A NEW MECHANISM FOR H_2O PRECIPITATION ON AN EARLIER MARS.
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Introduction: There is considerable evidence derived from both orbital observations of geomorphology and geochemical and mineralogical investigations by the Mars Exploration Rovers (MER) that suggests condensed H_2O was present at some location on the Martian surface in the past history. Orbital measurements by the Gamma Ray Spectrometer on board the Mars Odyssey spacecraft also indicate that abundant hydrogen, most probably in the form of ground ice is of still present in the shallow subsurface over much of the planet. In the absence of a massive early greenhouse effect, the wide spread precipitation of H_2O by rain appears improbable based on the one-third lower luminosity of the sun that is thought to have characterized this period. For this reason, it is interesting to consider potential alternative mechanisms for long distance atmospheric transport and precipitation of H_2O that may have occurred even under much colder early climate conditions.

Icy volcanic ash fallout: The eruption of ancient Martian volcanoes likely resulted in the atmospheric introduction of magmatic H_2O (as water vapor) and ash aerosol substrate for its prompt nucleation and condensation under presumed low temperature early environmental conditions. High altitude winds at altitude could have then transported the icy ash over considerable distances, allowing it to fall out over large regions of the planet.

Contemporary Martian dust storms illustrate the potential extent of volcanic ash transport following a volcanic eruption. Multiple episodes of eruptive activity followed by the atmospheric transport precipitation of icy ash may have resulted in the formation of thick deposits of frozen sediment that acted as surface reservoirs of H_2O. Mobilization of this H_2O may then have occurred by geothermal melting or by viscous deformation of the ice-rich sediment.

This model has terrestrial analogs that provide a basis for evaluating the general concept of production of icy ash in volcanic eruptions and the expectation of large area fallout for application to Mars. The expected early Mars thermal environment is likely to have enhanced this mechanism rather than preclude it. This mechanism may also help to explain recent MER geochemical findings about Mars.

Terrestrial volcanic examples: Ice-rich clouds during volcanic eruptions have been observed for occurrences at Rabaul in 1994 [1], Soufriere Hills, Montserrat in 1997 [2], and Hekla, Iceland in 2002 for which extensive data was recorded [3]. Among the evidence for the role of condensed ice in the evolution of the resulting volcanic ash cloud are satellite observations that revealed an increase of the radii of suspended particles over the first 36 hours after eruption [4]. The combination of the increased size and lower density of these particles would have enhanced their atmospheric transport whether on Earth or Mars. The Hekla event is of particular interest for the mechanism proposed for Mars because magmatic H_2O is considered the primary source for icing- amounting to an estimated 10 Gkg in the volcano's initial 10-11 km high column [3]. Similar magmatic releases are likely to have accompanied early Martian eruptions.

The question of how far a distance from the volcanic eruption the ice-coated ash might be transported can be addressed by the geological record of ash fall from past eruptions of the Yellowstone and Long Valley calderas. The 2 Ma BP ash fall from Yellowstone extended as far as 1600 km while that from the 700 Ka event carried toward the southeast for 2200 km [5]. Fall times for spheres and disks have been calculated at pressures of 2 and 7.5 mb on Mars and for spheres at 950 mb on Earth in the course of study of the decay of martian global dust storms [6]. Those results show a trend that tends to converge at a common fall time of $2\text{-}9 \times 10^4$ s for a particle of R=10 μm. This suggests a fall out over 10 km in altitude would occur on time scales of >50 hr. A high altitude wind of 50 km/s could transport icy ash as far as 2500-3000 km away from an eruption, and even greater distances are conceivable. There are indications in the literature for ash falls on Mars creating thick deposits [8-10].

Other considerations regarding Mars: For Martian volcanic eruptions it is expected that sulfur in the forms of SO_2 and H_2SO_4 would accompany H_2O as a component coating ash at cryogenic temperatures. This type of composition is consistent with the findings of S by the APXS and jarosite through Mössbauer spectroscopy by the Opportunity rover at Meridiani Planum [6,7].as well as with the measurements conducted by the Spirit rover at Gusev crater. Post-deposition melting of the H_2O ice component whether by local geothermal conditions or even solar heating would be expected to lead to interesting aqueous chemistry.

Finally what has been proposed here in association may have similar implications for impacts.

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