NOBLE GAS EVIDENCE OF AN AQUEOUS RESERVOIR NEAR THE SURFACE OF MARS MORE RECENTLY THAN 1.3 Ga; Michael J. Drake*, Toby Owen#, Timothy Swindle*, and Donald Musselwhite*. *Lunar and Planetary Laboratory, University of Arizona, Tucson, Arizona 85721. #Institute for Astronomy, University of Hawaii at Manoa, Honolulu, Hawaii 96822.

Considerable evidence points to a Martian origin of the SNC meteorites. One of these meteorites, Nakhla, contains a leachable component which has an elevated $^{129}Xe/^{132}Xe$ ratio relative to its $^{84}Kr/^{132}Xe$ ratio when compared to the approximately linear array defined by Chassigny, most shergottites, and lithology C of EETA 79001. This array is thought to be a mixing line between Martian mantle and Martian atmosphere. The leachable component probably consists in part of iddingsite, an alteration product produced by interaction of olivine with aqueous fluid at temperatures lower than 150°C. The radiogenic Xe component may represent a distinct reservoir in the Martian crust or mantle. More plausibly, it is Martian atmosphere, fractionated by solution in liquid water and by interaction with sediment. The crystallization age of Nakhla is 1.3 Ga. Its low shock state suggests that it was ejected from near the surface of Mars. Liquid water is required for the formation of iddingsite. These observations provide further evidence for the near surface existence of aqueous fluids more recently than 1.3 Ga.

There is both direct and indirect evidence for the existence of liquid water at the surface of Mars in the distant past [1]. Evidence of stable water is seen in the existence of ancient dendritic drainage channels that mimic terrestrial desert streams and, more controversially, in the suggestion that fossil shore lines of ancient oceans are visible in Viking Orbiter imagery [2]. Evidence for metastable water exists in the form of catastrophic outflow channels. Indirect evidence for the existence of substantial bodies of liquid water 4.5 Ga ago comes from considerations of the fractionation of Xe isotopic reservoirs on Mars [3]. Of considerable interest is the possible presence of liquid water close to the Martian surface in more recent times. Its presence has been suggested on the basis of O isotopic measurements [4], vacuum pyrolysis studies [5], and mineralogical studies of alteration products [6] of SNC meteorites .

Young crystallization ages and similarities in elemental and isotopic compositions of N_2, CO_2, and noble gases between the Martian atmosphere as measured by the Viking landers and lithology C of EETA 79001 have led to a strong consensus that SNC meteorites are samples of the Martian surface [7, 8].

Much of the elemental and isotopic structure of the noble gases may be explained as a mixture of two components [9-14]. One, perhaps mantle derived, is found in Chassigny, while the other is the Martian atmosphere-like component in EETA 79001,C. However, on a plot such as Figure 1, all nakhlites have $^{129}Xe/^{132}Xe$ ratios that are too high to fall on the mixing line. Ott *et al.* [10] showed that the radiogenic Xe component in Nakhla itself was largely removed by leaching in 6N HCl. These authors noted that the leached component constituted 15% of the sample, and concluded that it was largely olivine. However, iddingsite is prevalent in Nakhla and, almost certainly, it was dissolved as well. Iddingsite is a weathering product of olivine consisting of smectites, hematite, ferrihydrite, Ca carbonate and Ca sulfate and its formation requires the presence of liquid water at temperatures of <50°C to 150°C [6, 15]. Therefore, it is plausible that iddingsite is the carrier of the radiogenic Xe.

What is the source of the radiogenic Xe in Nakhla? Possibly the aqueous solution responsible for the formation of iddingsite sampled a crustal or mantle reservoir with a distinct noble gas isotopic composition. However, it is also plausible that the radiogenic component is a fractionated sample of the atmosphere, a possibility raised by Ott *et al.* [10]. Fractionation by water alone is inadequate. The Kr/Xe ratio in water is about a factor of two lower than a gas in equilibrium with it [16], while the radiogenic component of Nakhla is a factor of 5 - 8 lower in this ratio. However, terrestrial sedimentary rocks have Kr/Xe ratios lower than the atmosphere by factors of 2 - 1000 [16]. This range of sediment/atmosphere fractionation factors is consistent

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with the radiogenic Xe in Nakhla being contained in iddingsite, a sedimentary weathering product.

The conclusion that iddingsite contains the radiogenic Xe component is also consistent with the absolute abundance of ^{132}Xe. Unetched Nakhla contains approximately 6×10^{-12} ccSTP/g, while etched Nakhla contains approximately 3×10^{-12} ccSTP/g. Thus, the leachate contained about 3×10^{-12} ccSTP/g of ^{132}Xe. If iddingsite constituted, say, 1% of the leach, and all ^{132}Xe was contained in it, the abundance of ^{132}Xe in iddingsite would be 3×10^{-10} ccSTP/g. Terrestrial sedimentary rocks contain between 6×10^{-12} and 5×10^{-7} ccSTP/g [16], bracketing the iddingsite value.

Our conclusion is that Nakhla interacted with an aqueous fluid sometime after its crystallization at 1.3 Ga ago. Nakhla shows virtually no evidence of shock and, hence, must have been ejected from Mars by impact as a near surface "Grady - Kipp" fragment [17]. Thus, liquid water was present near the surface of Mars more recently than 1.3 Ga, at least in the region of origin of the nakhlites.

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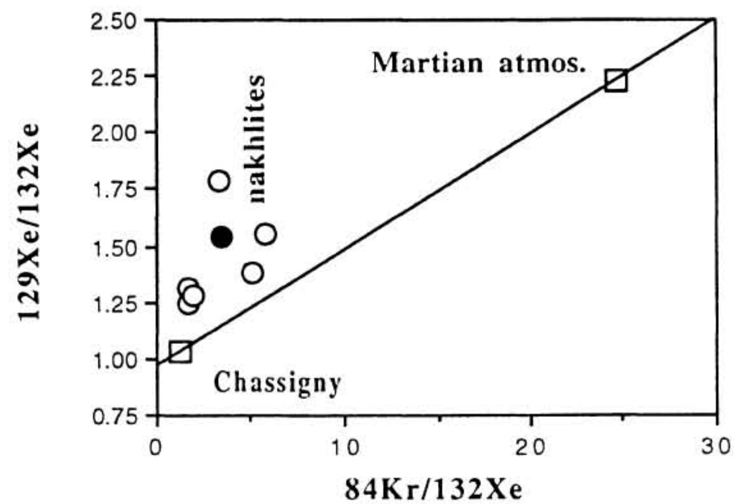

Figure 1. ^{84}Kr/^{132}Xe versus ^{129}Xe/^{132}Xe for some SNC meteorites. The Martian atmosphere point is lithology C of EETA 79001. Most shergottites (not shown) fall near this line, which is interpreted as a mixing line between Martian mantle (Chassigny) and Martian atmosphere. Open circles are from [9-11], filled circle is from [12-14].