BASALTIC VOLCANIC ACTIVITY ON MARS: NUMERICAL MODELLING OF LAVA FOUNTAIN ERUPTIONS; **S. A. Fagents**, Centre for Earth and Planetary Studies, National Air and Space Museum, Smithsonian Institution, Washington, DC 20560, and **L. Wilson**, Environmental Science Division, Institute of Environmental and Biological Sciences, Lancaster University, Lancaster LA1 4YQ, UK.

Numerical modelling of explosive basaltic eruptions on Mars indicates that widely dispersed deposits of cooled scoria should be the common result of steady lava fountain eruptions. This raises intriguing questions regarding the formation of martian lava flows, since explosive activity should be more common than on Earth as a result of the low martian atmospheric pressure and gravitational acceleration. Provided that martian flow-forming magmas are not essentially devoid of volatiles, flows may be fed by highly collimated fissure eruptions. Alternatively, unsteady, surging eruptions may create suitable near-vent conditions for lava flows to be formed. In either case, we anticipate that extensive mantles of pyroclastic material should commonly be associated with the source regions of fountain-fed lava flows, but which may not be of a sufficiently great thickness to allow identification from current Viking image data. The model results thus provide some predictions for testing with data from future missions to Mars.

A numerical model has been formulated to describe the physical processes involved in steady basaltic lava fountain eruptions [1,2]. The model describes the processes of magma ascent, gas exsolution and expansion, magma fragmentation, ejection of pyroclasts from the vent and their paths through the eruption column and atmosphere, such that, for any chosen set of initial parameters, the extent and likely nature of the resulting volcanic feature can be obtained. For any given planet, it is found that the magmatic gas content and magma mass flux most strongly influence the dynamic structure of the lava fountain and pyroclast size distribution (p.s.d.), which in turn determine the local pyroclast temperature and accumulation rate at any distance from the vent.

On Mars, it seems likely that explosive activity will be rather more common than on Earth as a result of both the low atmospheric pressure environment and the low gravitational acceleration [3]. These two factors combine to facilitate the exsolution and expansion of magmatic volatiles. This suggests that high eruption velocities would be achieved, and the model predicts velocities of between 200 and 300 m s^{-1}, compared to ~100 m s^{-1} for similar mass fluxes and volatile contents on Earth.

The low martian pressure and gravity environment also affects the p.s.d. expected to be produced for any set of initial conditions. First, a more thorough fragmentation of the magma is expected since the martian physical environment allows a greater degree of bubble nucleation and gas expansion. In addition, the low density of the erupting volcanic gas is unable to support clasts larger than a few centimetres in size [2], despite the higher expected eruption velocities. The ejected p.s.d. is therefore likely to be finer than on Earth, even if larger clasts are initially produced by the fragmentation process.

Under the current formulation, the model predicts vigorous, tall fountains and consequent widely and thinly dispersed accumulations of pyroclasts. The long trajectories and fine clast sizes suggest that clasts may undergo significant cooling which, together with the low accumulation rates, implies that the resulting volcanic feature will consist of discrete, cooled scoria forming a deposit of low relief. The table below gives some results for eruptions of magma containing 1 wt% H_2O. It appears that greater accumulation rates are possible for fissure eruptions, but it is still uncertain whether these are sufficient for clast coalescence and flow formation to occur.

Mass Flux	**Vent Geometry**	**Extent of Deposit /m**	**Max. Accumulation Rate /mm s^{-1}**
10^6 kg s^{-1}	Cylinder	1600	1.0
10^4 kg s^{-1}	Cylinder	1150	0.005
10^5 kg s^{-1} m^{-1}	Fissure	440	2.0

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Many questions arise concerning the mode of formation of the extensive lava flows that have been identified in the northern lowland areas of Mars (e.g. [4]). There is an apparent paradox arising from the inference that the southern explosive volcanism occurred much earlier than the flow-forming activity in the north [5]: the mass of Mars' atmosphere is thought to have decreased over time, so that explosive activity should have been be more common under recent atmospheric conditions, since only a few ppm by weight of volatiles is required for magma fragmentation [6].

Were martian flow-forming magmas essentially volatile-free? If so, this may have implications for Mars' volatile budget or may imply periods of sustained degassing of magma reservoirs at shallow depths in the crust. If volatiles were present why do we not commonly observe ashfall deposits or pyroclastic halos in source regions of lava flows?

To some extent, these questions may be answered with continued modelling. A lava fountain model may not be the most appropriate approach to martian explosive eruptions since there appears to be only a narrow range of conditions that could lead to the formation of true lava fountains on Mars [2]. The anticipated fine p.s.d.s may mean that explosive activity is better treated by a plume model (e.g. [7]). Alternatively, if larger clasts are initially present in the p.s.d., but cannot be supported out of the vent, an unsteady, surging eruption may occur: clasts will tend to collect at various depths in the conduit where they can be supported by the gas. This leads to a net narrowing of the conduit such that the product ρu^2 (where ρ is the local gas density and u the velocity) increases to the point where the obstruction can be removed [8]. In this way a cyclic perturbation in the velocity and pressure distribution is produced in the conduit as it is intermittently cleared of accumulating larger clasts. The velocities imparted to the clasts are likely to be low, causing short trajectories and larger accumulation rates at the ground surface, which may provide a mechanism for clast coalescence and the formation of lava flows.

However, there remains the problem of why extensive halos of fine material are not seen to accompany lava flow formation. In the Alba Patera region of Mars, lava flows are seen commonly to extend to many hundreds of km in length [9]. Adopting an expression relating the maximum length of cooling-limited lava flows to their volume eruption rates [10], a mass flux of $\sim 5 \times 10^6$ m^3 s^{-1} is obtained for a 300 km long lava flow. If as little as a tenth of this volume flux consists of additional fine material injected into a convecting eruption cloud, the cloud height is found to be ~25 km [3]. The width of the deposit produced by fallout of ash from the eruption cloud is roughly equivalent of the height of the cloud [11], so an eruption of 10 hours duration might therefore produce a mantling deposit of order 10 m thick (over an elliptical depositional area with longest axis 100 km), and one lasting for 10 days would produce a deposit >200 m thick. That very few ashfall deposits have been identified on Mars, when the modelling indicates that they should be common, remains a puzzle. The ease of erosion of such material may in part explain the paucity of readily identifiable ashfall deposits. The results presented thus provide impetus for further modelling, as well as some predictions for testing with high-resolution image data from future spacecraft missions, in order that the mode of formation of extensive lava flows on Mars may be more clearly determined.

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