Comparison of noble gas elemental and isotopic compositions among the solar, Q, and terrestrial noble gases suggests that both Q and terrestrial noble gases were derived from the solar noble gas by a Rayleigh distillation-like fractionation process [1, 2]. This may suggest that both components had already been fractionated by a similar fractionation process, likely in the primitive solar nebula, before their capture by the Earth or meteorite parent bodies. However, it is also possible that the fractionation took place in each planetary body after noble gas capture. In the latter case the primordial terrestrial noble gas must be solar [3,4]. A crucial test for resolving this fundamental problem is a comparison of the noble gas isotopic composition in the Earth’s interior (mantle) and the atmosphere, since large isotopic fractionation, such as that from the solar to the terrestrial isotopic composition, would be possible only in the atmosphere, while the mantle component would essentially be left intact from the fractionation. The purpose of this paper is to discuss the results of comparative studies of atmospheric and mantle noble gases on the basis of an extensive compilation of published data on mantle noble gases.

For the compilation of noble gas data, we used all available published data from 1985 through the summer of 1998. As the representative of the Earth’s interior (mantle), we used MORB and OIB samples. We took intermediate temperature fractions (800-1,000 C fraction) for step-heating experiments and a total datum for crushing experiments; both give generally less air-contaminated, and more pristine-mantle component. We observed that Ar, Kr and Xe are indistinguishable between the atmosphere and mantle-derived materials and that they are distinctly different from the solar composition. One might argue that the indistinguishable isotopic compositions are due to the mixing of subducted atmospheric components with the primordial mantle components. However, this possibility can be ruled out, because (i) the distributions of observed isotopic ratios are monomodal around the atmospheric ratios with no indication of a distinct second (mantle) component, (ii) there is no correlation between these isotopic ratios and 40Ar/36Ar ratio, the latter of which can be assumed to represent the degree of air contamination, (iii) there is no distinct difference between MORB and OIB - contamination of subducted material, which should be more pronounced for MORB. Therefore, we conclude that the mantle Ar, Kr, Xe are identical with the atmosphere and hence that the fractionation took place before or during the Earth’s accretion. We also infer that the primordial terrestrial noble gases are not solar.

Although mantle Ne differs from atmospheric Ne, it also appears to differ significantly from the solar Ne isotopic composition. Honda et al. [3] suggested that mantle Ne may be solar, because (i) 20Ne/22Ne ratios in mantle-derived materials range from the atmospheric ratio (9.8)
up to about 13 which is close to the solar Ne ratio (13.7) and (ii) the observed linear trend in a 20Ne/22Ne-21Ne/22Ne three isotope plot for some MORB and OIB samples can be interpreted on the basis of assumed values of the solar 20Ne/22Ne and 22Ne/3He ratios and a mantle production ratio of 21Ne*/4He (21Ne* indicates a nucleogenic component from U, Th). However, the distribution of 20Ne/22Ne ratios in MORB and OIB seen in our extended data base is more reasonably interpreted by assuming that the mantle Ne has a significantly smaller 20Ne/22Ne ratio of about 12 - 12.5 than the solar ratio (also see ref.4). Also, for much larger data set used in this study, the linear trend and hence the correlation between 21Ne/22Ne and 3He/4He almost disappears. The linear trend which can still be observed for some limited data set such as those obtained for a localized sampling site [5] is more reasonably interpreted as a mixing line between atmospheric Ne and mantle Ne specific to the particular sampling locale rather than a general mantle characteristic. It also should be noted that 21Ne*/4He ratios in MORB and OIB are totally different from a mantle production ratio in contrary to the assumption required for the interpretation of the linear array in the 20Ne/22Ne-21Ne/22Ne three isotope plot by Honda et al.[3].

While elemental abundances of Ar, Kr, Xe in mantle-derived materials (both MORB and OIB) are well correlated with each other, He (MORB and OIB) and Ne (MORB) totally lack correlation with the heavier noble gases. This indicates that lighter noble gases (He and Ne) are essentially decoupled from heavier ones (Ar, Kr, Xe) in the MORB-source mantle, or even that they may have a different origin from the heavier ones. This may be relevant to the unique isotopic characteristic of Ne, that is, the fact that the isotopic composition of the atmospheric Ne differs from the mantle component. In this regard, it is interesting to recall the recent suggestions concerning the origin of 3He and Ne in mantle-derived materials such as cosmic dust origin [6] or some isolated mantle source origin [7].