

SOLUBLE PHASES IN NAKHLA, THEIR Ar-Ar AGES AND NOBLE GAS CONTENTS J. D. Gilmour, R. Burgess, J. A. Whitby and G. Turner, Department of Earth Sciences, University of Manchester, Manchester, M13 9PL, United Kingdom. Email: James.Gilmour@man.ac.uk.

Introduction: The presence of halite, carbonate and gypsum/anhydrite in the Martian meteorite Nakhla is generally assumed to be the result of aqueous alteration some indeterminate time after the processes which generated the original igneous rock. Previous ion microprobe analyses in our laboratory [1], of oxygen isotopes in siderite /rhodochrosite from Nakhla, indicate $\delta^{18}\text{O} = 34.0 \pm 1.2 \%$, and are most easily understood in terms of deposition from a low temperature aqueous fluid. While the exact nature of the deposition processes are model dependent, the high $\delta^{18}\text{O}$ demonstrates unambiguously that the oxygen in the carbonate has never equilibrated with the silicate minerals in Nakhla. In an abstract in this volume [2], Bridges and Grady argue that the presence of halite, carbonate and gypsum/anhydrite in the Martian meteorite Nakhla can be attributed to the introduction of a sedimentary/evaporite component to the parent magma from which Nakhla crystallized. With a view to testing this hypothesis and understanding more fully the origin of the noble gas components in Nakhla we are in the process of carrying out Ar-Ar, noble gas and other analyses on chemically treated samples of the meteorite.

Results. Chemistry: A 210 mg sample of Nakhla supplied by the Natural History Museum, London, was lightly ground to a grain size of $<400 \mu\text{m}$ and divided into 3 subsamples: Nak1 (61.42 mg), Nak2 (97.99 mg), Nak3 (57.96 mg). A finer grain size was not used because of the anticipated difficulty in handling and analyzing powders after irradiation. Samples Nak2 and Nak3 were derived from the untreated sample by 20 hours' dissolution in water and 0.3 molar HNO_3 respectively. Samples from the solution above samples Nak2 and Nak3 were analyzed for a selection of cations using ICP-OES while anions from the solution above Nak2 were analyzed by ion chromatography (the ionic strength of the acid solution above Nak3 prevented use of this technique). Results of the analyses are presented in table 1. If halite dissolution is responsible for the sodium released from Nak2, halite constitutes at least 250 ppm of our sample. There is evidence for some further sodium release in the acid treatment that produced Nak3. However, this appears to have been dominated by the dissolution of olivine.

Argon-argon: Data from a previous argon-argon study of the Nakhrites [3], which predated the identification of their parent body as the planet Mars, revealed a

	Nak2 (water)	Nak3 (acid)
Ca	61.5 ppm	936 ppm
Fe	4.3 ppm	3.20%
Mg	48.0 ppm	0.606%
Na	103 ppm	142 ppm
Cl	213 ppm	-
NO_3^-	<19 ppm	-
SO_4^{2-}	21.2 ppm	-

Table 1: Measured concentrations wt% or ppm of whole rock derived from ICP-OES and ion chromatography of Nakhla samples.

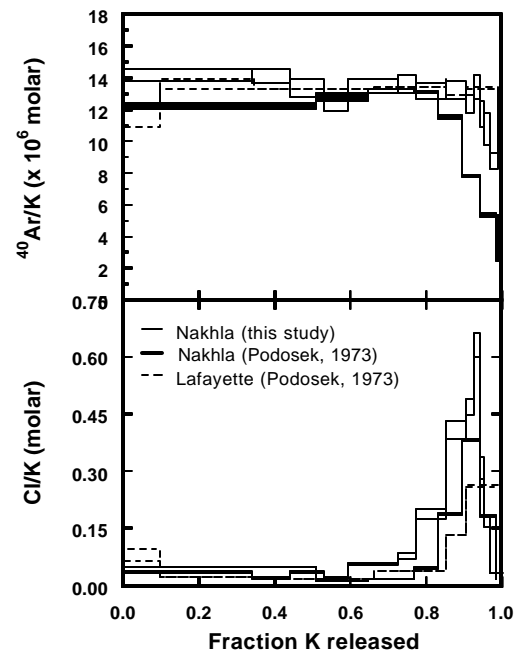


Figure 1: Step release patterns from argon-argon analyses. Data from this work and reference [3].

difference in the high temperature Ar release between Nakhla and Lafayette (figure 1). The Nakhla data displayed a pronounced drop in apparent age in the high temperature releases. At the time the author [3] suggested that this was the result of ^{39}Ar recoil, an effect which has been frequently observed in whole rock analyses of meteorites and lunar samples, though seldom so pronounced as in Nakhla. Surprisingly, Lafayette, which is petrologically very similar, showed no high temperature age decrease. Given the known presence of Martian alteration products, this prompted us to reinvestigate the

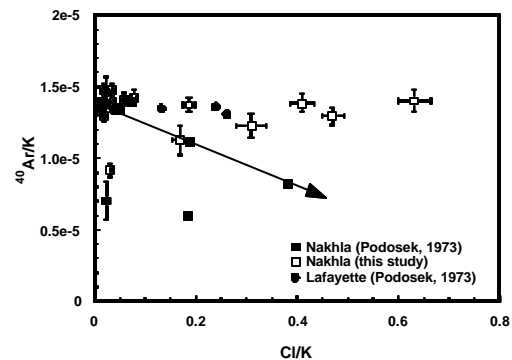


Figure 2. Argon-argon data from analysis of Nakhla and Lafayette ([3] and this work). The arrow shows the drop in apparent age accompanied by chlorine release at high temperature from the Nakhla analysis of [3].

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Ar-Ar systematics of Nakhla. We noted that large amounts of Cl-derived ^{38}Ar were evolved in the high temperature release and that the decrease in $^{40}\text{Ar}/\text{K}$ appeared to correlate with Cl/K (Figure 2). Several explanations are possible: there could be a younger phase in Nakhla containing Cl and K; a water soluble phase containing Cl and K, could have lost radiogenic ^{40}Ar as a result of partial dissolution during curation or laboratory handling; the correlation could be fortuitous and the high temperature age decrease be, as originally suggested, an artifact of recoil.

To investigate this further, aliquots from samples Nak1, Nak2 and Nak3 are currently being irradiated at the Ford nuclear reactor, University of Michigan. Meanwhile, we have analyzed a previously irradiated sample of Nakhla. These results are also displayed in figures 1 and 2. This sample is a broken fragment from the same NHM piece as Nak1-3 and has not been exposed to water. As in the earlier analyses of Nakhla and Lafayette, our data show high Cl/K ratios in the high temperature release (1000 - 1200°C). However, in contrast to the earlier work, our data display a uniform Ar-Ar age in both high- and low-chlorine releases, with only a small high temperature age decrease, and are thus similar to the previous analysis of Lafayette. This suggests that the age decrease may be either due to recoil or sample treatment, but until the chemically treated samples are analyzed we cannot be certain. If recoil is the correct explanation, we would expect our chemically etched samples to show a more pronounced high temperature effect. If young alteration products are the cause we would expect the high temperature age decrease to be absent in the etched samples.

Xenon: The presence of an (elementally fractionated) trapped noble gas component derived from the Martian atmosphere in Nakhla has been widely reported [4], but its carrier phase or phases remains uncertain. Ott et al. [5] found that 90% of $^{129}\text{Xe}_{\text{XS}}$ was removed by etching with 6N HCl and attributed this to an association of the trapped gas with olivine. Drake [6] invoked a combination of dissolution of Martian atmosphere in water and subsequent trapping of gas in alteration products (iddingsite) to explain the elemental fractionation of the trapped component; however, the concentrations of noble gases so far detected in iddingsite are insufficient to explain the total xenon budget in Nakhla.

We have previously reported the first results of xenon analyses of mineral concentrates from Nakhla [7]. Fractions rich in clinopyroxene and olivine tended to be a factor of 5 to 10 less rich in $^{129}\text{Xe}_{\text{XS}}$ than those rich in feldspar or containing significant chlorine and phosphorus. However, all exhibited trapped Martian atmospheric xenon (figure 3) and the relative abundances of the minerals suggests that the majority of the trapped atmospheric xenon is associated with pyroxene. We concluded that the formation of alteration products was not responsible for the introduction of the trapped noble gas component into Nakhla.

The trapped component appears to be widespread throughout the minerals in Nakhla. The origin of the elemental fractionation, which apparently precludes direct trapping from the atmosphere, remains to be explained. We have argued elsewhere [8] that the origin of similar elemental fractionation in the trapped component of ALH84001 can be attributed to shock incorporation of gas that had been adsorbed on the surface of mineral grains. Nakhla is not shocked, so a different explanation must be sought in this case. The theory of Bridges and Grady potentially provides a means of decoupling to some extent the process that produced fractionation of the noble gas component from that which trapped it in its present location. Elemental fractionation may reflect the incorporation of noble gases into evaporites by solution in water and adsorption or other trapping mechanisms; gas released from evaporites on melting was then introduced into the parent melt of the Nakhrites.

Conceivably this process may have left some trace in an enrichment of xenon in the minerals derived from the salt-rich melt fraction. To determine if there is any enrichment of Xenon analysis of separates Nak1, Nak2 and Nak3 is currently underway. Preliminary results show that both Nak1 and Nak2 release gas with the high $^{129}\text{Xe}/^{132}\text{Xe}$ ratio characteristic of the Martian atmosphere and that little if any loss of excess ^{129}Xe occurred during water dissolution.

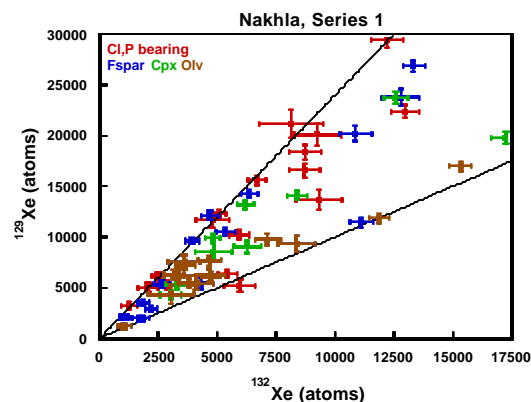


Figure 3: Xenon components from stepped heating of Nakhla mineral separates. Grain sizes were 100 - 400 μg and each point represents a single temperature extraction.

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References: [1] J. M. Saxton et al., *Meteoritics* **32**, A113-A114 (1997). [2] J. C. Bridges and M. M. Grady, *this volume*. [3] F. A. Podosek, *E.P.S.L.* **19** 135-144 (1973). [4] U. Ott, *G.C.A.* **52** 1937-1948 (1988). [5] U. Ott et al., *Meteoritics* **23** 295-296 (1988). [6] M. J. Drake et al., *Meteoritics* **29** 854-859 (1994). [7] G. Turner et al., *Meteoritics* **31** A143-A144 (1996). [8] J. D. Gilmour et al., *G.C.A.* (submitted).