^{40}Ar–^{39}Ar AGES OF L AND LL CHONDRITES FROM ALLAN HILLS, ANTARCTICA: ALHA77015, 77214 AND 77304

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Abstract: ^{40}Ar–^{39}Ar ages have been determined for three chondrites (ALHA 77015, 77214, 77304) from Allan Hills, Antarctica.

Although younger ages have been observed at lower and higher temperatures for ALHA77015 (L3), the intermediate plateau-like age indicates a value of $4514 \pm 48 (1\sigma)$ Ma, though the plateau range is relatively narrow about 27% of the total ^{39}Ar.

ALHA77304 (LL3) shows a typical plateau age of 4503 ± 52 Ma at higher temperatures, covering about 46% of the total ^{39}Ar.

Seriously weathered ALHA77214 (L or LL) exhibits a typical stair-case age pattern, increasing from about 1600 Ma up to about 4450 Ma.

When coupled with reported data on other chondrites, there may be a rough correlation between the ^{40}Ar–^{39}Ar age and the degree of metamorphism defined from their petrologic type for unshocked L chondrites. However, such a trend is not clear for H and LL chondrites and a more systematic survey is required to settle the problem.

1. Introduction

Following the classification of chondrites by VAN SCHMUS and WOOD (1967), several attempts have been made to find other characteristics related to petrologic type (*e.g.* ZÄHRINGER, 1966). Most ordinary chondrites are relatively equilibrated (petrologic types 5 and 6); the unequilibrated ones (petrologic type 3) are less abundant. If the petrologic grade reflects thermal history of the parent body, it may also be paralleled by the age. Since a total gas retention age reflects only an averaged value corresponding to several secondary disturbances, it is not an appropriate way to address the problem. Rb-Sr, Pb-Pb and Sm-Nd methods are applicable, but each systematics may not always behave in the same manner, reflecting the different diffusivity of each element at moderate temperature. In this respect, Ar is expected to be more sensitive to thermal effects than the solid elements like Sr, Pb and Nd. Hence, the ^{40}Ar-^{39}Ar method is considered to be suitable to monitor the relationships between petrologic type and age of chondrites.

So far, a number of investigators have reported ^{40}Ar–^{39}Ar ages for ordinary chondrites (*e.g.* TURNER, 1968, 1969; PODOSEK, 1971, 1972; BOGARD *et al.*, 1976;

TURNER *et al.*, 1978). Among them, however, only unshocked chondrites are suitable for the present purpose, because it is known that the main shock probably occurred long after the formation of chondrites (*e.g.* BOGARD *et al.*, 1976). If we limit consideration to the unshocked chondrites, the number of chondrites where ^{40}Ar–^{39}Ar ages are reported does not exceed 30. Among them, to my knowledge Tieschitz (H3) is the only sample which belongs to the least equilibrated petrologic type 3 (TURNER *et al.*, 1978). Hence, more data are required on the ^{40}Ar–^{39}Ar age of unequilibrated chondrites.

Among meteorites recovered from Antarctica, many unequilibrated chondrites (petrologic type 3) are found. One L3 and one LL3 chondrite were selected for ^{40}Ar–^{39}Ar analyses to study the problem mentioned above. One weathered chondrite was also studied to check the effect of weathering on the age spectrum.

2. Samples

Two unequilibrated ordinary chondrites, ALHA77015 (L3) and ALHA77304 (LL3), were selected to investigated whether they retain a relatively primitive record in the ages. Both were among the least weathered meteorites found in Allan Hills, Antarctica. ALHA77214 (L or LL) is, however, seriously weathered and has a rusty surface; it was analyzed to examine the effect of such weathering on its age spectrum.

These meteorites were prepared as blocks ranging from about a few mm to less than 9 mm in size. The blocks with fusion clasts were removed from samples for analysis. However, they were not powdered in order to avoid Ar loss and/or atmospheric contamination during the procedure.

3. Experimental Procedures

Since most of the experimental procedures are similar to those reported in a previous paper (KANEOKA *et al.*, 1979), only the essential and modified parts are described here.

Each sample (about 0.6–0.9 g) was wrapped in Al-foil and stacked in a quartz ampoule (10 mm $\times$ 70 mm) paired with two standard samples, one at each side. Remelted CaF_2 and K_2SO_4 were also included to monitor Ca- and K-derived interference correction factors. The standard sample MMhb-1 (hornblende, K–Ar age: 519.5$\pm$2.5 Ma) (ALEXANDER *et al.*, 1978) was used as the age monitor.

Samples were irradiated in the JMTR reactor of the Tohoku University receiving total fast neutron fluence of about 10^{18} nvt/cm^2. After cooling for about one month, Ar was extracted in a conventional extraction and purification system. Samples were dropped from a sample holding arm into a Mo crucible by pushing an iron piece with a hand magnet. Each temperature was kept for 45 min and then the next step taken without cooling between steps. Blanks were taken before each sample analysis. Since the extraction and purification system is separated from the mass spectrometer, this may not directly correspond to a conventional blank. However, I believe that the application of this blank correction together with the background correction in the mass spectrometer and sample introduction system will approximate the true value of sample gases much better than no correction. Hence, the corrections mentioned above were applied for all present data. Blank has almost atmospheric Ar composition, but the Ar peaks ranging from m/e=37 to 40 appear as memories of the previous analyses in the background of the mass spectrometer. Blank levels are $(2\text{–}3)\times 10^{-8}$ ccSTP ^{40}Ar below 1300°C, but increase up to $(1\text{–}3)\times 10^{-7}$ ccSTP at the highest temperature (~1650°C) for 45 min.

Ar isotopes were analyzed on a Reynolds type mass spectrometer with a Farady cage. 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. About 30% uncertainty is assigned on the basis of reproducibility. Mass discrimination among Ar isotopes were estimated to be 0.44% per atomic mass unit favoring heavier isotopes by measuring atmospheric Ar. The following correction factors were used for Ca- and K-derived interference, as determined by analysis of the CaF_2 and K_2SO_4:

$(^{39}Ar/^{37}Ar)_{Ca}=(11.6\pm 0.8)\times 10^{-4}$, $(^{38}Ar/^{37}Ar)_{Ca}=(3.3\pm 0.04)\times 10^{-3}$,
$(^{36}Ar/^{37}Ar)_{Ca}=(2.1\pm 1.6)\times 10^{-4}$, $(^{40}Ar/^{39}Ar)_{K}=(8.1\pm 1.0)\times 10^{-2}$,
and $(^{38}Ar/^{39}Ar)_{K}=(6.1\pm 0.03)\times 10^{-2}$.

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. When the $^{38}Ar/^{36}Ar$ ratio exceeds 1.5, the excess ^{38}Ar is presumed due to ^{37}Cl $(n, \gamma\beta)$ ^{38}Ar, and the remainder spallogenic. However, this assumption seems to be not always appropriate, as discussed later. Cl-derived ^{38}Ar can be present even if the $^{38}Ar/^{36}Ar$ does not exceed 1.5 and we cannot exclude this possibility for the present samples. Hence, no exposure ages are reported in this paper.

4. Results

The observed Ar isotopic ratios and the amount of ^{40}Ar for each temperature fraction are shown in Table 1. Blank and background in the mass spectrometer plus gas introduction system were subtracted. The radioactive decay of ^{37}Ar between irradiation and analysis was also corrected, but the data except to the $^{40}Ar^*/^{39}Ar^*$ ratio represent those before other corrections were applied. All contributions other than the decay of ^{40}K or ^{39}K (n, p) ^{39}Ar were corrected to obtain $^{40}Ar^*/^{39}Ar^*$ ratios,

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

ALHA77015 (L 3) 0.8879 g, $J=0.003597\pm0.000035$

T(°C)	[^{40}Ar] $\times10^{-8}$ ccSTP/g	^{36}Ar/^{40}Ar ($\times10^{-4}$)	^{37}Ar/^{40}Ar ($\times10^{-4}$)	^{38}Ar/^{40}Ar ($\times10^{-4}$)	^{39}Ar/^{40}Ar ($\times10^{-4}$)	^{40}Ar*/^{39}Ar*	Age (Ma)
700	571	17.36 ± 0.71	12.46 ± 0.39	9.097 ± 0.257	5.763 ±0.194	1739 ± 59	3575 ± 55
800	609	10.80 ± 0.16	9.873 ± 0.064	27.83 ± 0.23	4.277 ±0.263	2344 ±144	4048 ±100
900	383	18.08 ± 0.21	8.709 ± 0.094	13.26 ± 0.27	3.169 ±0.166	3163 ±166	4539 ± 88
1000	377	101.4 ± 1.2	14.98 ± 0.46	27.53 ± 0.29	3.266 ±0.160	3062 ±150	4485 ± 83
1100	209	357.9 ± 9.8	22.74 ± 0.80	75.58 ± 1.81	3.178 ±0.225	3115 ±220	4514 ±118
1200	235	671.1 ± 18.1	37.25 ± 1.29	137.7 ± 2.8	3.126 ±0.125	3136 ±125	4524 ± 68
1300	372	744.3 ± 12.9	66.57 ± 1.39	140.6 ± 2.3	4.687 ±0.198	2089 ± 88	3864 ± 69
1450	642	450.3 ± 9.0	116.8 ± 1.6	87.90 ± 2.22	4.236 ±0.305	2383 ±172	4075 ±118
1650	40.1	570.7 ±145.6	206.6 ±54.3	111.0 ±28.4	7.462 ±2.294	1345 ±413	3183 ±459
Total	3438.1	256.8	41.79	57.85	4.218	2368	4065

ALHA77304 (LL 3) 0.9442 g, $J=0.003515\pm0.000034$

T(°C)	[^{40}Ar] $\times10^{-8}$ ccSTP/g	^{36}Ar/^{40}Ar ($\times10^{-4}$)	^{37}Ar/^{40}Ar ($\times10^{-4}$)	^{38}Ar/^{40}Ar ($\times10^{-4}$)	^{39}Ar/^{40}Ar ($\times10^{-4}$)	^{40}Ar*/^{39}Ar*	Age (Ma)
700	51.4	41.43 ± 3.00	86.81 ± 7.54	69.93 ± 4.99	76.05 ±6.02	131.5 ± 10.4	685.5 ± 45.4
800	232	36.63 ± 0.56	36.75 ± 0.66	27.66 ± 0.54	20.23 ±0.86	494.6 ± 21.0	1817 ± 50
900	—	—	—	—	—	—	—
1000	265	31.28 ± 0.55	20.29 ± 0.44	14.65 ± 0.35	3.713 ±0.321	2708 ±234	4245 ±142
1100	345	15.71 ± 0.29	32.94 ± 0.61	11.49 ± 0.40	3.191 ±0.217	3170 ±216	4504 ±114
1200	956	7.208 ± 0.089	19.37 ± 0.31	5.099 ± 0.086	3.166 ±0.171	3179 ±176	4509 ± 93
1300	413	15.89 ± 0.25	51.72 ± 0.96	13.37 ± 0.33	3.150 ±0.170	3235 ±173	4538 ± 90
1450	697	34.48 ± 0.98	91.29 ± 1.48	18.95 ± 0.64	3.258 ±0.137	3166 ±141	4502 ± 75
1650	792	25.98 ± 0.63	36.61 ± 0.82	7.407 ± 0.274	3.255 ±0.281	3107 ±268	4471 ±143
Total	>3751.4	21.97	43.25	12.62	5.297	1904	3680

Table 1 (Continued).

ALHA77214 (L or LL) 0.5550 g, $J = 0.003436 \pm 0.000033$

T(°C)	[^{40}Ar] $\times 10^{-8}$ ccSTP/g	^{36}Ar/^{40}Ar ($\times 10^{-4}$)	^{37}Ar/^{40}Ar ($\times 10^{-4}$)	^{38}Ar/^{40}Ar ($\times 10^{-4}$)	^{39}Ar/^{40}Ar ($\times 10^{-4}$)	^{40}Ar*/^{39}Ar*	Age (Ma)
700	140	35.38 ± 1.76	19.04 ± 1.10	41.49 ± 2.04	23.68 ±3.38	422.0 ± 60.2	1617 ±153
800	858	8.531 ± 0.212	11.11 ± 0.28	21.17 ± 0.61	10.32 ±0.50	969.9 ± 47.9	2645 ± 76
900	634	49.42 ± 0.46	5.895 ± 0.048	10.70 ± 0.30	7.961 ±0·620	1254 ± 98	3012 ±115
1000	282	292.7 ± 6.0	17.38 ± 0.37	55.91 ± 1.49	6.034 ±0.402	1638 ±109	3412 ±103
1100	234	932.1 ± 24.8	48.54 ± 1.48	175.9 ± 6.5	3.455 ±0.305	2805 ±248	4266 ±145
1200	200	1263 ± 46	79.46 ± 4.63	242.3 ± 7.8	3.762 ±0.380	2553 ±258	4113 ±164
1450	441	547.7 ± 28.2	109.4 ± 5.3	102.9 ± 5.4	3.363 ±0.420	3005 ±375	4379 ±206
1650	307	380.8 ± 35.5	143.2 ±14.1	73.26 ± 6.71	3.288 ±0.311	3142 ±297	4452 ±157
Total	3096	308.5	45.32	65.88	7.418	1336	3105

1) All tabulated data have been corrected for the blanks and radioactive decay of ^{37}Ar between irradiation and 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 ($\equiv$^{40}Ar*) to the K-derived ^{39}Ar by a reaction of ^{39}K$(n,p)^{39}$Ar ($\equiv$^{39}Ar*).

from which ^{40}Ar–^{39}Ar ages shown in the last column of Table 1 were calculated. The assigned uncertainties in the Ar isotopic ratios are statistical (1σ).

4.1. ^{40}*Ar*/^{39}*Ar ages*

In Figs. 1–3, the age spectra of the present samples are shown together with the ^{40}Ar/^{36}Ar–^{39}Ar/^{36}Ar plots. The calculated age in each temperature fraction is included in the last column of Table 1.

The sample ALHA77015 (L3) shows a rather peculiar age spectrum which indicates lower ^{40}Ar–^{39}Ar ages at lower and higher temperatures than the intermediate temperature fractions. The intermediate temperature fractions (900–1200°C) seem to show a plateau-like pattern, corresponding to the age of 4515±48 Ma, though the fractions cover only 27% of the total ^{39}Ar released. The maximum ^{40}Ar–^{39}Ar age of 4539±88 Ma is observed in the 900°C fraction. The total ^{40}Ar–^{39}Ar age is 4065 Ma, which suggests the probable radiogenic ^{40}Ar loss from the sample. The apparent low ^{40}Ar–^{39}Ar ages in the low temperature fractions can be explained as the partial radiogenic ^{40}Ar loss, but those in the high temperature fractions require other explanations. Decreases in the apparent ^{40}Ar–^{39}Ar age at higher temperatures

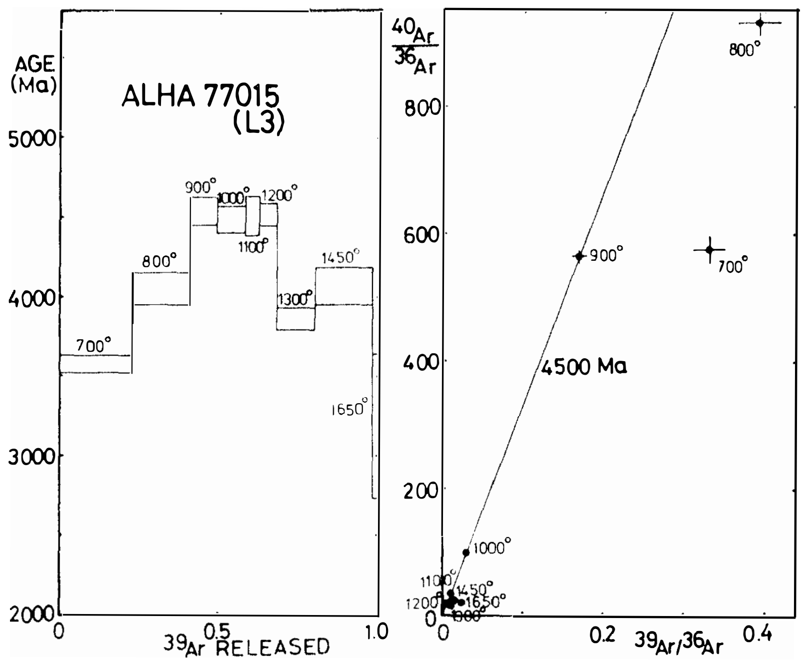

Fig. 1. The ^{40}Ar–^{39}Ar age diagram and the $^{40}Ar/^{36}Ar$–$^{39}Ar/^{36}Ar$ plot for ALHA77015 (L3). The numerical figure at each column indicates the degassing temperature in °C. The uncertainties represent 1σ. In the $^{40}Ar/^{36}Ar$–$^{39}Ar/^{36}Ar$ plot, a reference isochron of 4500 Ma is drawn which goes through the zero point.

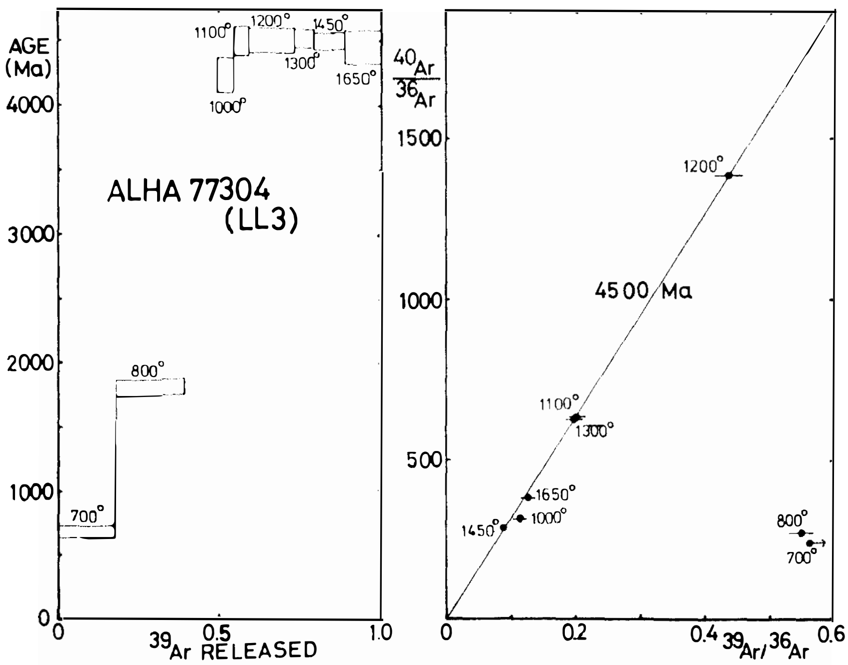

Fig. 2. The ^{40}Ar–^{39}Ar age diagram and the $^{40}Ar/^{36}Ar$–$^{39}Ar/^{36}Ar$ plot for ALHA77304 (LL3). The 900°C fraction was lost and 10% loss of ^{39}Ar is assumed in the age diagram. In the right figure, a reference isochron of 4500 Ma is drawn which goes through the zero point.

have often been observed in meteorites (*e.g.* TURNER and CADOGAN, 1974; TURNER *et al.*, 1978) and lunar samples (*e.g.* TURNER *et al.*, 1971; KIRSTEN *et al.*, 1972). To explain this phenomenon, ^{39}Ar recoil from fine-grained K-bearing phases into low-K retentive phases such as olivine or pyroxene has been suggested (TURNER and CADOGAN, 1974; HUNEKE and SMITH, 1976). In this case, it is assumed that the high apparent ages at lower temperatures are raised and the high temperature ages are lowered by the recoiling of ^{39}Ar in a closed system. If this is the case for the sample ALHA77015, an integrated ^{40}Ar–^{39}Ar age of 4228±66 Ma for the fractions from 900°C to 1650°C may be more significant than the apparent plateau age of 4515± 48 Ma. However, the plateau-like age is much closer to the plateau or maximum ages observed for the other two samples in this study than is the integrated age described above. Furthermore, the four intermediate temperature fractions (900–1200°C) show almost identical ^{40}Ar–^{39}Ar ages. For these reasons, the plateau age seems more significant than the integrated age (≥900°C) for this sample. To some extent, the decrease in the ^{40}Ar–^{39}Ar age at higher temperatures might be due to blank+background corrections, but it is difficult to attribute the whole phenomenon to this only. Hence, the meaning of the ^{40}Ar–^{39}Ar age of this sample is less clear than those of the other two samples.

For the sample ALHA77304 (LL3), the 900°C fraction was lost due to experimental error. However, the remaining fractions show a rather well-defined plateau

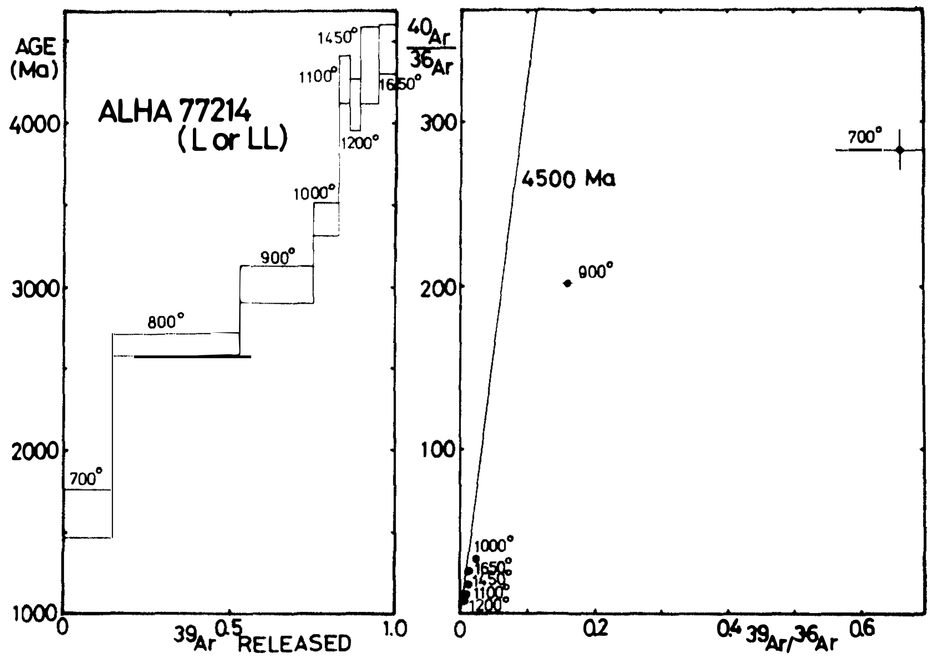

Fig. 3. The ^{40}Ar–^{39}Ar age diagram and the $^{40}Ar/^{36}Ar$–$^{39}Ar/^{36}Ar$ plot for ALHA77214 (L or LL). The line of 4500 Ma in the right figure is drawn as a reference.

age of 4503±52 Ma for 1100–1650°C fractions. Assuming 10% of ^{39}Ar release in the 900°C fraction, the plateau range covers about 46% of total ^{39}Ar. As shown in Fig. 2, this sample shows partial radiogenic ^{40}Ar loss in lower temperature fractions. A relatively low total ^{40}Ar–^{39}Ar age of 3680 Ma reflects this effect.

In Fig. 3, the result for the sample ALHA77214 (L or LL) is shown; this is a typical stair-case pattern age spectrum. No definite plateau is observed. The total ^{40}Ar–^{39}Ar age for this sample is 3105 Ma, the youngest among the present three samples. The 1450°C and 1650°C fractions show, however, relatively high ^{40}Ar–^{39}Ar ages of about 4400 Ma. The rather steep increase of apparent ^{40}Ar–^{39}Ar age from the value of about 1600 Ma suggests that the radiogenic ^{40}Ar loss might have occurred rather recently. Furthermore, such a steep increase of ^{40}Ar–^{39}Ar age over 80% of ^{39}Ar released is not so common for meteorites and needs some intense effect on this sample. However, age spectra do not support the shock effect on this sample. Since this sample is strongly weathered, the Ar loss is probably attributable mainly to the weathering of the sample. Hence, the highest apparent ^{40}Ar–^{39}Ar age for

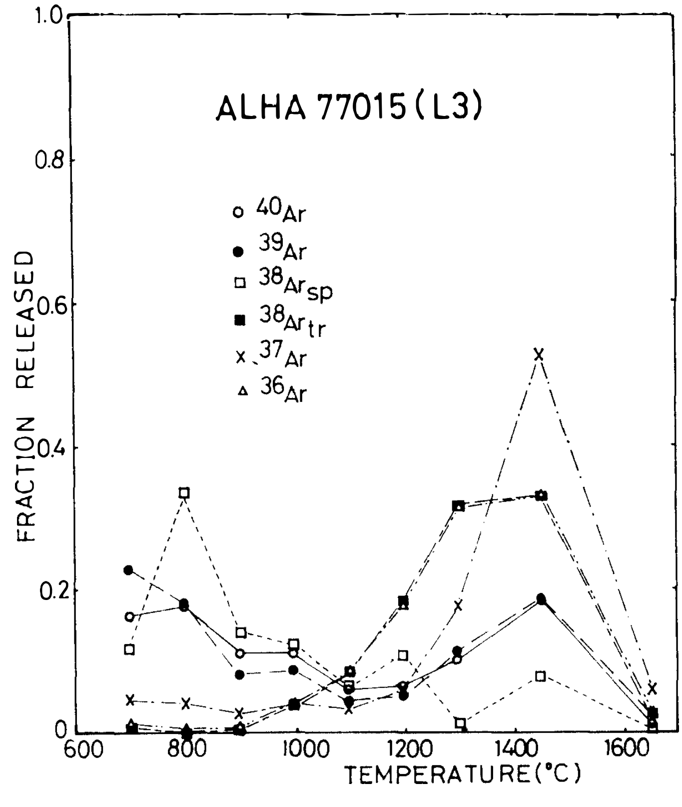

Fig. 4. The release patterns of Ar isotopes for ALHA77015. Note that ^{36}Ar correlates well with $^{38}Ar_{tr}$ and shows a quite different pattern from $^{38}Ar_{sp}$. Relatively high release of $^{38}Ar_{sp}$ at the lower temperatures suggests that those fractions may mostly include Cl-derived ^{38}Ar artificially produced by neutron irradiation.

this sample is closer to the time of thermal event for this sample and indicates the lower limit to the age of the event.

4.2. Release patterns of Ar isotopes

In Fig. 4, the release patterns of Ar isotopes for ALHA77015 are shown as an example to compare the different characteristics of degassed Ar of different origin. Clear correlations are observed between $^{38}Ar_{tr(trapped)}$ and ^{36}Ar, and between ^{40}Ar and ^{39}Ar. Ca-derived ^{37}Ar is mostly degassed at higher temperatures, especially in the 1450°C fraction. K-derived ^{39}Ar and ^{40}Ar which is mostly radiogenic derived from the decay of ^{40}K are degassed at lower and higher temperatures. The low temperature degassing components of both ^{39}Ar and ^{40}Ar were probably trapped in relatively loose sites such as grain boundaries and interstitials. The release pattern of $^{38}Ar_{sp(spallogenic)}$ is completely different from other Ar isotopes. As shown in Table 1, the $^{38}Ar/^{36}Ar$ ratio in the 800°C fraction exceeds 2.5 and clearly indicates the occurrence of Cl-derived ^{38}Ar in this fraction. Furthermore, apparent $^{38}Ar_{sp}$ is degassed mostly at lower temperatures. The most low temperature fractions of $^{38}Ar_{sp}$ are probably Cl-derived ^{38}Ar artificially produced in the reactor and not reflect the true spallogenic component. Only the high temperature fractions of $^{38}Ar_{sp}$ may indicate the net spallogenic component for this sample, but it is difficult to identify each component separately in each fraction.

4.3. K and Ca concentrations

By comparing the total amounts of K-derived ^{39}Ar and Ca-derived ^{37}Ar of a sample with those of the standard, we can estimate the K- and Ca-contents.

Based on the results of the standard sample MMhb-1, we have for the $^{39}K\,(n, p)$ ^{39}Ar reaction,

Table 2. Summary of ^{40}Ar–^{39}Ar ages of meteorites from Allan Hills, Antarctica.

Sample	[K] (%)*	[Ca] (%)*	^{40}Ar–^{39}Ar age (Ma)** Total	Minimum	Maximum	Plateau	Plateau range
ALHA77015 (L 3)	0.060	1.1	4065	3183 ±459	4539 ± 88	(4514 ±48)	900-1200°C (27% of released ^{39}Ar)
ALHA77304 (LL 3)	>0.080	>1.3	3680	685.5 ± 45.4	4538 ± 90	4503 ±52	1100-1650°C (46% of released ^{39}Ar)
ALHA77214 (L or LL)	0.093	1.1	3105	1617 ±153	4452 ±157	—	—

* K- and Ca-contents were estimated from the total amounts of ^{39}Ar and ^{37}Ar of samples 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. $\lambda_e = 0.581 \times 10^{-10}\,yr^{-1}$, $\lambda_\beta = 4.962 \times 10^{-10}\,yr^{-1}$, $^{40}K/K = 1.167 \times 10^{-4}$ (STEIGER and JÄGER, 1977). Uncertainties in the ages correspond to 1σ.

$^{39}Ar^*/K=(2.5\pm0.4)\times10^{-5}$ ccSTP/gK. Similarly, we obtain

$K/Ca=(0.51\pm0.11)$ $^{39}Ar^*/^{37}Ar$.

This coefficient is quite similar to that reported earlier (KANEOKA *et al.*, 1979), 0.54 ± 0.11.

By using these relationships, K- and Ca-contents were estimated for the present samples. The results are summarized in Table 2, together with the ^{40}Ar–^{39}Ar ages. As shown in Table 2, K-contents for present samples estimated range from 0.06 to 0.09%. Considering the 30% uncertainty, these values are compatible with reported values for L and LL chondrites (MASON, 1971). Ca-contents vary from 1.1 to 1.3%, which also agree with the reported values (MASON, 1971) within the experimental uncertainty. These results imply that the recovery of Ar gases from each sample was reasonable.

5. Discussion

The present results suggest that even the unequilibrated chondrites of petrologic

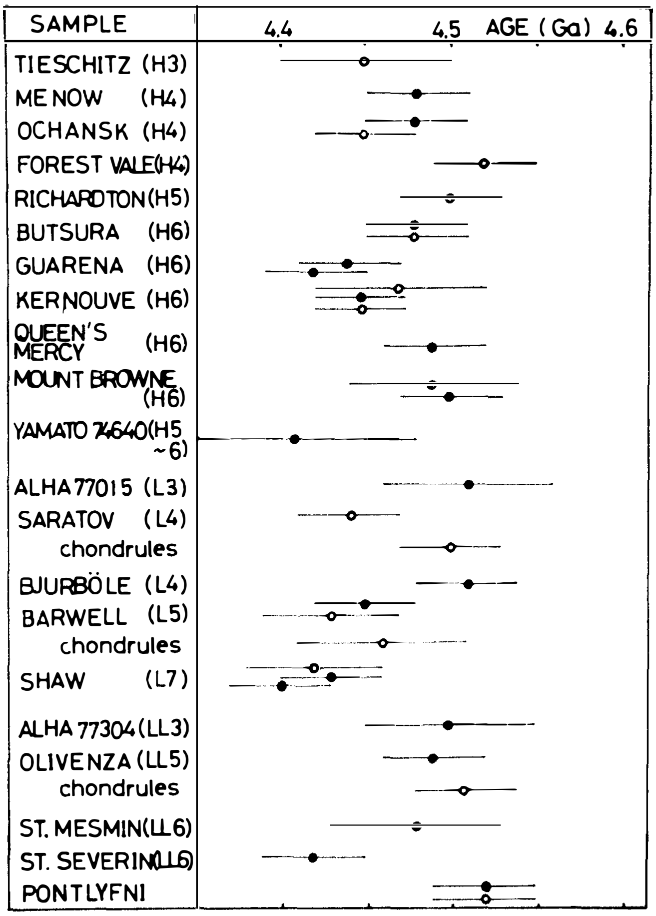

Fig. 5. ^{40}Ar–^{39}Ar ages of unshocked ordinary chondrites. Samples are arranged in the order of H, L and LL chondrites with the less equilibrated chondrite at the upper row. Closed symbol indicates a plateau ^{40}Ar–^{39}Ar age and open symbol a total ^{40}Ar–^{39}Ar age of a sample which shows no significant loss of radiogenic ^{40}Ar. The uncertainty indicates 1σ. In the L-chondrite group, there seems to be a correlation between the age and the petrologic type of a sample. Such a correlation is not clear for H- and LL-chondrite groups. Data sources: CADOGAN and TURNER (1975); KANEOKA et al. (1979); PODOSEK and HUNEKE (1973); TURNER et al. (1978) and present study.

type 3 show partial degassing of radiogenic ^{40}Ar to some extent. Compared with the results of equilibrated chondrites such as Yamato-74640 (H5–6) (KANEOKA *et al.*, 1979), the total ^{40}Ar–^{39}Ar ages seem to have no correlation with their petrologic types. This means that the total ^{40}Ar–^{39}Ar (and K-Ar) ages do not always reflect the degree of metamorphism, but include the effect of later disturbances such as weathering effects. This conjecture is compatible with the results reported by other investigators (*e.g.* TURNER *et al.*, 1978).

The ^{40}Ar–^{39}Ar plateau or plateau-like ages may correlate better with the petrologic type, since these ages are much less affected by later disturbances in comparison with total ^{40}Ar–^{39}Ar (and K-Ar) ages. The results are summarized in Fig. 5, where present results are included together with other meteorite results, most of which were obtained by TURNER *et al.* (1978). The result for Yamato-74640 (H5–6) (KANEOKA *et al.*, 1979) is also included.

As shown in Fig. 5, there seems to be a trend that unequilibrated chondrites show slightly older ^{40}Ar–^{39}Ar ages than equilibrated chondrites in the L-chondrite group. However, the trend is not clear in the H- and LL-chondrite groups. In these groups, the unequilibrated chondrites show relatively old ^{40}Ar–^{39}Ar ages, but some equilibrated chondrites also show similar old ages and it is difficult to identify the difference. Furthermore, there may be some systematic differences in the obtained ^{40}Ar–^{39}Ar ages among different investigators, which may also affect to obscure the trend. With the condition that such effects are relatively small, we can say that the difference in the age among these chondrites depending on their petrologic type may not exceed 100 Ma.

On the other hand, the average ^{40}Ar–^{39}Ar age for each chondrite group seems to be systematically younger than those of Pb-Pb and Sm-Nd ages (KIRSTEN, 1978). Such differences in the ages determined by different methods probably relate to the different critical temperatures for each radioactive and radiogenic element.

In order to elucidate the time relationship with the degree of metamorphism, a more systematic survey for unshocked chondrites is required. The application of different dating techniques for the same sample is also much desired to clarify the detailed structure of the thermal history of a meteorite.

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