
1	7.0 %		0.00175	0.00027	0.00063	0.00348	0.04430	12.73	284.36	146.40	7.89	5.45	5.45
2	7.5 %		0.00040	0.00046	0.00007	0.00762	0.04268	5.60	130.63	40.34	26.58	7.05	4.57
3	8.0 %		0.00046	0.00130	0.00001	0.01805	0.08864	4.91	115.12	18.79	39.40	5.99	1.18
4	9.0 %	✓	0.00118	0.00555	0.00000	0.06573	0.27482	4.18	98.45	6.86	43.97	5.09	0.28
5	10.0 %	✓	0.00119	0.00982	0.00000	0.11145	0.44930	4.03	95.01	4.25	56.12	4.88	0.20
6	11.0 %	✓	0.00122	0.01055	0.00000	0.12142	0.48624	4.00	94.40	3.72	57.43	4.95	0.19
7	12.0 %	✓	0.00104	0.00920	0.00000	0.10636	0.43044	4.05	95.37	4.00	58.36	4.97	0.23
8	13.0 %	✓	0.00142	0.01184	0.00000	0.13541	0.53711	3.97	93.52	3.79	56.14	4.92	0.19
9	14.2 %	✓	0.00134	0.01069	0.00000	0.12869	0.49986	3.88	91.63	3.74	55.88	5.18	0.22
10	15.5 %	✓	0.00094	0.00836	0.00000	0.09437	0.37604	3.98	93.94	4.18	57.39	4.86	0.24
11	17.0 %	✓	0.00077	0.00680	0.00000	0.07608	0.30115	3.96	93.33	4.74	57.03	4.81	0.27
12	19.0 %	✓	0.00069	0.00545	0.00000	0.06393	0.24498	3.83	90.43	6.03	54.42	5.04	0.28
13	21.0 %	✓	0.00084	0.00715	0.00000	0.08499	0.34822	4.10	96.52	4.48	58.45	5.11	0.26
14	24.0 %	✓	0.00539	0.04693	0.00000	0.56049	2.30876	4.12	97.03	2.79	59.18	5.14	0.17
15	25.0 %	✓	0.00253	0.02208	0.00000	0.25734	1.04020	4.04	95.26	3.06	58.16	5.01	0.17
16	26.0 %	✓	0.00170	0.01506	0.00000	0.16759	0.66004	3.94	92.87	3.74	56.75	4.78	0.19
17	27.5 %	✓	0.00114	0.00969	0.00000	0.11523	0.46694	4.05	95.49	3.79	58.13	5.11	0.24
18	29.5 %	✓	0.00074	0.00616	0.00000	0.06830	0.26677	3.91	92.12	5.24	54.89	4.77	0.29
19	32.0 %	✓	0.00053	0.00428	0.00000	0.04452	0.17180	3.86	91.04	7.99	52.50	4.48	0.35
20	35.0 %	✓	0.00040	0.00307	0.00000	0.03658	0.14341	3.92	92.46	9.15	54.82	5.13	0.50
21	40.0 %		0.00019	0.00141	0.00003	0.01151	0.03155	2.74	65.13	27.47	35.58	3.51	0.83
22	50.0 %		0.00014	0.00056	0.00001	0.00614	0.01262	2.06	49.11	56.16	23.23	4.74	2.45
		Σ	0.02599	0.19670	0.00076	2.28529	9.22589						

	$^{40}Ar^{*}/^{39}Ar_{K}$	2σ	$^{40}Ar/^{36}Ar$	2σ	Age (Ma)	2σ (Ma)	MSWD	$^{39}Ar_{K}$ (%,n)	K/Ca	2σ
Weighted plateau	4.01	± 0.04	-	-	94.48	1.37 ± 1.45%	0.84	97.95% 17	4.97	0.07
Total fusion age	4.04	± 0.05	-	-	95.14	1.46 ± 1.53%	-	- 22	4.96	0.08
Inverse isochron	3.85	± 0.37	310.63	± 38.14	90.91	8.58 ± 9.43%	0.85	- -	-	-

NOTE: Isotope data corrected for blank, radioactive decay, mass discrimination and interferring reactions
$(^{40}Ar/^{39}Ar)_{K}$ = 0.001830 ± 0.000092, $(^{39}Ar/^{37}Ar)_{Ca}$ = 0.000699 ± 0.000035, $(^{36}Ar/^{37}Ar)_{Ca}$ = 0.000270 ± 0.000014
Ages include 0.5% error assigned to J-parameter

Table 2. Ar isotope data for sample 62/7-1 (packet 48)

62/7-1 [packet 48], 13.67 mg plagioclase, J = 0.0133377 ± 0.0000667, lab# 13029-13052

	Furnace power	Plateau steps	$^{36}Ar_{atm}$ (V)	$^{37}Ar_{Ca}$ (V)	$^{38}Ar_{Cl}$ (V)	$^{39}Ar_{K}$ (V)	$^{40}Ar^{*}$ (V)	$^{40}Ar^{*}/^{39}Ar_{K}$	Age (Ma)	2σ (Ma)	$^{40}Ar^{*}$ (%)	K/Ca	2σ
1	7.0 %		0.00126	0.00045	0.00034	0.00453	0.02830	6.25	144.83	± 86.80	7.05	4.35	2.61
2	7.5 %		0.00049	0.00078	0.00004	0.00880	0.04276	4.86	113.58	± 30.07	22.97	4.85	1.65
3	8.0 %		0.00056	0.00221	0.00004	0.02215	0.07759	3.50	82.57	± 13.87	31.98	4.32	0.48
4	9.0 %	✓	0.00106	0.00690	0.00000	0.07756	0.30627	3.95	92.81	± 4.83	49.47	4.83	0.22
5	10.0 %	✓	0.00127	0.01062	0.00000	0.12025	0.46713	3.88	91.35	± 3.49	55.42	4.87	0.17
6	11.0 %	✓	0.00141	0.01232	0.00000	0.13785	0.53141	3.86	90.67	± 3.37	56.05	4.81	0.18
7	12.0 %	✓	0.00137	0.01195	0.00000	0.13239	0.51751	3.91	91.90	± 3.18	56.14	4.76	0.18
8	13.0 %	✓	0.00137	0.01111	0.00000	0.12824	0.50038	3.90	91.74	± 4.00	55.18	4.96	0.20
9	14.2 %	✓	0.00121	0.01055	0.00000	0.11390	0.44932	3.95	92.73	± 3.44	55.64	4.64	0.18
10	15.5 %	✓	0.00088	0.00775	0.00000	0.08654	0.32650	3.77	88.78	± 3.67	55.77	4.80	0.18
11	17.0 %	✓	0.00078	0.00710	0.00000	0.07821	0.30302	3.87	91.11	± 3.85	56.73	4.74	0.23
12	19.0 %	✓	0.00064	0.00636	0.00000	0.06624	0.25942	3.92	92.07	± 4.08	57.87	4.48	0.20
13	21.0 %	✓	0.00094	0.00799	0.00000	0.09241	0.36474	3.95	92.77	± 3.56	56.78	4.98	0.20
14	22.0 %	✓	0.00147	0.01349	0.00000	0.15679	0.64490	4.11	96.58	± 3.04	59.76	5.00	0.18
15	23.0 %	✓	0.00222	0.01949	0.00000	0.22988	0.93223	4.06	95.26	± 2.90	58.65	5.07	0.17
16	24.0 %	✓	0.00218	0.01965	0.00000	0.22910	0.94210	4.11	96.56	± 2.93	59.41	5.01	0.16
17	25.0 %	✓	0.00155	0.01341	0.00000	0.15341	0.59839	3.90	91.71	± 3.22	56.60	4.92	0.17
18	26.0 %	✓	0.00186	0.01611	0.00000	0.18505	0.73013	3.95	92.74	± 3.11	57.03	4.94	0.18
19	27.5 %	✓	0.00113	0.01000	0.00000	0.11615	0.47184	4.06	95.41	± 3.27	58.48	5.00	0.20
20	29.5 %	✓	0.00044	0.00384	0.00000	0.04279	0.16792	3.92	92.25	± 5.98	56.51	4.79	0.27
21	32.0 %	✓	0.00042	0.00425	0.00000	0.04331	0.17780	4.11	96.40	± 6.25	58.78	4.38	0.32
22	35.0 %		0.00017	0.00190	0.00004	0.01832	0.07811	4.26	100.01	± 12.18	61.07	4.14	0.44
23	40.0 %		0.00015	0.00130	0.00000	0.01237	0.04187	3.38	79.83	± 18.33	49.04	4.10	0.75
24	50.0 %		0.00015	0.00151	0.00000	0.01324	0.05690	4.30	100.77	± 17.76	56.55	3.76	0.65
		Σ	0.02497	0.20105	0.00046	2.26949	9.01655						

	$^{40}Ar^{*}/^{39}Ar_{K}$	2σ	$^{40}Ar/^{36}Ar$	2σ	Age (Ma)	2σ (Ma,%)	MSWD	$^{39}Ar_{K}$ (%,n)	K/Ca	2σ
Weighted Plateau	3.96	± 0.05	-	-	93.09	1.41 ± 1.51%	1.65	96.50% 18	4.86	0.08
Total Fusion Age	3.97	± 0.04	-	-	93.37	1.26 ± 1.35%	-	- 24.00	4.84	0.09
Inverse isochron	3.99	± 0.57	292.60	± 71.12	93.77	13.09 ± 13.96%	1.76	- -	-	-

NOTE: Isotope data corrected for blank, radioactive decay, mass discrimination and interferring reactions
$(^{40}Ar/^{39}Ar)_{K}$ = 0.001830 ± 0.000092, $(^{39}Ar/^{37}Ar)_{Ca}$ = 0.000699 ± 0.000035, $(^{36}Ar/^{37}Ar)_{Ca}$ = 0.000270 ± 0.000014
Ages include 0.5% error assigned to J-parameter

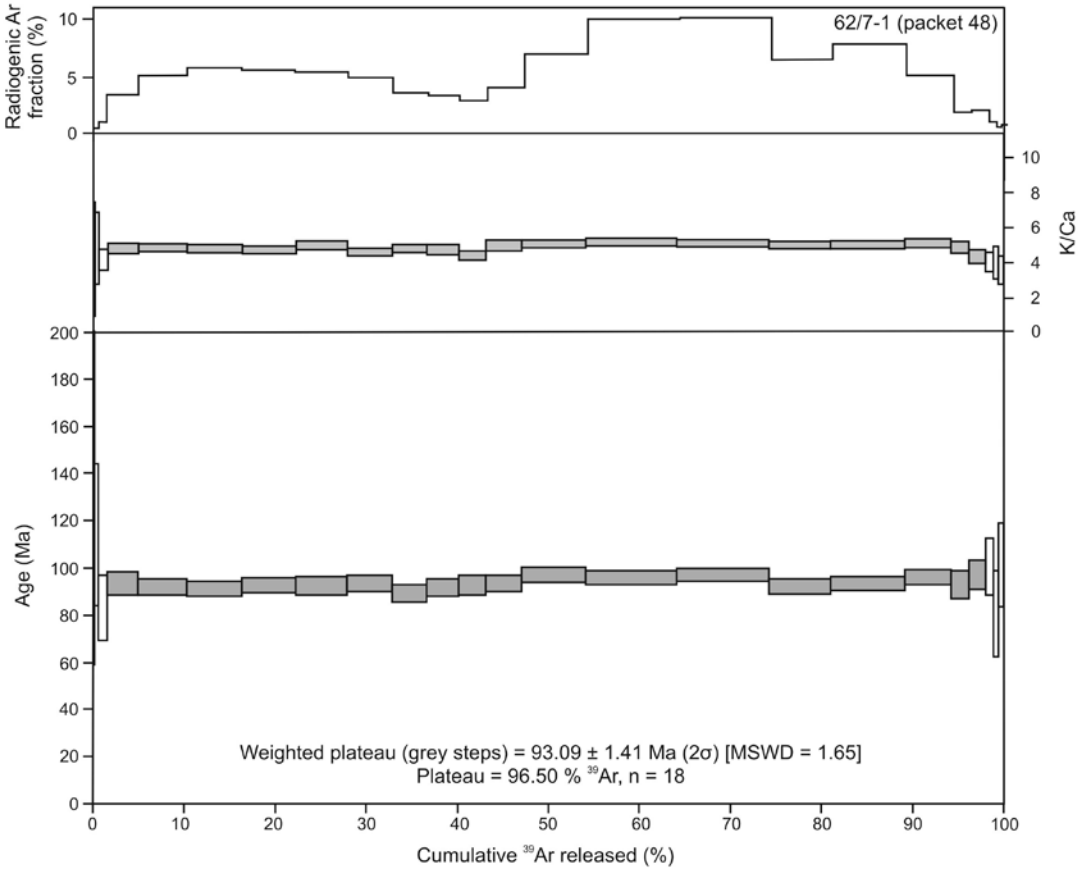

Figure 1.3 Ar-Ar age spectrum, K/Ca ratios and percentage of radiogenic ^{40}Ar released during each step for sample 62/7-1 (packet 48).

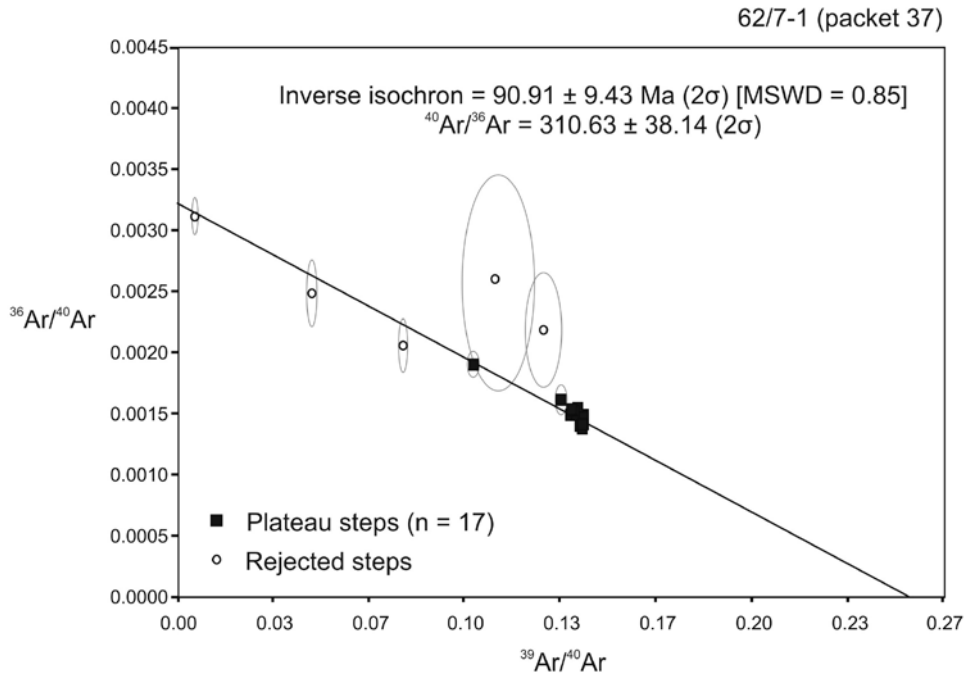

Figure 1.2 Inverse isochron plot constructed using accepted steps from age spectrum for sample 62/7-1 (packet 37).

released during each step for sample 62/7-1 (packet 37).

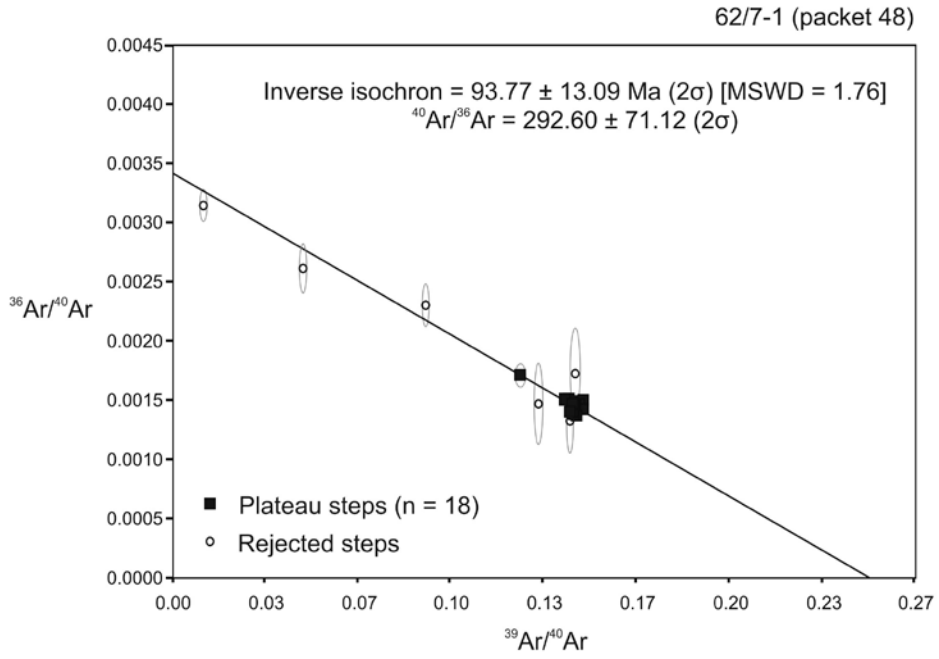

Figure 1.4 Inverse isochron plot constructed using accepted steps from age spectrum for sample 62/7-1 (packet 48).

3. U-Pb geochronology

A sample of basalt from well 13/3-1 did not contain suitable feldspar crystals for Ar-Ar dating. It was therefore decided to attempt to derive U-Pb and/or Pb-Pb isochron ages using separates of pyrite and apatite. This approach relies on the fact that apatite may have elevated U/Pb ratios, leading to the formation of radiogenic lead, whereas pyrite has very low U/Pb.

Pyrite and apatite crystals were concentrated using heavy liquids and magnetic separation. Pure separates were hand-picked using a binocular microscope. After washing with MilliQ water in an ultrasonic bath, the samples were spiked with an enriched ^{205}Pb-^{235}U tracer, and dissolved in nitric acid. U and Pb were separated using standard anion-exchange techniques, and analysed on a Thermo Scientific Triton thermal ionisation mass spectrometer. Results are shown in Table 3. Unfortunately, the range in U/Pb and Pb-isotope ratios was not sufficient to allow calculation of a meaningful age.

Table 3. U-Pb data for pyrite and apatite separates from 13/3-1.

	^{238}U/^{204}Pb	% err	^{206}Pb/^{204}Pb	% err	$\rho_{8/4\text{-}6/4}$	^{235}U/^{204}Pb	% err	^{207}Pb/^{204}Pb	% err	$\rho_{5/4\text{-}7/4}$
Pyrite	0.4516	0.16	17.947	0.14	0.34	0.00327	0.16	15.509	0.23	0.39
Apatite	253.4	1.23	24.099	1.22	0.99	1.838	1.23	15.898	1.23	0.97

4. Discussion

Basalts from 62/7-1 have previously been described by Tate & Dobson (1988), who reported K-Ar ages of c. 85 and 133.5 Ma. On the basis that the lavas are extrusive, and are overlain by a

thick Cretaceous section, Tate & Dobson considered that the c. 85 Ma age must be invalid, and preferred the c. 133.5 Ma age. The Ar-Ar age reported here (93.8 ± 1.0 Ma) is closer to the younger K-Ar age and this has potential implications for the age of the overlying Cretaceous sediments.

References

British Geological Survey holds most of the references listed below, and copies may be obtained via the library service subject to copyright legislation (contact libuser@bgs.ac.uk for details). The library catalogue is available at: http://geolib.bgs.ac.uk.

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