the formation of putative glacial features in the southern highlands, and probably did not exist (see discussion in [19]). More realistic are the smaller, isolated lacustrine basins proposed for low-lying areas in the northern plains surrounded by outflow channels [20,21] and in the cratered highlands where numerous ancient valley networks terminate [22]. Such basins are supported by geomorphic evidence (e.g., possible wave-cut terraces [20,21]) and occur during the interval that other fluvial features were forming. In addition to these basins, smaller isolated pools may have developed in topographic depressions (e.g., impact craters) if precipitation occurred in the highlands as suggested in [3]. It is especially likely that these smaller pools allowed eroded materials to concentrate, raise the local pH, and induce the formation of carbonates. Such “oases” could be the most likely locations of carbonate deposits on Mars. Other oases may exist underground where oxidizing volcanic gases interact with groundwater to raise the pH, and may help explain the presence of carbonates in the SNC meteorites [23]. Based on this view and the terrestrial example [14], a “two-box” model for the oxidizing stages for Mars is proposed (Fig. 1).


Fig. 1. A two-box model showing the location of reducing (R) and oxidizing (O) conditions on Mars through time. Oxidizing conditions in stage I represent local O oases, which may have developed in small pools formed by precipitation or seepage. Oxidizing conditions in stage II represent buried O oases located where groundwater is enriched by volcanics from an evolved mantle. Based on Fig. 3 in [14].
and 1200°C accounted for 2.2 wt% of the sample, far in excess of even the most C-rich SNCs; clearly care must be taken when using palagonites as analogs of martian weathering products. The isotopic release profile of PN-9 shows at least three distinct C components. The first is a heavy component, reaching a δ^13C of -9.5‰, and released between room temperature and 200°C, accounting for 210 ± 10 ppm. This low-temperature C may be a loosely bound labile material or it may be adsorbed atmospheric CO₂. Atmospheric CO₂ will be adsorbed more easily onto fine-grained material and so analysis of size separates may prove interesting. A second component is released between 300°C and 450°C, which reaches a δ^13C maximum of -21.4‰; this represents a lower limit to the actual isotopic composition of this component because of a concomitant release of third-component organic materials (δ^13C = -25‰) over the temperature range 200°-600°C. Carbon components with a similar release temperature and isotopic composition have been observed in SNCs on previous occasions; e.g., LEW 88516, (subsamples 8 and 13) have distinct C components of δ^13C of -19.5‰ and -21.6‰ respectively across the 250°-450°C temperature interval [10]. This possibly coincidental similarity between SNCs and palagonites deserves further study.

The other palagonite sample analyzed (PH-1) was collected from the Puu Huluhulu cinder cone on Mauna Kea, immediately adjacent to the Puna lava flow [8]. It consists of a thermally altered Rapa cinder cone on Mauna Kea, immediately adjacent to the Puna lava flow [8]. This possibly coincidental similarity between SNCs and palagonites as analogs of martian weathering products. It is hoped that this particular study will help with studies of smectite and montmorillonite clays may help to clarify the situation. A complete understanding of the low-temperature weathering products produced on Earth will ultimately help clarify the situation. A complete understanding of the low-temperature weathering products produced on Earth will ultimately help clarify the situation. A complete understanding of the low-temperature weathering products produced on Earth will ultimately help clarify the situation.

The role of dissociative recombination of N₂^+ is important because it involves an inherent fractionation mechanism in addition to that produced by diffusive separation between the homopause and the exobase. Previously we have assumed that the rate of dissociative recombination at earlier times scales as the mixing ratio of N₂ at the exobase. Although this is a good approximation for small mixing ratios of N₂, it is an overestimate for large mixing ratios. Ion-neutral chemistry tends to transform ions whose parent neutrals have high ionization potentials, such as N₂⁺, into ions whose parents have lower ionization potentials. The ratio of exobase densities of N₂ to those of other ions is thus smaller than the ratio of the production rates. For example, we have found that if the mixing ratio of N₂ is 0.75 at the homopause, it is about 0.95 at the exobase, but N₂⁺ constitutes only half the total ion density at the exobase. Thus the dissociative recombination rate and the fractionation due to dissociative recombination are slightly reduced at earlier times. Another possibility that we will explore for reducing

\[ \text{N}_2^+ + \text{O} \rightarrow \text{NO}^+ + \text{N} \]  
\[ \text{O}^+ + \text{N}_2 \rightarrow \text{N}^+ + \text{N} + \text{O}^+ \]  

are thus changed slightly at earlier times compared to models in which the O mixing ratio is assumed to be proportional only to the CO₂ mixing ratio.