
Introduction. Extensive $^{40}$Ar-$^{39}$Ar dating of various lithologies of the CV meteorite Allende (1,2) resulted in the following findings: 1. a major age mark in the meteorite's history is 4.52 $\pm$ .03 AE; 2. the matrix age of $\sim$3.8 AE reflects a minor outgassing event at this or a later time or it results from continuous loss of radiogenic $^{40}$Ar from the very fine-grained material at relatively low temperatures (3); 3. one composite sample of coarse-grained white inclusions had a K-Ar age of 4.8 AE. The latter result stimulated the continuing search for inclusions having anomalously high ages. Here we report on a $^{40}$Ar-$^{39}$Ar study on six whole rock samples from individual white inclusions.

Samples and Results. All our dated samples are numbered sequentially. Inclusions 19,20,21 and 23 obtained from B. Mason have been chemically investigated before (4). Sample 19 is classified by (4) as chemical Group II, probably it is Type B of (5) as are also samples 17 and 18; samples 20,21,23 are chemically Group I (4) and Type A of (5). Sample 18 has also been investigated petrologically (6).

Procedures of irradiation, measurement and data reduction are the same as previously published (7) with the exception that samples 17 and 18 have not been predegassed at 2000C as usual. Therefore, an unknown degree of atmospheric contamination is present in the initial release fractions. A maximum correction for this is applied by assuming that all "trapped" $^{39}$Ar is atmospheric ($^{40}$Ar/$^{39}$Ar=295.5). Apparent ages after this correction are plotted as bars in Fig.3 and are the basis of the further discussion; the dashed lines give the uncorrected minimum ages. The errors of some apparent ages are rather large due to the small sample size and especially at higher extraction temperatures, due to the low $^{40}$K/$^{39}$Ar ratios implying large corrections for $^{39}$Ar/Ca (Fig.1). All results are compiled in Table 1 and graphically shown in Figs.1-3.

First of all, it is noteworthy that the total K-Ar ages of five samples are in excess of 4.52 AE thus drastically increasing the frequency of the exceptional ages to 6 samples out of 14 white inclusion samples dated so far (1,2). It is also noteworthy that not all white inclusions have anomalous ages. (An "age" is a number calculated from a $^{40}$Ar/K ratio!)

On the basis of the age spectra the samples are divided into three groups: a) sample 23 (Fig.1), the age spectrum does not define a plateau; at lower extraction temperatures young apparent ages indicate moderate loss of radiogenic $^{40}$Ar; the K-Ar age is 4.57 $\pm$ .41 AE. b) Samples 19,20,21 (Figs. 1 and 2): Initial apparent ages are considerably older than 4.52 AE and tend to decrease with increasing extraction temperature; in a three-isotope diagram (Fig.2) the high temperature data points (above 9000C) define linear arrays with x-axis intercepts corresponding to the $^{37}$Ar/$^{39}$Ar$_{calc}$ ratio measured for K-free CaF$_2$ irradiated along with the samples. The y-axis intercepts for samples 19 and 21 indicate ages of 4.68 $\pm$ .12 AE and 4.62 $\pm$ .10 AE, respectively, while for inclusion 20 the intercept age is 5.27 $\pm$ .18 AE. Assuming that the intercept ages are "true" there exists at present no substantiated interpretation for the high initial ages. (The data of samples 17,18 and 23 are not correlated.) c) Samples 17 and 18 (Fig.3): the age spectra show typical two-step age patterns also encountered before in studying lunar highland breccias (8); the lower temperature plateau ages are 4.98 $\pm$ .06 AE and 4.90 $\pm$ .03 AE, respectively; large fractions of argon released at higher temperatures (11300 and 13000C) have apparent ages of 5.4 $\pm$ .1 AE; the Ca-concentrations are exceptionally low.

Exposure ages (production rate $p_{{}^{40}}$Ca=2.8$\times$10$^{-8}$ccSTP$^{38}$Ar/gCa my) as listed in Table 1 are similar to the previously published age of 5 my (9) which indicates
the absence of significant amounts of C1 (1) and of preirradiation.

Discussion. The results of the present \(^{40}\text{Ar}-^{39}\text{Ar}\) study again demonstrate the variability of ages obtained from white inclusions of Allende. The ages fall into two categories: a) Those at 4.52 AE include coarse- as well as fine-grained white inclusions and they are contemporaneous with most constituents of Allende (1). b) Inclusions with anomalous ages are apparently not randomly just older than 4.52 AE, instead their ages tend to be near 4.95 AE with high temperature fractions at \(<5.4\) AE. The complex mineralogy of sample 18 (6) indicates several sequential events in the history of the inclusion, but to associate the ages with the events is at present not justified.

Two plausible interpretations for the high ages are admixture of very old STARDUST (10) or an isotopic \(^{40}\text{K}\) enhancement in all or some constituents of some inclusions. The latter idea is waiting to be tested experimentally for which research is under way (11). Calculations show (12) that in the explosive carbon burning phase of a supernova a \(^{40}\text{K}/^{39}\text{K}\) ratio 70 times the solar system ratio 4.6 AE ago is produced while for an apparent age of 5.1 AE a \(^{40}\text{K}\) enrichment of only 35% is required. (In \(^{40}\text{Ar}-^{39}\text{Ar}\) dating an age is produced from a measured \(^{40}\text{Ar}/^{39}\text{Ar}\) ratio which is proportional to \(^{40}\text{Ar}^{40}\text{Ar}/^{40}\text{K}\) under the assumption of a known \(^{40}\text{Ar}/^{39}\text{K}\) ratio.) If the old ages reflect the survival of presumably very old (10) presolar matter they should be interpreted as mixing ages indicating the varying proportions of STARDUST present in Allende inclusions.


**TABLE 1:** \(^{40}\text{Ar}-^{39}\text{Ar}\) Results on Allende Inclusions

<table>
<thead>
<tr>
<th>Sample</th>
<th>Weight (mg)</th>
<th>(^{38}\text{Ar}^{38}\text{Ar})/(^{37}\text{Ar}^{37}\text{Ar}) of main (^{37}\text{Ar}^{37}\text{Ar}) release fractions</th>
<th>(^{36}\text{Ar}^{36}\text{Ar})/(^{35}\text{Ar}^{35}\text{Ar}) of main (^{35}\text{Ar}^{35}\text{Ar}) release fractions</th>
<th>(^{40}\text{K})/(^{39}\text{K}) of Allende</th>
<th>(^{40}\text{K})/(^{39}\text{K}) of Allende</th>
<th>(^{40}\text{Ar}^{40}\text{Ar}/^{40}\text{Ar}^{40}) of Allende</th>
</tr>
</thead>
<tbody>
<tr>
<td>17</td>
<td>15.1</td>
<td>155</td>
<td>53.1</td>
<td>5.12±0.03</td>
<td>4.98±0.66</td>
<td>5.43±0.04</td>
</tr>
<tr>
<td>18(H126m78,1)</td>
<td>40.0</td>
<td>70</td>
<td>10.6</td>
<td>12.5±0.4</td>
<td>5.08±0.08</td>
<td>4.89±0.03</td>
</tr>
<tr>
<td>19(4691)</td>
<td>9.8</td>
<td>60</td>
<td>21.1</td>
<td>4.41±0.4</td>
<td>4.92±1.1</td>
<td>4.68±1.2e</td>
</tr>
<tr>
<td>20(3529,33)</td>
<td>5.0</td>
<td>60</td>
<td>18.7</td>
<td>3.7±2.0</td>
<td>5.54±0.90</td>
<td>5.27±1.8e</td>
</tr>
<tr>
<td>21(3525,29)</td>
<td>9.5</td>
<td>55</td>
<td>19.8</td>
<td>4.1±1.1</td>
<td>5.26±0.10</td>
<td>4.62±1.0e</td>
</tr>
<tr>
<td>23(3525,26)</td>
<td>6.2</td>
<td>110</td>
<td>18.3</td>
<td>6.7±1.2</td>
<td>4.57±1.41</td>
<td>5.37±0.10</td>
</tr>
</tbody>
</table>

a) in brackets source number of (6)
b) calculated from \(^{38}\text{Ar}^{38}\text{Ar}/^{37}\text{Ar}^{37}\text{Ar}\) of the main \(^{37}\text{Ar}^{37}\text{Ar}\) release fractions
c) sample contains approximately 200 ppm C1
d) in brackets source number of (4)
e) from correlation of >900°C fractions in three-isotope diagram (Fig.2)
Further K-Ar Ages of Allende Inclusions

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Fig. 1 (left): Apparent ages and K/Ca spectra of 4 white Allende inclusions. Error bars of fractions with low K/Ca are large because of substantial corrections for $^{39}\text{Ar}/^{40}\text{Ar}$.

Fig. 3 (below): Apparent age and K/Ca spectra of inclusions 17 and 18 of Allende. Numbers are extraction temperatures. Bars are minimum ages, stippled lines maximum ages (see text).

Fig. 2 (above): Three-isotope diagram ($^{40}\text{Ar}$ vs. $^{37}\text{Ar}$, both relative to $^{39}\text{Ar}$ uncorrected for $^{39}\text{Ar}/^{40}\text{Ar}$ of Allende inclusions 19, 20, and 21. Correlated data points are shown as filled symbols. Intercepts correspond to $^{37}\text{Ar}/^{39}\text{Ar}$ from n-irradiated K-free CaF$_2$ and high temperature ages as listed in Table 1, respectively.

Fig. 3 reproduced courtesy of NATURE