Supplementary Information for:

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At least fifteen K/Ar and $^{40}Ar/^{39}Ar$ dating studies targeting both whole rock and mineral separates have been conducted on the nakhlites (*1-16*). This study relies on the recently published $^{40}Ar/^{39}Ar$ study of Swindle and Olson (*13*) and Bogard and Garrison (*17*), which had many heating steps, enabling us to characterize the spatial distribution of Ar in the meteorites with high spatial resolution.

Fig. S1. Diffusivity as a function of temperature (Arrhenius plot) for (**A**) Nakhla (subsample 2) (**B**) Lafayette, and (**C**) ALH84001 inferred from the ^{39}Ar release data of Swindle and Olson (*13*) and Bogard and Garrison (*17*). Circles are the diffusion coefficients as calculated following (*18*). Red curves: best-fit two-domain model. Solid and dotted black lines: model $D(T)/a^2$ for the high-retentivity domains (HRD) and low-retentivity domain (LRD), respectively. Dashed black lines: one-domain models, given by the linear regression fit only to the subset HRD arrays (temperature steps 375° to 675 °C). Error bars (specified by vertical line through each point) are smaller than the size of the circles for all but the lowest three temperature steps.

Fig. S2. Measured and modeled $^{40}Ar^*/^{39}Ar$ ratio evolution spectra for (**A**) Nakhla (subsample 2) (**B**) Lafayette and (**C**) ALH84001. These spectra were calculated using the two-domain models shown in Fig. S1 for various assumed diffusively-cooling thermal pulses experienced by the high-retentivity domain (HRD). Shown are the calculated $^{40}Ar^*/^{39}Ar$ ratios, R (normalized to the bulk ratio, R_{bulk}) plotted as a function of the cumulative ^{39}Ar release fraction $\Sigma F^{39}Ar$. Circles are the data of (*13*) (for Nakhla and Lafayette) and (*17*) (for ALH84001). Solid curves correspond to various temperature pulses during ejection from Mars which occurred at 11 Ma and 15 Ma for the nakhlites and ALH84001, respectively: black = no diffusive loss experienced by the HRD, green = 250 °C, pink = 300 °C, red = 350 °C, dark green = 400 ^{o}C, dark red = 450 ^{o}C. For the nakhlites, the low retentivity domain (LRD) was assumed to contain no $^{40}Ar^*$, while for

ALH84001, the LRD was assumed to be completely full of $^{40}Ar^*$ prior to the thermal pulse. Error bars (specified by vertical line through each point) are smaller than the size of the circles for all but the lowest 8 temperature steps.

Fig. S3. Estimated uncertainties for the time-temperature limits in Fig. 3 in the main text for (**A**) Nakhla and (**B**) ALH84001. For Nakhla, the HRD diffusion kinetics differ depending on whether one uses a one-, two- or three-domain model. The differences in the diffusion kinetics between these models are larger than the formal regression errors for the kinetics in the one-domain model. The opposite is true for ALH84001, for which the best-fit HRD diffusion kinetics for the one- and two-domain model are the same. Therefore, for Nakhla we estimated the uncertainty in the time-temperature limits using the range in diffusion kinetics implied by the different domain models, while for ALH84001 we estimated the uncertainty using the formal regression errors of the one-domain model. The range of values for a given temperature excursion duration are shaded so as to provide a sense of the uncertainty envelope around the favored two-domain models shown in Fig. 3. My, millions of years. **(A)** Each triplet of curves depicts the maximum constant temperature that the meteorite could have experienced as a function of the time in history at which the temperature excursion is assumed to occur, calculated using the one, two, and three-domain diffusion models. Each triplet corresponds to a particular assumed duration for the temperature excursion. The HRD of the meteorites are assumed to experience no diffusive loss at all times other than during the temperature excursion. The one-domain models slightly overestimate the diffusivity and so place a rough lower bound on our estimate of the maximum temperature. The two- and three-domain models give roughly similar estimates of the maximum temperature, with the latter models giving slightly higher values. We favor the two-domain models because they fit the data much better than the one-domain models while also requiring a smaller number of tunable parameters than the three-domain models (5 parameters instead of 8). **(B)** The triplet of curves for ALH84001 is calculated from the maximum range in diffusion kinetics implied by the formal regression errors at the 95% confidence interval.

References

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Figure S1

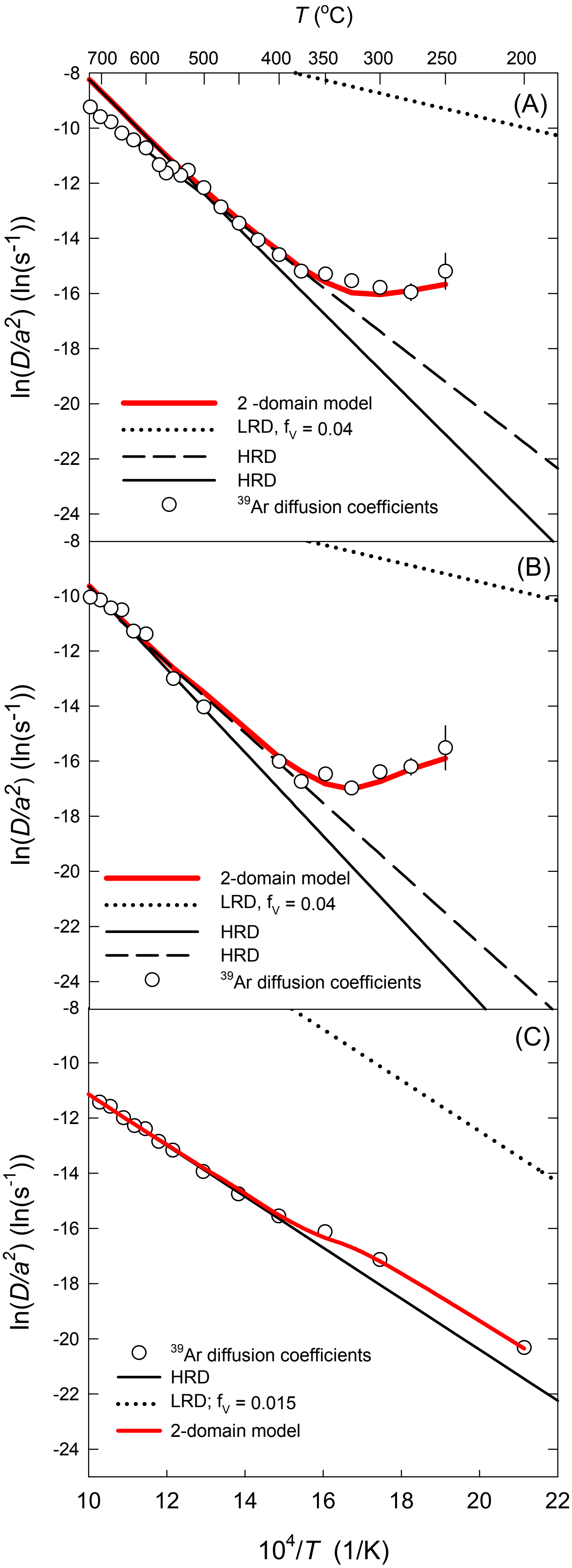

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Figure S2

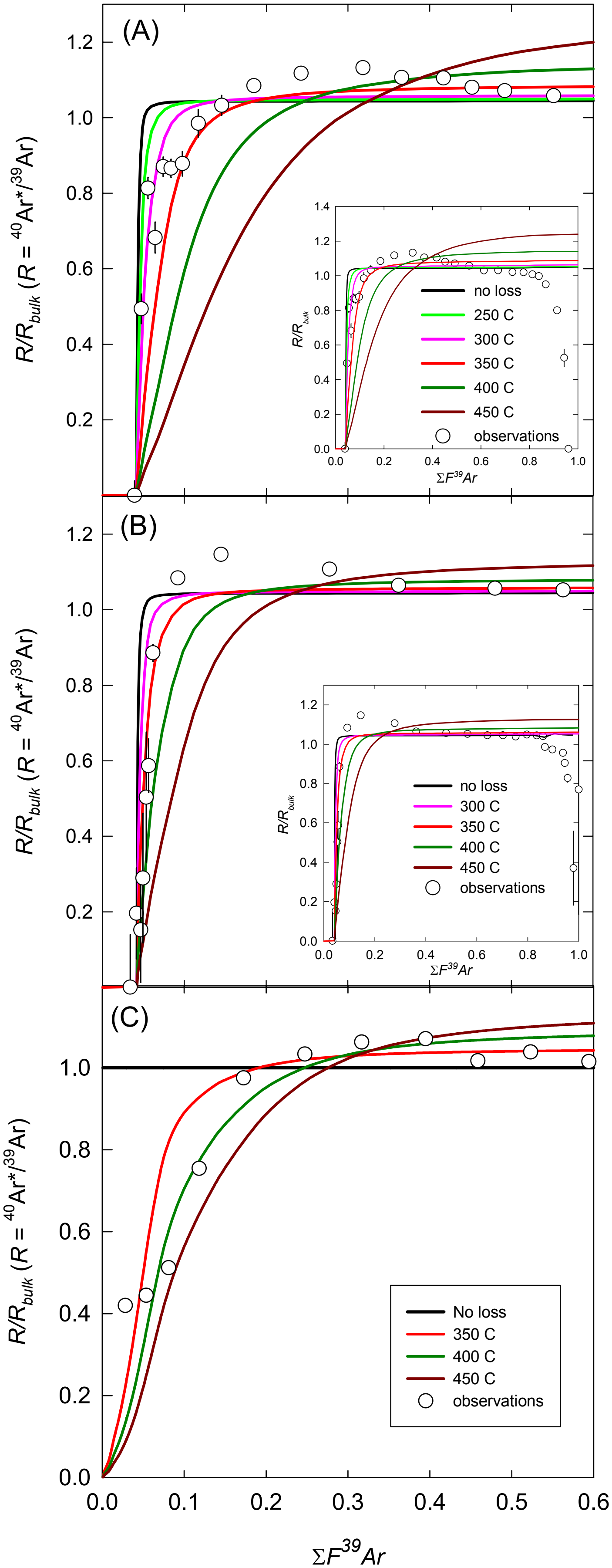

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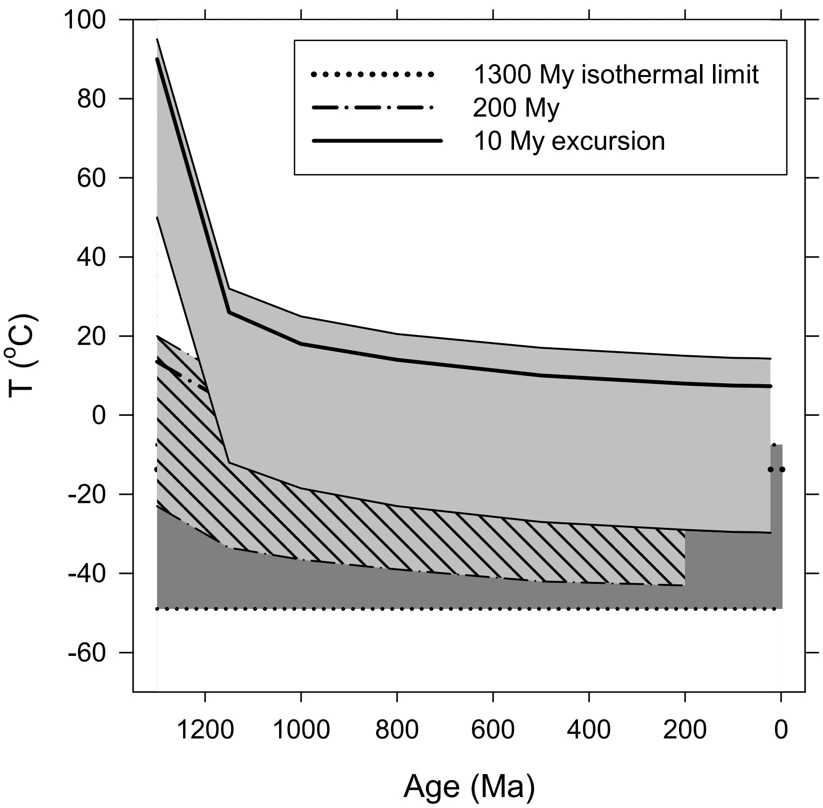
Figure S3

(A) Nakhla



(B) ALH84001