We report nitrogen and xenon isotopic signatures in Yamato nakhlites and use the data to assess properties of the magma source of NC meteorites in planet Mars. The Chassigny meteorite was investigated by Floran et al. [1], who classified it as a cumulate dunite with hydrous amphibole-bearing melt inclusions with no preferred orientation of the olivines. Their inferred composition of the parent magma, which was based on electron microprobe analyses, has been questioned [2]. The trace and minor elements in minerals were analyzed in nakhlites and in Chassigny [3] and the authors conclude that nakhlites may represent samples from different horizons of the same lithologic unit, but that Chassigny was not co-magmatic with the nakhlites.

It has long been recognized that Chassigny may be closely related to the nakhlites because of identical crystallization and ejection ages [4] and an agreement in initial strontium isotopic composition [5]. Nitrogen concentrations in Yamato nakhlites are similar to those in Nakhl, but smaller than in NWA 817 [6]. Isotopic signatures observed in broad plateau releases (400° to 1040°C) with signature $\delta^{15}N = +13‰$ in the Yamato nakhlites (Fig. 1) compare well with data in Chassigny (Chass-E). The data of temperature steps <300°C in Y000749, although afflicted by terrestrial contaminants, show a minor component of light nitrogen as observed in Chass-S [7]. The $\delta^{15}N = +13‰$ signature is also observed in the plateau release of Nakhl [8].

These data document the presence of two nitrogen signatures in Chassigny and nakhlite magma sources. Furthermore, the primitive nitrogen isotopic signature of $\delta^{15}N = -30‰$ was measured in ALH84001-b and in Chassigny [7], but their $^{129}\text{Xe}/^{132}\text{Xe}$ ratios differ strikingly (Fig. 1). Abundance ratios of the heavy noble gases Kr and Xe, again plotted vs. $^{129}\text{Xe}/^{132}\text{Xe}$ ratios (Fig. 2), show obvious similarities in nakhlites and in the low-temperature (<350°C) data of ALH84001.

A remarkable feature of the 1.3 Ga old NC meteorites, Chassigny and in Yamato nakhlites, Nakhl and NWA817, is that they contain fission Xe components produced mostly by the decay of extinct $^{244}\text{Pu}$. Xe was released at temperatures above 900°C and well mixed with indigenous (Chass-S) Xe. In Fig.3 we see a good isotopic correlation of spallation-corrected Xe ratios for nakhlites as well as for Chass-E along the tie-line of end members Chass-S Xe and fission Xe. The isotope ratios shown in Fig 3 permit the identification of the fission progenitor, extinct $^{244}\text{Pu}$, while minor contributions from $^{238}\text{U}$ can not be excluded. However, in situ-produced fission Xe from $^{238}\text{U}$ during 1.3 Ga, based on the measured U abundance of 55 ppb [9] can only account for ~5% of the observed fission Xe. Figure 3 also shows that Xe data cannot be explained as mixtures of modern Martian atmospheric Xe components with fission gas. However, we note in this figure that, although well-mixed components were reported in nakhlites, a variability is observed in the mixing ratios of fission and indigenous components, with Chass-S Xe representing the fission-devoid end-point (solar Xe) composition, while Chass-E plots about halfway towards ALH84001 and the nakhlite data. If the radiogenic $^{129}\text{Xe}$ component was cycled through the mantle, it should be well mixed with the fission component, which in turn was generally well mixed with indigenous mantle Xe. The data show that radiogenic $^{129}\text{Xe}$ is decoupled from fission Xe and indigenous mantle gas and that radiogenic $^{129}\text{Xe}$ components were not mixed in the nakhlite magma source.
The low ratios $^{129}$Xe/$^{132}$Xe in Chass-S xenon are an important characteristic and can be understood if reservoirs with high abundances of primitive interior gas components existed and were trapped in magmatic inclusions in Chassigny olivines from the martian interior, as indicated by high concentrations of nitrogen and noble gases in Chassigny. In this interpretation the incorporation of primitive components occurred late in the process at or after the 1.3 Ga event, since the components are not tightly bound and were released at low temperatures. Any of the gas-rich percolating fluids would also have affected the composition of fluid inclusions in olivines and the mesostasis. Chassigny contains also a significant amount of water and the D/H ratio is consistent with terrestrial water [12]. Both hydrogen and nitrogen isotopic signatures demonstrate that exchanges between the solid planet and its modern atmosphere have been very limited.


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