MICROMETEORITIC NEON IN THE EARTH'S MANTLE. M.Maurette[1] and Ph.Sarda. [1]CSNSM, 91406 Orsay-Campus, France; [2]Departement des Sciences de la Terre, 91406 Orsay-Campus, France.

The neon and xenon problems. Two major problems with the distribution of noble gases on the Earth are quoted in the literature [1]. They concern: – the light noble gases, with atmospheric neon showing a $^{20}Ne/^{22}Ne$ ratio much smaller than that locked in rocks from the upper mantle; – the marked depletion of xenon relatively to Ar and Kr, observed in both the atmosphere and the upper mantle, and which defines the mystery of the "missing" xenon.

One of us (M.M.) proposed a scenario, coined as ***EMMA*** (Early MicroMeteorite Accretion), for the formation of the Earth's atmosphere [2], which is based on the accretion formula given in a companion paper [3]. It involves the accretion of a high fluence of juvenile micrometeorites, similar to Antarctica micrometeorites (AMMs) —about 95% and 5% of them are related to the CM2- and CI-types hydrous carbonaceous chondrites, respectively. This mostly occurred during the first ≈100 Myr of the post-lunar period of the late heavy bombardment.

Suggestions about micrometeoritic neon in the mantle. The neon problem is illustrated in the compilation of analyses reported by Ozima and Igarashi [4], and displayed in figure 3 of their paper. For the sake of simplicity, we will only focus on rocks from the upper mantle coined as Mid Oceanic Ridge basalts (MORBs), which are considered as sampling the degassed upper mantle. About 98% of these rocks show $^{20}Ne/^{22}Ne$ ratios larger than the atmospheric value of 9.8. About ~65% of these ratios cluster in a solar zone defined by the ratios measured in the solar wind (SW) and solar energetic particles (SEPs) , of about 13.8 and 11.2, respectively.

This finding led geochemists in the late 1980's to suggest that solar neon still present in the mantle was just carried by the fraction of unmelted micrometeorites that get deposited on the oceanic crust and transferred to the mantle during subduction [5, 6, 7]. This would simultaneously justify our deduction that the mass fraction of juvenile micrometeorites, which are destroyed upon atmospheric entry (~75% of the incoming flux), did deliver the same solar neon in the atmosphere.

But it was soon argued that micrometeoritic neon would be quickly lost during subduction. Moreover, the accumulation of MORB analyses showed two peaks in the distribution of the $^{20}Ne/^{22}Ne$ ratios at ~11.9 and ~10.5 —see figure 3 in Ref. 4. The peak around 11.9 could not be related to either the SW or the SEPs values. Therefore the accretion and subsequent subduction of neon-rich micrometeorites got disregarded. This would weaken ***EMMA***.

Most of the alternative models still postulate the trapping of a "solar" neon component in the mantle. But this occurred at much earlier times during the formation of the building materials of the Earth, when they were formed in the early solar nebula. This neon got subsequently degassed quickly into the early atmosphere. Therefore, in both ***EMMA*** and these more "primordial" models, the initial high $^{20}Ne/^{22}Ne$ ratio of atmospheric neon (generally approximated by the SW value) has to be decreased to the present day atmospheric value of 9.8 through a preferential loss of ^{20}Ne. A favourite loss mechanism is the gravitational escape of a huge flow of hydrogen, fed by the dissociation of water, which dragged the excess of ^{20}Ne into space [8].

At this stage, we had to face the two difficulties of both finding a specific signature of AMM-neon in MORB and transferring a significant amount of it to the mantle. But we knew that ***EMMA*** rightly predicts (i.e., within a factor 2): – the total amounts of neon and nitrogen in the atmosphere, even though these two elements have not the same origin and show concentrations in AMMs differing by a factor of 100,000 [2]; – the iridium content of lunar samples [3].

A highly specific isotopic signature of micrometeoritic neon. We realized only recently that AMMs-neon has a unique "two components" signature. The first one is indeed well preserved in MORBs! It can be decrypted in figure 3 of reference [4], where the data clustering in the solar zone yield an average value of ~11.9. This ratio well fits the micrometeoric value of 11.8. The second component of the signature is the very low content of cosmogenic ^{21}Ne in AMMs [9] induced by galactic cosmic rays (GCRs). Thus, their $^{21}Ne/^{22}Ne$ ratio is very close to the "primordial" value of 0.029 —the excess of ^{21}Ne observed in MORBs is due to a nucleogenic ^{21}Ne component derived from U, Th decays [1].

This shows that the exposure times of AMMs to GCRs were much shorter than those of grains recycled within a regolith, either on the Moon or on the parent asteroids of gas-rich meteorites [9] —they accumulated high ^{21}Ne contents during their long residence time in the few top meters of a regolith . Therefore, the $^{20}Ne/^{22}Ne$ ratios of AMMs could have only been acquired during short flight times in the interplanetary medium, after their release from parent bodies "*denuded of a regolith*" (i.e., comets?).

In fact, SW and SEPs neon implantations are both requested to get this value of 11.8. Studies of SW ion implantation effects in silicates, such as olivine [10], show that this value reflects a *highly specific distribution of the flight times* of micrometeorites to the Earth. Indeed, SW neon quickly reaches a saturation concentration (a few times 10^{-5} cc STP/g) in less than 100 years of exposure in space —this is related to the sputtering of the grains by SW helium. But with a flux about 10,000 times smaller, and a much larger penetration depth, SEPs neon accumulates in ~100 µm size grains without reaching a saturation value. This decreases the SW $^{20}Ne/^{22}Ne$ ratio, which would reach a value of ~11.8 after an exposure to SEPs of ~0.5 Myr in space.

It would be a pure "miracle" whether this $^{20}Ne/^{22}Ne$ ratio found in AMMs, and related to their flight times to the Earth in the contemporary solar system, could have been incorporated at much earlier times, before the formation of the terrestrial planets, during the making of their building material in the early solar nebula —see the astonishing variety of neon loading processes in Ref.1). So, micrometeoritic solar neon was effectively transferred to the mantle. We have just to check that there was an ample supply of it, as to feed the huge losses expected during subduction.

An ample supply of micrometeoritic neon. In ***EMMA***, the total amount of solar neon (1.5×10^{16} g) deposited on the oceanic crust is delivered by unmelted micrometeorites, which represents ~25% of the incoming flux of micrometeorites. A "bulk" Earth content of micrometeoritic neon can be derived by diluting it to the total volume of the whole mantle, which represents about 0.46 Earth mass. This value is ~350 times larger than the estimated neon content of the upper mantle. Therefore, there was an ample reserve of micrometeoritic neon in the oceanic crust, as to feed the very inefficient process required to transfer ~0.3% of it to the mantle during subduction of the oceanic crust. *These observations simultaneously support the delivery of the same micrometeoritic neon to the atmosphere by the remaining fraction (~75%) of the incoming micrometeorites, which are volatilized and/or melted upon atmospheric entry*.

Challenges with the heavier noble gases. ***EMMA*** cannot account for the distribution of the other heavier noble gases in the atmosphere. The accretion formula presented in a companion paper [3], and the data reported by Osawa et al [11], predicts total amounts of ^{36}Ar and ^{84}Kr in the atmosphere, which are about 10 times and 100 times smaller than the observed quantities, respectively. Moreover, to further confuse this issue, this formula yields the right amount of xenon, within a factor 2! As we still do not understand the origin of this fit, we have to momentarily discard it, even though it would apparently gives a solution to the stumbling problem of the "missing" xenon!

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