^{40}Ar-^{39}Ar AGES OF ANTARCTIC METEORITES: Y-74191, Y-75258, Y-7308, Y-74450 AND ALH-765

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Abstract: The ^{40}Ar-^{39}Ar ages have been determined for two chondrites (Y-74191, Y-75258), one howardite (Y-7308) and two eucrites (Y-74450, ALH-765) from Antarctica.

Y-74191 (L3) shows a disturbed age spectrum with a maximum apparent age of 4506±31 Ma in the intermediate temperature fraction. Y-75258 (LL6) shows a plateau age of 4377±14 Ma at higher temperatures except for the highest temperature fraction.

A howardite Y-7308 has an inversed age spectrum, but the intermediate temperature fractions indicate a plateau-like age of 4480±30 Ma. The apparent very old age at the lowest temperature might have been caused either by the effect of atmospheric contamination to the sample or by the redistribution of radiogenic ^{40}Ar in the sample.

One eucrite Y-74450 shows a plateau age of 4012±22 Ma, indicating a later thermal event on the parent body of the meteorite. The other eucrite ALH-765 indicates a gradual increase in the apparent ^{40}Ar-^{39}Ar ages with increasing degassing temperature, but even the highest temperature fraction shows an age of about 3700 Ma.

The present results together with those of reported ^{40}Ar-^{39}Ar and K-Ar ages suggest that meteorites found in Antarctica represent thermal histories very different from one another.

1. Introduction

Since 1969, a large number of meteorites have been collected from Antarctica by the Japanese Antarctic Research Expedition Team and the number of total specimens collected so far exceeds 4000 (YANAI *et al.*, 1981). To clarify the genetic relationships of the respective meteorites, the information on their age is indispensable. However, a very limited number of Antarctic meteorites have been dated and it is urgently required to get information on ages of these meteorites. Since Antarctic meteorites have been subject to the weathering effect, it is necessary to adopt a dating method which can overcome the effect. In this respect, the ^{40}Ar-^{39}Ar method has been successfully applied to meteorites and lunar samples (*e.g.* TURNER, 1969; TURNER *et al.*, 1971). By applying stepwise heating technique, it can also reveal a later thermal event which affected the parent body of the sample.

In general, unshocked ordinary chondrites show old ^{40}Ar-^{39}Ar ages of about 4400 ~

4500 Ma unless they were affected by much younger events, whereas achondrites show relatively younger ages of less than 4300 ~ 4400 Ma (*e.g.* KIRSTEN, 1978). Such a difference is often attributed to the different histories of parent bodies of these meteorites. However, the quantity of the data is limited and it is premature to give a conclusion. In order to get more information on ages of the two types of meteorites, two chondrites and three achondrites were selected out of the Antarctic meteorites and were dated by the ^{40}Ar-^{39}Ar method.

2. Samples

Among two ordinary chondrites dated in this study, one (Y-74191) is an unequilibrated chondrite (L3) and has been reported to contain a large amount of trapped rare gases (TAKAOKA and NAGAO, 1980a, b). However, the other meteorite (Y-75258) is an equilibrated one (LL6). Y-7308 is classified as a howardite, but it shows the texture of polymict breccia. It is reported that this howardite is rich in diogenitic components but eucritic clasts are also present (YANAI, 1979). Y-74450 is a eucrite and it is reported that its chemical trends and zoning of the pyroxenes resemble those of the Pasamonte eucrite (TAKEDA *et al.*, 1978). The above-mentioned meteorites were collected from the Yamato Mountains area, Eastern Queen Maud Land, Antarctica.

On the other hand, ALH-765 is a eucrite collected from Allan Hills, Antarctica. These meteorites were prepared as small blocks ranging from a few mm to less than 9 mm in diameter. The sample preparation procedures are the same as those described before (KANEOKA *et al.*, 1979; KANEOKA, 1980).

3. Experimental Procedures

The experimental procedures for the most part are the same as those reported before (KANEOKA *et al.*, 1979; KANEOKA, 1980) and only the essential data relevant to the evaluation for the present experimental procedures are given here.

Samples were irradiated together with remelted CaF_2 and K_2SO_4 in the JMTR of Tohoku University receiving total fast neutron fluence of about 10^{19} nvt/cm^2. The standard sample MMhb-1 (hornblende, K-Ar age: 519.5±2.5 Ma) (ALEXANDER *et al.*, 1978) was used as the age monitor.

Blanks were taken before each sample analysis and were applied for the correction of the present data. Blank levels are $(2 \sim 3) \times 10^{-8}$ cm^3 STP ^{40}Ar below 1300°C, but they increase up to $(1 \sim 2) \times 10^{-7}$ cm^3 STP at the highest temperature (~1600°C) for 45 minutes.

The amounts of Ar were estimated from the sensitivity of the mass spectrometer deduced from the amount of radiogenic ^{40}Ar in the standard sample. They include about 30% uncertainty on the basis of reproducibility. The mass discrimination among Ar isotopes was estimated to be 0.42% per mass unit favoring heavier isotopes by measuring atmospheric Ar. The analyses of CaF_2 and K_2SO_4 gave the following values as the correction factors for Ca- and K-derived interference Ar isotopes.

$$({}^{39}Ar/{}^{37}Ar)_{Ca}=(8.5\pm0.3)\times10^{-4}, \quad ({}^{38}Ar/{}^{37}Ar)_{Ca}=(1.8\pm0.2)\times10^{-3},$$
$$({}^{36}Ar/{}^{37}Ar)_{Ca}=(3.8\pm0.3)\times10^{-4},$$
$$({}^{40}Ar/{}^{39}Ar)_{K}=(13.0\pm0.2)\times10^{-2} \quad \text{and} \quad ({}^{38}Ar/{}^{39}Ar)_{K}=(3.0\pm0.1)\times10^{-2}.$$

The amounts of trapped and spallogenic components were calculated by assuming that the ${}^{38}Ar/{}^{36}Ar$ ratios for trapped and spallogenic components are 0.187 and 1.5, respectively. ${}^{40}Ar$ is corrected for trapped (${}^{40}Ar/{}^{36}Ar=0.5$) and spallogenic (${}^{40}Ar/{}^{38}Ar=0.15$) components. In the present study, most ${}^{38}Ar/{}^{36}Ar$ ratios exceed 1.5 and the excess ${}^{38}Ar$ is assumed to have been produced by the reaction ${}^{37}Cl(n, \gamma\beta){}^{38}Ar$. The remainder is presumed to be spallogenic following conventional procedures. However, the latter assumption is not always guaranteed in the present case due to a relatively high neutron fluence on samples. Because of this uncertainty, no exposure ages are reported in this paper.

4. Results

In Table 1, the observed Ar isotopic ratios and the amount of ${}^{40}Ar$ in each temperature fraction are shown. They are tabulated after the blanks and the background in the mass spectrometer plus the gas introduction system were subtracted. They include only the correction for the radioactive decay of ${}^{37}Ar$ between the neutron irradiation and Ar analysis except for ${}^{40}Ar^*/{}^{39}Ar^*$. The uncertainty assigned in each Ar isotopic ratio is statistical (1σ).

4.1. ${}^{40}Ar$-${}^{39}Ar$ ages

In the last column of Table 1, the ${}^{40}Ar$-${}^{39}Ar$ age of each sample for each temperature fraction is shown. The age spectra and the isochron plots of samples are demonstrated in Figs. 1–5.

The age spectrum of Y-74191 (L3) shows a rather strange pattern, where the 1000°C fraction indicates a maximum ${}^{40}Ar$-${}^{39}Ar$ age of 4506 ± 31 Ma. Low ${}^{40}Ar$-${}^{39}Ar$ ages in the lower temperature fractions may be explained by partial radiogenic ${}^{40}Ar$ loss from the sample. In practice, the total ${}^{40}Ar$-${}^{39}Ar$ age indicates an age of only 3558 Ma, which agrees with the reported K-Ar ages of 3400 and 3530 Ma for this meteorite (NAGAO and TAKAOKA, 1979; TAKAOKA and NAGAO, 1980a). Although this meteorite has been reported to contain a relatively large amount of trapped components (TAKAOKA and NAGAO, 1980a), it clearly indicates an evidence of partial radiogenic ${}^{40}Ar$ loss. Hence, the original amount of the trapped components might have been larger than those which we observe at present. To explain the lower ${}^{40}Ar$-${}^{39}Ar$ ages at higher temperatures, a recoil effect of ${}^{39}Ar$ due to ${}^{39}K(n, p){}^{39}Ar$ reaction from relatively K-

Table 1. Ar isotopes in neutron-irradiated meteorites from Antarctica.

Y-74191 (L3) 1.1133 g, $J=0.02591\pm0.00018$

T(°C)	$[^{40}Ar]$ ($\times10^{-8}$ cm^3 STP/g)	$^{36}Ar/^{40}Ar$ ($\times10^{-3}$)	$^{37}Ar/^{40}Ar$ ($\times10^{-3}$)	$^{38}Ar/^{40}Ar$ ($\times10^{-3}$)	$^{39}Ar/^{40}Ar$ ($\times10^{-3}$)	$^{40}Ar^*/^{39}Ar^*$	Age (Ma)
600	306	1.930 ±0.018	20.02 0.84	53.93 ±0.30	16.65 ±0.10	59.98 ±0.36	1692 ±10
700	419	0.4279 ±0.0076	5.591 ±0.086	8.829 ±0.133	4.849 ±0.075	206.3 ±3.2	3333 ±26
800	516	0.4451 ±0.0117	4.773 ±0.130	5.115 ±0.038	3.206 ±0.052	312.1 ±4.9	3981 ±28
900	905	0.6649 ±0.0070	4.951 ±0.084	4.971 ±0.058	2.439 ±0.025	410.7 ±4.2	4428 ±20
1000	557	1.470 ±0.018	5.486 ±0.212	5.213 ±0.051	2.327 ±0.040	430.5 ±7.4	4506 ±31
1100	725	4.416 ±0.060	9.536 ±0.293	7.443 ±0.050	3.043 ±0.031	329.2 ±3.4	4067 ±20
1200	417	9.606 ±0.090	15.78 ±0.37	14.17 ±0.14	3.535 ±0.060	283.1 ±4.3	3826 ±27
1300	492	13.28 ±0.12	20.87 ±0.80	17.50 ±0.20	3.550 ±0.041	282.0 ±3.3	3819 ±22
1600	1100	23.18 ±0.22	85.06 ±0.65	39.59 ±0.42	4.652 ±0.154	217.2 ±7.2	3412 ±52
Total	5437	7.661	24.95	17.21	4.192	238.8	3558

Y-75258 (LL6) 0.7830 g, $J=0.02958\pm0.00021$

T(°C)	$[^{40}Ar]$ ($\times10^{-8}$ cm^3 STP/g)	$^{36}Ar/^{40}Ar$ ($\times10^{-3}$)	$^{37}Ar/^{40}Ar$ ($\times10^{-3}$)	$^{38}Ar/^{40}Ar$ ($\times10^{-3}$)	$^{39}Ar/^{40}Ar$ ($\times10^{-3}$)	$^{40}Ar^*/^{39}Ar^*$	Age (Ma)
600	322	0.1283 ±0.0054	2.864 ±0.025	5.055 ±0.087	2.993 ±0.031	334.3 ±3.5	4308 ±21
700	630	0.02815 ±0.00247	3.415 ±0.100	5.013 ±0.104	3.164 ±0.037	316.2 ±3.7	3217 ±22
800	911	0.09789 ±0.00362	4.028 ±0.134	2.419 ±0.016	3.196 ±0.040	313.1 ±3.9	4201 ±23
900	1690	0.04394 ±0.00438	3.861 ±0.129	2.599 ±0.020	2.893 ±0.015	346.0 ±1.8	4364 ±14
1000	1280	0.09803 ±0.00547	4.549 ±0.202	4.801 ±0.049	2.834 ±0.026	351.6 ±3.2	4391 ±19
1100	445	0.2165 ±0.0073	7.449 ±0.112	0.6073 ±0.0056	2.879 ±0.039	347.8 ±4.7	4373 ±25
1200	301	0.2723 ±0.0120	19.81 ±0.31	19.00 ±0.28	2.888 ±0.083	348.1 ±10.0	4374 ±49
1300	290	0.3578 ±0.0122	29.36 ±0.34	21.95 ±0.37	2.836 ±0.053	355.6 ±6.6	4402 ±33
1600	704	1.677 ±0.031	17.1 ±1.8	30.99 ±0.36	2.211 ±0.031	485.0 ±6.8	4927 ±27
Total	6573	0.2754	24.57	7.866	2.881	349.6	4381

Table 1. (*Continued*).

Y-7308 (Howardite) 1.0558 g, J=0.04082±0.00058

T(°C)	[^{40}Ar] ($\times 10^{-8}$ cm^3 STP/g)	^{36}Ar/^{40}Ar ($\times 10^{-3}$)	^{37}Ar/^{40}Ar ($\times 10^{-3}$)	^{38}Ar/^{40}Ar ($\times 10^{-3}$)	^{39}Ar/^{40}Ar ($\times 10^{-3}$)	^{40}Ar*/^{39}Ar*	Age (Ma)
700	180	3.471 ±0.149	19.73 ±0.92	11.52 ±0.56	1.878 ±0.100	447.5 ±23.8	5337 ± 94
800	53.1	1.275 ±0.036	315.9 ±8.2	2.102 ±0.210	3.946 ±0.110	271.7 ± 7.6	4497 ± 52
930	52.0	0.8201 ±0.0390	356.6 ±8.7	1.105 ±0.050	4.029 ±0.138	268.1 ± 9.2	4475 ± 61
1050	184	0.8909 ±0.0101	334.5 ±4.2	1.291 ±0.022	3.730 ±0.040	271.3 ± 2.9	4494 ± 29
1140	143	0.9572 ±0.0368	345.5 ±6.8	1.697 ±0.046	4.062 ±0.110	265.3 ± 7.2	4457 ± 51
1250	77.9	2.330 ±0.132	462.7 ±20.1	2.273 ±0.108	4.993 ±0.361	217.0 ±15.7	4128 ±120
1330	52.4	5.406 ±0.419	1065 ±82	4.784 ±0.388	6.875 ±0.526	202.2 ±15.5	4014 ±125
1450	38.2	6.768 ±0.831	2015 ±246	9.289 ±1.163	6.282 ±0.772	218.4 ±26.8	4139 ±200
1600	0	—	—	—	—	—	—
Total	780.6	3.316	408.8	4.486	3.866	278.6	4538

Y-74450 (Eucrite) 1.0997 g, J=0.03847±0.00050

T(°C)	[^{40}Ar] ($\times 10^{-8}$ cm^3 STP/g)	^{36}Ar/^{40}Ar ($\times 10^{-3}$)	^{37}Ar/^{40}Ar ($\times 10^{-3}$)	^{38}Ar/^{40}Ar ($\times 10^{-3}$)	^{39}Ar/^{40}Ar ($\times 10^{-3}$)	^{40}Ar*/^{39}Ar*	Age (Ma)
600	118	1.569 ±0.029	218.3 ± 1.7	26.07 ±0.21	5.191 ±0.053	199.7 ±2.0	3899 ±26
700	220	1.430 ±0.026	215.7 ± 3.9	4.600 ±0.107	4.875 ±0.087	213.1 ±3.8	4003 ±36
800	146	1.529 ±0.015	201.5 ± 2.3	3.135 ±0.090	4.910 ±0.039	212.9 ±1.7	4002 ±25
910	338	1.434 ±0.010	202.8 ± 1.3	2.821 ±0.056	4.750 ±0.034	215.5 ±1.5	4021 ±24
1000	689	1.580 ±0.011	216.0 ± 0.9	2.879 ±0.022	4.873 ±0.022	213.1 ±1.0	4003 ±22
1100	—	Lost from the line				—	—
1180	287	2.221 ±0.035	288.0 ± 3.1	4.676 ±0.073	4.847 ±0.068	214.9 ±3.0	4017 ±31
1300	395	4.027 ±0.035	501.6 ± 4.4	8.323 ±0.104	5.049 ±0.056	216.2 ±2.4	4027 ±28
1600	438	5.783 ±0.085	686.3 ±10.2	9.918 ±0.139	4.583 ±0.059	249.6 ±3.2	4260 ±30
Total	2631	2.682	342.5	6.252	4.849	218.7	4045

Table 1. (*Continued*).

ALH-765 (Eucrite) 0.8219 g, J=0.03982±0.00034

T(°C)	[^{40}Ar] (×10^{-8}cm^3 STP/g)	^{36}Ar/^{40}Ar (×10^{-3})	^{37}Ar/^{40}Ar (×10^{-3})	^{38}Ar/^{40}Ar (×10^{-3})	^{39}Ar/^{40}Ar (×10^{-3})	^{40}Ar*/^{39}Ar*	Age (Ma)
600	24.9	2.441 ±0.106	209.9 ±8.8	33.40 ±1.39	15.76 ±0.70	64.00 ±2.84	2285 ±59
700	71.3	1.121 ±0.078	400.4 ±25.2	22.18 ±1.41	16.21 ±1.00	63.77 ±3.92	2280 ±80
800	128	0.6597 ±0.0476	323.5 ±4.0	3.607 ±0.098	8.671 ±0.112	119.0 ±1.5	3152 ±23
900	194	0.5042 ±0.0270	274.5 ±3.1	1.618 ±0.054	8.184 ±0.102	125.6 ±1.6	3233 ±23
1000	452	0.3562 ±0.0085	316.4 ±1.4	1.723 ±0.041	8.030 ±0.090	128.6 ±1.4	3268 ±21
1100	245	0.5880 ±0.0158	356.9 ±7.9	1.692 ±0.050	7.339 ±0.094	142.0 ±1.8	3419 ±23
1200	158	0.8860 ±0.0239	446.1 ±9.2	2.259 ±0.073	7.279 ±0.156	144.8 ±3.1	3449 ±35
1300	120	2.759 ±0.091	123.4 ±4.1	6.172 ±0.223	7.893 ±0.256	146.0 ±4.7	3462 ±51
1600	172	3.904 ±0.135	155.5 ±5.1	6.839 ±0.260	7.315 ±0.240	166.6 ±5.5	3667 ±53
Total	1565.2	1.131	301.0	4.263	8.329	127.1	3251

1) All tabulated data have been corrected for the blanks including the background in the mass spectrometer plus the sample inlet system and for the radioactive decay of ^{37}Ar between neutron irradiation and Ar analysis, but do not include other corrections.

2) ^{40}Ar*/^{39}Ar* indicates a ratio of the radiogenic ^{40}Ar from the decay of ^{40}K (≡^{40}Ar*) to the K-derived ^{39}Ar by a reaction of ^{39}K (n, p)^{39}Ar(≡^{39}Ar*).

rich phase such as glass to K-poor Ar-retentive phase such as olivine has been proposed (Huneke and Smith, 1976). This process requires the presence of relatively K-rich phase such as glass or fine-grained matrix whose Ar-retentivity is not so tight. In this context, it is interesting to note that two unequilibrated chondrites Tieschitz (H3) and ALH-77015 (L3) also show the large decrease in the apparent ^{40}Ar-^{39}Ar ages at higher temperatures (Turner *et al.*, 1978; Kaneoka, 1980). Compared with equilibrated chondrites, unequilibrated chondrites may be more likely to be affected by the recoil effects, because they seem to include more fine-grained phase than equilibrated chondrites. Thus, the age spectrum in Fig. 1 might have been caused by the recoil effect of ^{39}Ar in the sample and Ar loss. It is difficult to say definitely whether the maximum ^{40}Ar-^{39}Ar age in the intermediate temperature fraction might have been affected by the above-mentioned effect or it still keeps the age which corresponds to some gelogical event.

On the other hand, Y-75258 (LL6) shows a plateau age of 4377±14 Ma for 900–1300°C fractions which include about 61% of released ^{39}Ar. At the highest tempera-

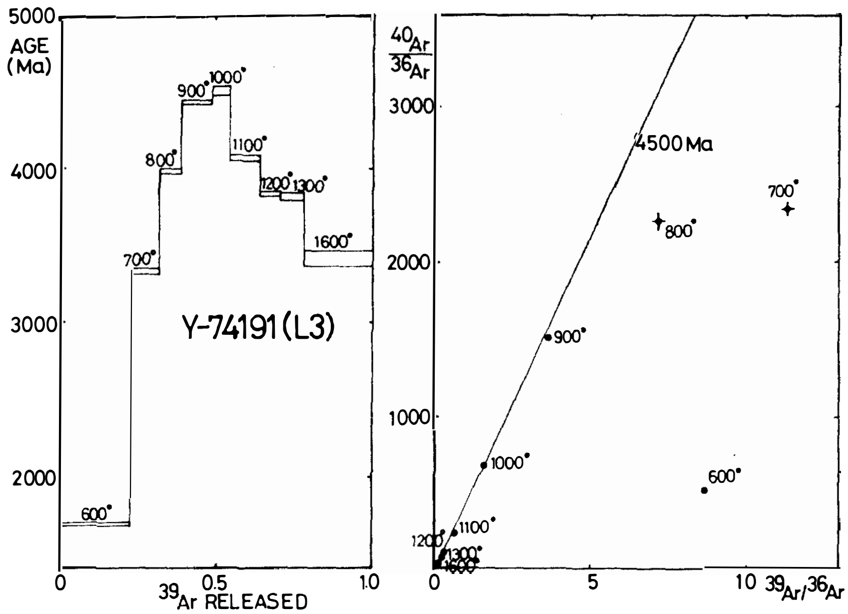

Fig. 1. The ^{40}Ar-^{39}Ar age spectrum and the $^{40}Ar/^{36}Ar$–$^{39}Ar/^{36}Ar$ plot for Y-74191 (L3). The numerical figure at each column represents the degassing temperature in °C. The uncertainty in each value corresponds to 1σ. A reference isochron of 4500 Ma is drawn in the $^{40}Ar/^{36}Ar$–$^{39}Ar/^{36}Ar$ plot, where the isochron goes through the zero point.

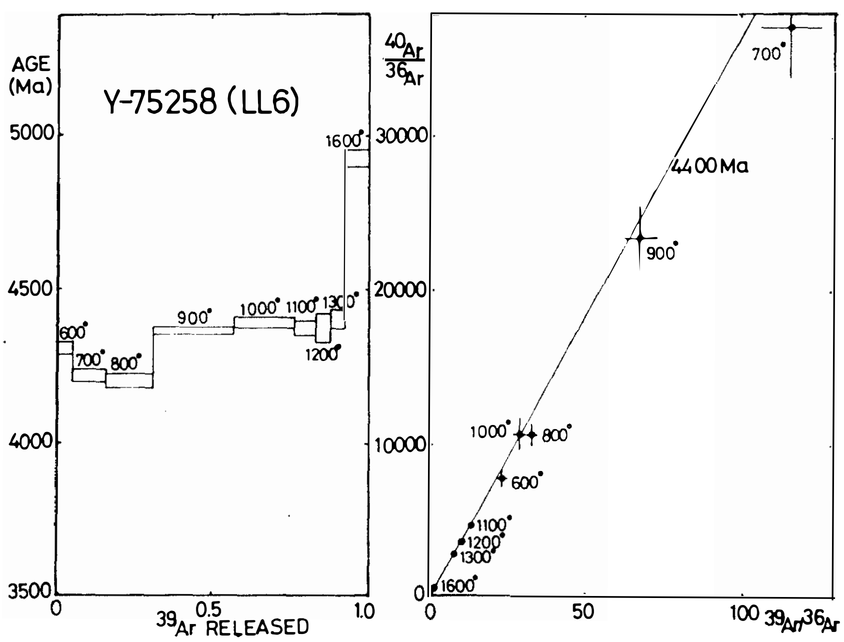

Fig. 2. The ^{40}Ar-^{39}Ar age spectrum and the $^{40}Ar/^{36}Ar$–$^{39}Ar/^{36}Ar$ plot for Y-75258 (LL6). In the right figure, a reference isochron of 4400 Ma is drawn.

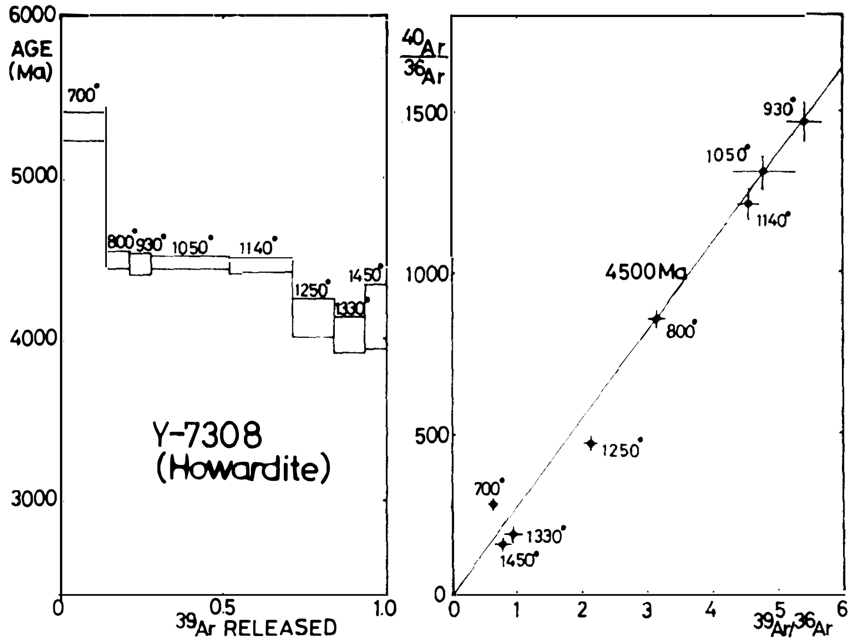

Fig. 3. The ^{40}Ar-^{39}Ar age spectrum and the $^{40}Ar/^{36}Ar$–$^{39}Ar/^{36}Ar$ plot for Y-7308 (howardite). In the right figure, the isochron is drawn as a reference which goes through the zero point. The 700°C fraction may include atmospheric contamination.

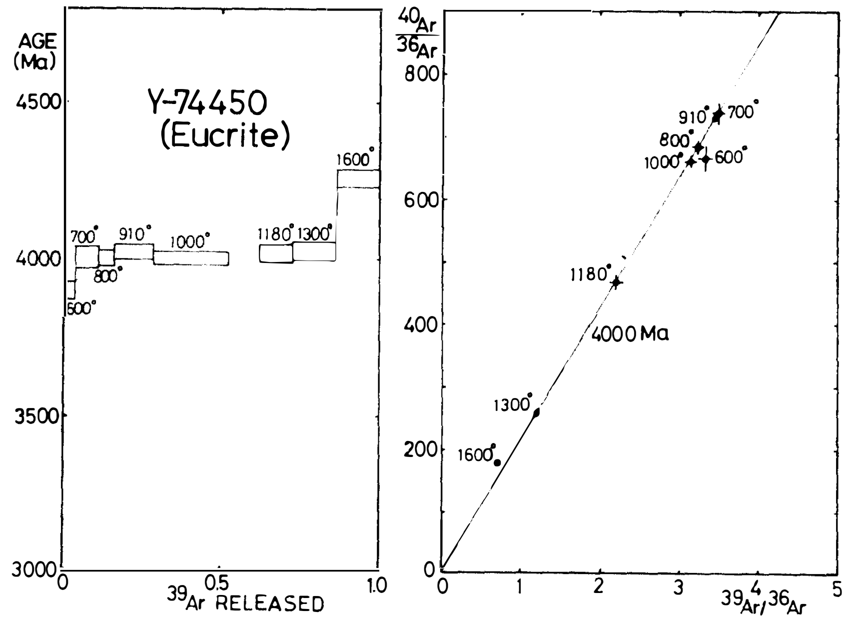

Fig. 4. The ^{40}Ar-^{39}Ar age spectrum and the $^{40}Ar/^{36}Ar$–$^{39}Ar/^{36}Ar$ plot for Y-74450 (eucrite). The 1100°C fraction was lost, but assigned to be 10% of released ^{39}Ar. A reference isochron of 4000 Ma is drawn in the right figure.

ture, however, the apparent ^{40}Ar-^{39}Ar age exceeds 4900 Ma, which has probably been caused by some artifacts such as insufficient corrections of blank and/or neutron produced interference Ar isotopes. The total ^{40}Ar-^{39}Ar age for this meteorite is about 4400 Ma, which implies that radiogenic ^{40}Ar loss is small for this sample. On the other hand, TAKAOKA and NAGAO (1980b) reported a K-Ar age of about 3000 Ma for this meteorite, which is much younger than the total ^{40}Ar-^{39}Ar age. Such a difference may be attributed to sample heterogeneity with respect to both the Ar retentivity and the K content.

As shown in Fig. 3, Y-7308 (howardite) seems to show an inversed staircase pattern with lower ^{40}Ar-^{39}Ar ages at higher temperatures. Such a pattern may be interpreted as the result of redistribution of radiogenic ^{40}Ar in a sample. Although we cannot preclude this possibility, we have an evidence which suggests that the apparent high ^{40}Ar-^{39}Ar age in the 700°C fraction might have been caused by the atmospheric contamination for this sample. In effect, at 700°C about 40% of ^{36}Ar was released from this sample. However, all the other samples in this study show the degassing rate of less than 5% for ^{36}Ar at the lowest degassing temperature. Hence, the effect of atmospheric contamination in the 700°C fraction is very likely. If we exclude the 700°C fraction, the total ^{40}Ar-^{39}Ar age of Y-7308 becomes 4109 Ma instead of 4538 Ma. Furthermore, 800–1140°C fractions seem to indicate a plateau age of 4480±30 Ma covering about 57% of the released ^{39}Ar. If this is the case, the result seems to be a little different from that repotred by BALACESCU and WÄNKE (1977), who recorded the

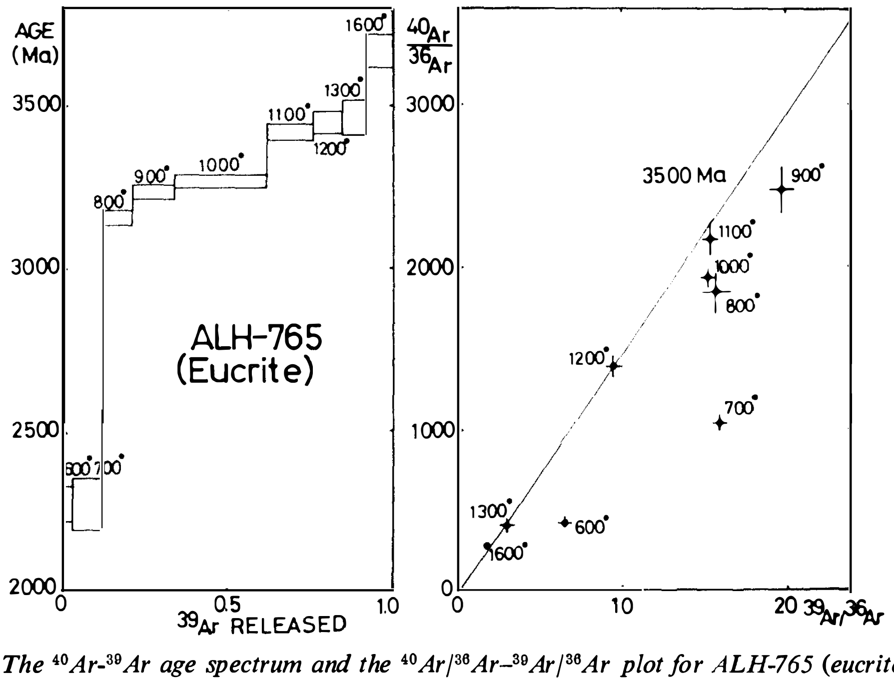

Fig. 5. The ^{40}Ar-^{39}Ar age spectrum and the $^{40}Ar/^{36}Ar$–$^{39}Ar/^{36}Ar$ plot for ALH-765 (eucrite). The line of 3500 Ma is a reference isochron in the right figure.

minimum and the maximum ^{40}Ar-^{39}Ar ages for Y-7308 as 3980 Ma and 4540 Ma, respectively, but with no plateau age. Based on the present data, however, we favor an opinion that the plateau age is meaningful.

Y-74450 (eucrite) also shows a plateau age of 4012±22 Ma for 700–1300°C fractions. Unfortunately, the 1100°C fraction was lost from the line due to insufficient experimental procedure. Judging from the results of 1000 and 1180°C fractions, however, the 1100°C fraction would be expected to show a ^{40}Ar-^{39}Ar age of about 4000 Ma. The released fraction of ^{39}Ar has been assigned to be 10% for the 1100°C fraction. At the highest degassing temperature (1600°C), the ^{40}Ar-^{39}Ar age increases up to 4260 Ma. For this sample, BALACESCU and WÄNKE (1977) got almost a similar plateau age (4030 Ma) to the present one, but with a different maximum ^{40}Ar-^{39}Ar age of 4530 Ma.

As shown in Fig. 5, ALH-765 (eucrite) shows a typical staircase pattern with no definite plateau. The apparent ^{40}Ar-^{39}Ar age increases from about 2300 Ma to about 3700 Ma gradually. Although 1100–1300°C fractions seem to show a plateau-like age of about 3400 Ma, it covers only 30% of the released ^{39}Ar. Hence, it is not clear whether the value corresponds to some chronological event or not. The total ^{40}Ar-^{39}Ar age for this sample is about 3300 Ma, indicating a relatively large amount of radiogenic ^{40}Ar loss.

4.2. K and Ca concentrations

For each sample, we can estimate its K and Ca contents by comparing the total amounts of K-derived ^{39}Ar and Ca-derived ^{37}Ar of a sample with those of the standard. The results are summarized in Table 2, together with the ^{40}Ar-^{39}Ar ages. It has been revealed that the relationship,

$$K/Ca = (0.48 \pm 0.10)\ {}^{39}Ar^{*}/{}^{37}Ar\ ,$$

is maintained for the present samples.

For all samples studied here, the K and Ca contents were chemically determined and reported. For Y-74191, the K and Ca contents were reported to be 0.108% and 1.6%, respectively (YANAI, 1979). Compared with them, the present result seems to be somewhat lower, especially for Ca. Considering the uncertainty in the absolute amount of Ar, however, the difference is still within the range of uncertainty. For Y-75258, the reported K and Ca contents are 0.066% and 1.6%, respectively (YANAI, 1979). The present results agree with them within the experimental uncertainty. For Y-7308, Ca is reported to be 3.0% (YANAI *et al.*, 1978). However, the reported K content in this sample is different by two groups. According to YAGI *et al.* (1978), its K content was determined to be 0.05%, whereas BALACESCU and WÄNKE (1977) reported it to be 0.007%. As shown in Table 2, the present result on the Ca content agrees with the reported value and the estimated K content is closer to that reported by BALACESCU and WÄNKE (1977). For Y-74450, the K and Ca con-

Table 2. Summary of ^{40}Ar-^{39}Ar ages of meteorites from Antarctica.

Sample	[Ca]* (%)	[K]* (%)	^{40}Ar-^{39}Ar age (Ma)** Total	Mini-mum	Maxi-mum	Plateau	Plateau range
Y-74191 (L3)	1.1	0.093	3558	1692 ±10	4506 ±31	—	—
Y-75258 (LL6)	1.3	0.074	4381	4201 ±23	4927 ±27	4377 ±14	900–1300°C (61.1% of released ^{39}Ar)
Y-7308 (Howardite)	2.6	0.011	4538	4014 ±125	5337 ±94	4480 ±30	800–1140°C (57.4% of released ^{39}Ar)
Y-74450 (Eucrite)	6.9<	0.048<	4045	3899 ±26	4260 ±30	4012 ±22	700–1300°C (72.4% of released ^{39}Ar***)
ALH-765 (Eucrite)	7.0	0.049	3251	2280 ±80	3667 ±53	(3438 ±22)	1100–1300°C (29.6% of released ^{39}Ar)

* K- and Ca-contents were estimated on the basis of the total amounts of ^{39}Ar and ^{37}Ar by comparing those of the standard sample MMhb-1. About 30% uncertainty is included in each value.

** ^{40}Ar-^{39}Ar age was calculated by using the following constants for ^{40}K. $\lambda_e=0.581\times10^{-10}$ yr^{-1}, $\lambda_\beta=4.926\times10^{-10}$ yr^{-1}, $^{40}K/K=1.167\times10^{-4}$ (STEIGER and JÄGER, 1977). Uncertainties in the ages correspond to 1σ.

*** The lost fraction (1100°C) for Y-74450 is assumed to cover 10% of the released ^{39}Ar, but not included in the plateau range to calculated the plateau age.

tents were reported to be 0.05% and 8.3%, respectively (YANAI, 1979). Furthermore, BALACESCU and WÄNKE (1977) reported its K content to be 0.045%. Even if we take Ar loss in a temperature fraction into account, the present results are not unreasonable. The reported K and Ca contents for ALH-765 are 0.05% and 7.9%, respectively (YANAI, 1979), which agree with the present results within the experimental uncertainty.

From these comparisons, we may say that the estimated K and Ca contents are reasonable within the experimental uncertainty.

5. Discussion

Among the present 5 samples, only 3 samples show plateau ages, which might have been related to some events on the parent body of each meteorite.

The ^{40}Ar-^{39}Ar age of 4377 Ma for Y-75258 (LL6) is slightly younger than those determined for other LL chondrites. In a previous paper (KANEOKA, 1980), we have examined the relationship between the apparent ^{40}Ar-^{39}Ar age and the petrologic type of each unshocked chondrite in each group and pointed out that there seems to be a relationship between them at least for L chondrites. If we include Y-75258 in the same diagram, it means a relatively young ^{40}Ar-^{39}Ar age with equilibrated properties. This trend may not contradict a direction expected for the LL-chondrite group if the same relationship as the L-chondrite group holds.

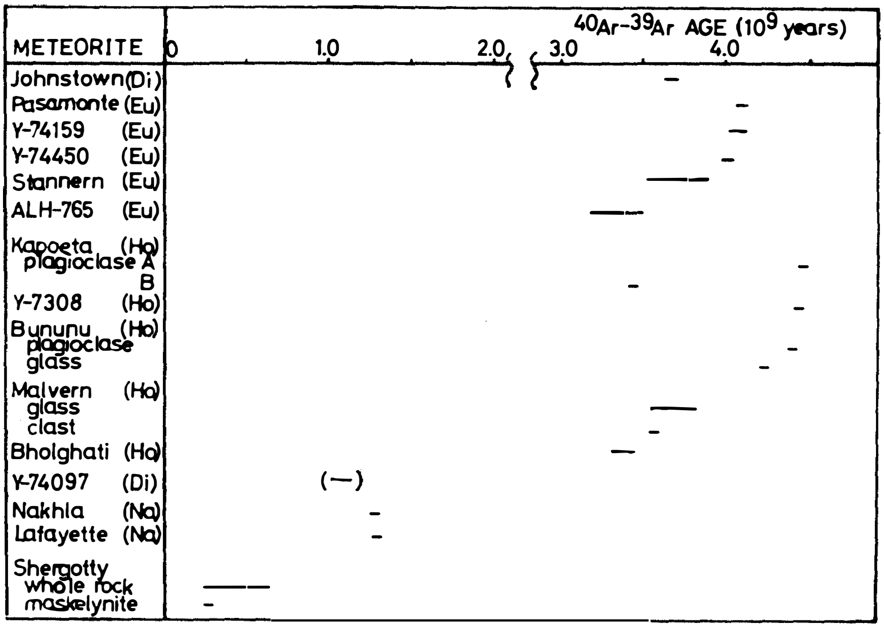

Fig. 6. Summary of ^{40}Ar-^{39}Ar ages of achondrites. Note that they show variable ^{40}Ar-^{39}Ar ages indicating later events on the parent body (or bodies) of these meteorites.

Compared with chondrite groups, the observed age distribution for achondrites is much more variable. As far as the ^{40}Ar-^{39}Ar ages are concerned, they are generally younger than those determined for unshocked ordinary chondrites. This situation is shown in Fig. 6, where the ^{40}Ar-^{39}Ar ages of achondrites of different groups are summarized. Since the ^{40}Ar-^{39}Ar ages are more sensitive to later thermal events than the other dating methods, they can show later events which might have occurred on the parent body (or bodies) of achondrites.

As shown in Fig. 6, among achondrites relatively old ^{40}Ar-^{39}Ar ages are found in howardites. Although the ^{40}Ar-^{39}Ar age of Y-7308 shows a relatively old value, similar ages have been found in plagioclase of Kapoeta and Bununu (RAJAN *et al.*, 1975, 1979). It may be worthwhile to note that among achondrite groups some howardites still keep relatively old ^{40}Ar-^{39}Ar ages of more than 4400 Ma. On the other hand, the ^{40}Ar-^{39}Ar ages of eucrites show generally later events such as about 4000 Ma. On the basis of petrography and mineralogy, it has been suggested that Pasamonte, Y-74159 and Y-74450 have common features and might have a common origin (TAKEDA *et al.*, 1978). The result of the ^{40}Ar-^{39}Ar analyses for these eucrites supports the above conjecture. Pasamonte shows a plateau age of about 4050 Ma at the intermediate temperatures (PODOSEK and HUNEKE, 1973), whereas Y-74159 indicates a similar pattern with a plateau age of 4075 Ma (KANEOKA *et al.*, 1979). In the present study, Y-74450 also demonstrates a plateau age of about 4010 Ma at the intermediate temperatures. These results agree with one another within the experimental uncertainty and suggest that they were derived from a similar portion of the common parent body. Other eucrites show more variable ^{40}Ar-^{39}Ar ages and indicate later events.

Among achondrite groups, there are very strange groups such as nakhlites and shergottites which show much later events of less than 1500 Ma on their parent body (or bodies).

These results on the ^{40}Ar-^{39}Ar ages of achondrite groups imply that the parent body (or bodies) of achondrites might have been located in some spaces where later events more frequently affected the surface of the parent body (or bodies) of the achondrites compared with those of ordinary chondrites. More systematic investigation is demanded to clarify the relationships between the time span of such events and the meteorite groups.

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