SULFUR OUTGASSING BY VOLCANOES ON MARS: WHAT REALLY MATTERS. F. Gaillard[1] and B. Scaillet[1], [1] CNRS-Université d'Orléans, (ISTO, 1a rue de la Ferollerie, 45071 Orléans, France ; gaillard@cnrs-orleans.fr).

Introduction: Sulfate-dominated sedimentary deposits are widespread on the surface of Mars, which contrasts with the rarity of carbonate deposits, and indicates surface waters with chemical features drastically different from those on Earth [1-4]. While the Earth's surface chemistry and climate are intimately tied to the carbon cycle, it is the sulfur cycle that most strongly influences the Martian systems [4,5]. The presence of sulfate minerals observed from orbit and in-situ via surface exploration within sedimentary rocks and unconsolidated regolith traces a history of post-Noachian aqueous processes mediated by sulfur. These materials likely formed in water-limited aqueous conditions compared to environments indicated by clay minerals and localized carbonates that formed in surface and subsurface settings on early Mars [3,4,5]. The volatile inventory is tightly related to the enduring magmatism that has been produced throughout the Martian history [7,6,8]. Constraining the timing of sulfur delivery to the Martian exosphere, as well as volcanogenic H_2O is therefore central, as it combines with volcanogenic sulfur to produce acidic fluids and ice [9]. Here, we reassess and analyze how volcanic activities may have transferred igneous sulfur into the exosphere and evaluate the mass transfers and speciation relationships between volcanic sulfur and other outgassed products such as water and carbon dioxide.

Conditions enhancing sulfur outgassing: How much of C-H-S-Cl volatiles are stored in the Martian mantle and how much of these mantle volatiles can be transferred to the surface by magma ascending through the crust is a fundamental topic [9,10,11,12,13]. However, the amount of sulfur outgassed by volcanoes to the atmosphere is chiefly controlled by other parameters, that are, by order of importance, 1- the atmospheric pressure at venting conditions [14], 2- the magma oxygen fugacity [15], 3- the amount of other volatiles (H-C-Cl…) being present in the ascending magma [9]. In comparison to these three parameters, whether the basalts sourcing the volcanic degassing are sulfur rich or not is of secondary importance.

Pressure of degassing. We show that low venting pressure is required to degas significant amount of sulfur. Degassing at pressure ≥1 bar release negligible sulfur amounts and gases are H_2O-CO_2-rich, whereas lower venting pressure, similar to the present-day atmospheric pressure enhances the degassing of sulfur.

Oxygen fugacity. We show that oxidizing conditions favor the outgassing of sulfur. Maximum efficiency of sulfur outgassing is obtained at the upper range of Martian magmatic fO2. According to estimation from Martian meteorites, this yields conditions close to one log-unit below the Fayalite-Magnetite-Quartz redox buffer [16,17]. If most Martian magmas are reduced, that is equal to or lower than the oxygen fugacity of the iron-wustite buffer [13], the amount of sulfur released by degassing tends to zero implying that volcanic gases are dominated by H_2 and CO.

C-O-H volatiles. We have little constraints on the amount of carbon and hydrogen being present in the Martian mantle and the existing tentative estimates indicate that the cumulated amount of CO_2 released by volcanoes might have not been sufficient to sustain enough green house warming during the early Martian history [13]. If low CO_2 [13] and low H_2O content [12] is the rule for the Martian magmatism, little amount of sulfur is transferred from the melt to the atmosphere, but the volcanic gases would be sulfur-rich.

Conclusion: Mass transfers of sulfur by volcanic degassing can conservatively explain the abundance of surficial sulfate minerals: considering the Hesperian and Amazonian volcanism only [6] and assuming that 500 ppm S has been liberated by these melts, that is enough to form a 1 meter-thick uniform layer of $CaSO_4$ covering the entire Martian surface. Five hundred ppm of sulfur can be relased as SO_2 from H and C depleted melts at 0.1 bar and moderately reduced conditions; the corresponding volcanic gases would be S-rich, C-H-poor and would produce strongly acidic brines.

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