SESSION 3

Volatiles on Earth, Venus, and Mars — Lessons from ROSETTA

Invited Lecture

DAY 2 – Feb.18, 2016
4:30 pm – 5:30 pm

ORIGINS OF VOLATILE ELEMENTS ON EARTH, VENUS AND MARS IN LIGHT OF RECENT RESULTS FROM THE ROSETTA COMETARY MISSION.

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Recent measurements of the volatile composition of the coma of Comet 67P/Churyumov-Gerasimenko (hereafter 67P) allow constraints to be set on the origin of volatile elements (water, carbon, nitrogen, noble gases) in inner planets' atmospheres. Analyses by the ROSINA mass spectrometry system onboard the Rosetta spacecraft indicate that 67P ice has a D/H ratio three times that of the ocean value and contains significant amounts of N_2, CO, CO_2, and importantly, argon. Here we establish a model composition of cometary composition based on literature data and the ROSINA measurements. From mass balance calculations, and provided that 67P is representative of the cometary ice reservoir, we conclude that the contribution of cometary volatiles to the Earth's inventory was minor for water (≤ 1%), carbon (≤ 1%), and nitrogen species (a few % at most). However, cometary contributions to the terrestrial atmosphere may have been significant for the noble gases. They could have taken place towards the end of the main building stages of the Earth, after the Moon-forming impact and during either a late veneer episode or, more probably, the Terrestrial Late Heavy Bombardment around 4.0-3.8 Ga ago. Contributions from the outer solar system via cometary bodies could account for the dichotomy of the noble gas isotope compositions, in particular xenon, between the mantle and the atmosphere. A mass balance based on 36Ar and organics suggests that the amount of prebiotic material delivered by comets could have been quite considerable – equivalent to the present-day mass of the biosphere. On Mars, several of the isotopic signatures of surface volatiles (notably the high D/H ratios) are clearly indicative of atmospheric escape processes. Nevertheless, we suggest that cometary contributions after the major atmospheric escape events, e.g., during a Martian Late Heavy Bombardment towards the end of the Noachian era, could account for the Martian elemental C/N/^{36}Ar ratios, solar-like krypton isotope composition and high $^{15}N/^{14}N$ ratios. Taken together, these observations are consistent with the volatiles of Earth and Mars being trapped initially from the nebular gas and local accreting material, then progressively added to by contributions from wet bodies from increasing heliocentric distances. Overall, no unified scenario can account for all of the characteristics of the inner planet atmospheres. Advances in this domain will require precise analysis of the elemental and isotopic compositions of comets and therefore await a cometary sample return mission.