

A SOLAR COMPONENT IN THE EARTH : NEON ISOTOPE ANOMALIES IN LOIHI AND KILAUEA BASALTS, HAWAII; M. Honda, I. McDougall, D. B. Patterson, A. Doulgeris, and D. A. Clague*, Research School of Earth Sciences, The Australian National University, Canberra ACT 2601, Australia, *U. S. Geological Survey, Menlo Park, CA.

Non-atmospheric Ne isotopic ratios and coexisting primordial ^3He have previously been identified in basaltic glasses and volcanic gases from mid-ocean ridges (1, 2, 3), from the Hawaiian (2, 4) and Yellowstone hotspots (5), and from diamonds (6, 7). In particular, the Ne results (2) from mid-ocean ridge basalts (MORB) lie on a correlation line in $^{20}\text{Ne}/^{22}\text{Ne}$ - $^{21}\text{Ne}/^{22}\text{Ne}$ space, with one end member being atmospheric Ne, and the other end member enriched in ^{20}Ne and ^{21}Ne relative to ^{22}Ne (Fig. 1). In order to determine whether a similar Ne correlation can be identified in samples from the so-called undepleted mantle source, we have measured Ne and He isotopic ratios in 24 fresh basaltic glass samples dredged from Loihi Seamount and the East Rift Zone of Kilauea, Hawaii (hereafter referred to as the L-K samples); the Ne results are shown in Fig. 1 (open and filled circles in the figure are data from Loihi and Kilauea samples, respectively). Ne isotopic ratios measured on the L-K samples lie on a linear trend, which has a slope intermediate between those of the MORB line and the mass fractionation line (m/f), all lines passing through atmospheric Ne. This indicates that the linear trend observed for the L-K samples cannot simply be explained by mass fractionation processes operating on atmospheric Ne, nor by mixing with MORB Ne. This requires that the source of the non-atmospheric Ne in the L-K samples must have different characteristics compared with the MORB source. Individual samples are enriched in ^{20}Ne and ^{21}Ne by as much as 16% and 12%, respectively, relative to atmospheric ratios. The L-K samples with atmospheric-like Ne generally have large Ne gas concentrations, consistent with a significant degree of atmospheric contamination of the magmas prior to eruption (8). In this regard, Ne isotope results from the L-K and MORB samples can be interpreted as mixing between present-day atmospheric Ne as a common end member, and non-atmospheric components in the L-K and MORB samples, derived from mantle sources characterized by different proportions of non-atmospheric components. Non-atmospheric Ne components that have been identified include solar, planetary and nucleogenic. However, none of these lie directly on either the L-K or MORB correlation lines. Thus, in order to explain the enrichment of ^{21}Ne and ^{20}Ne in the mantle sources for the L-K and MORB samples, it is necessary to mix at least two distinctive non-atmospheric Ne components. The two most likely candidates are nucleogenic and solar Ne. Nucleogenic ^{21}Ne , produced through $^{18}\text{O}(\alpha, n)^{21}\text{Ne}$ and $^{24}\text{Mg}(n, \alpha)^{21}\text{Ne}$ reactions from local decay of U and Th, elevates $^{21}\text{Ne}/^{22}\text{Ne}$ ratios. Solar Ne is the only known component which has a $^{20}\text{Ne}/^{22}\text{Ne}$ ratio greater than the atmospheric value and the $^{20}\text{Ne}/^{22}\text{Ne}$ ratios observed in the L-K and MORB samples. We suggest, therefore, as a working hypothesis to account for the L-K and MORB Ne, that there has been mixing of three Ne components: solar, nucleogenic and present-day atmospheric. By assuming simple three component mixing, the relative contributions of the three Ne components in each sample can be deconvolved. The implication is that there may be a significant solar component present in the Earth when it formed.

After subtraction of the present-day atmospheric component, the remaining Ne (and He) would be mantle derived. These mantle derived gases would be a mixture of primordial, radiogenic and nucleogenic components. If the Earth's primordial composition was solar, then we expect to see a correlation between the Ne and He isotope systematics. This is because primordial He and Ne would all be solar, (where $(^3\text{He}/^4\text{He})_{\text{Solar}} = 4 \times 10^{-4}$, $(^{20}\text{Ne}/^{22}\text{Ne})_{\text{Solar}} = 13.6$, $(^{21}\text{Ne}/^{22}\text{Ne})_{\text{Solar}} = 0.032$, $(^3\text{He}/^{22}\text{Ne})_{\text{Solar}} = 3.3$), and variations in the observed $^3\text{He}/^4\text{He}$ and $^{21}\text{Ne}/^{22}\text{Ne}$ ratios in the mantle would be due to the time integrated ingrowth of radiogenic $^4\text{He}^*$ and nucleogenic $^{21}\text{Ne}^*$, having an unique radiogenic $^4\text{He}^*/\text{nucleogenic } ^{21}\text{Ne}^*$ production ratio of $\sim 1 \times 10^{-7}$ (9).

This relationship can be explicitly stated as

$$^{21}\text{Ne}^*/^{22}\text{Ne}_S = \{(^4\text{He}/^3\text{He})_{\text{observed}} - (^4\text{He}/^3\text{He})_S\} \cdot ^{21}\text{Ne}^*/^4\text{He}^* \cdot ^3\text{He}_S/^{22}\text{Ne}_S,$$

where subscript S denotes the solar composition. Because there is no significant contribution from nucleogenic production to ^{20}Ne and ^{22}Ne , the $^{20}\text{Ne}/^{22}\text{Ne}$ ratio in the mantle is not likely to have changed since the Earth formed. Thus, the $^{20}\text{Ne}/^{22}\text{Ne}$ ratio in the mantle sources is essentially primordial and under the present hypothesis would be of solar composition. Using the above equation we can calculate hypothetical $^3\text{He}/^4\text{He}$ ratios related to the Ne mixing lines (full lines) with different slopes in Fig. 2. Each mixing line has the present-day atmospheric Ne as one end member, with the other end member comprising a mixture of solar and nucleogenic Ne. Neon isotope data observed from the L-K samples and the MORB correlation line (dotted) from Sarda et al. (2) also are shown in Fig. 2. By adding radiogenic $^4\text{He}^*$ and the corresponding nucleogenic $^{21}\text{Ne}^*$, the slope of the mixing line becomes less steep (Fig. 2). The L-K samples lie on the hypothetical mixing line corresponding to a $^3\text{He}/^4\text{He}$ ratio between 2 and 4×10^{-5} , which is within the range of $^3\text{He}/^4\text{He}$ ratios actually observed in the L-K samples. Furthermore, the hypothetical mixing line with corresponding $^3\text{He}/^4\text{He}$ ratio of 1×10^{-5} , close to the MORB ratio, lies almost exactly on the MORB correlation line.

Thus, our solar hypothesis for the origin of the Earth's primordial noble gas composition, at least for He and Ne, appears to be internally consistent, as it accounts for both Ne and He data from the L-K samples, as well as providing an explanation for the MORB data. We conclude, therefore, that the noble gas composition in the mantle is distinctly different from that of the present-day atmosphere and that it involves a significant solar component. We infer that this solar-like component was acquired during the formation of the Earth. Clearly, this has important implications as to the primordial gas composition in the Earth.

References:

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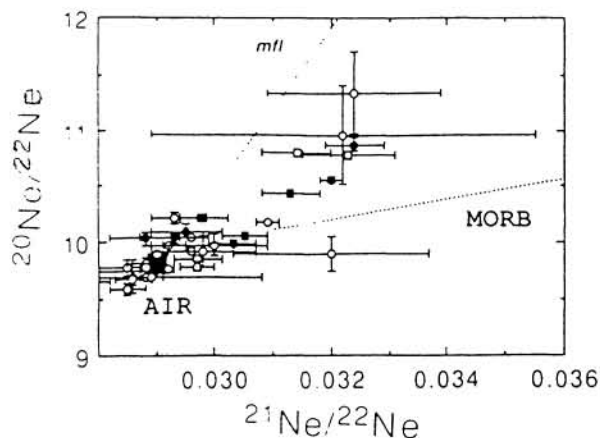


Fig. 1

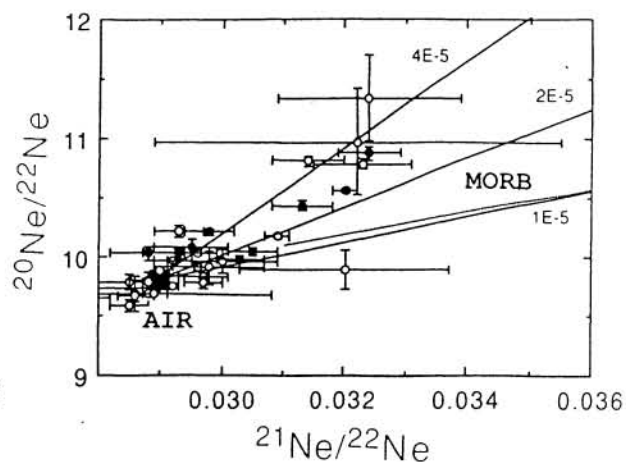


Fig. 2