EMPLACEMENT MECHANISMS OF VOLCANIC MATERIALS ON MARS; **S.A. Fagents,** Department of Geology, Arizona State University, Box 871404, Tempe, AZ 85287-1404.

The physical environmental conditions on Mars suggest that basaltic magmas containing even small amounts of typical volatile species should commonly have erupted explosively. Theoretical considerations indicate that enhanced volatile exsolution and expansion, together with the increased atmospheric trajectories of pyroclasts expected under martian conditions, should have promoted distribution of fine material over great distances. This implies that widespread pyroclastic deposits should be common in Mars' geologic record, but the identification of numerous lava flows and effusively constructed volcanic edifices indicates otherwise. Lava flows may have formed effusively on Mars if the magma reaching the surface of the planet was essentially devoid of volatiles; either as a result of depletion in the magma source region, or as a consequence of gas-loss during storage or transport. However, consideration of the details of the mechanisms of ascent and eruption of basaltic magmas under martian planetary conditions reveals that it may be possible for lava flows to form as a by-product of explosive volcanism in highly overpressured explosive eruptions.

The low atmospheric pressure and gravity environment of Mars has important consequences for almost every process involved in the generation, ascent, storage, eruption and emplacement of volcanic material [1-4]. Exsolution and expansion of magmatic volatiles would be enhanced with respect to the Earth, such that under current atmospheric conditions, only 5 to 10 ppm of H_2O or CO_2 is expected to cause fragmentation of an ascending magma and subsequent explosive eruption (c.f. <0.06 wt% H_2O on Earth) [5]. The fragmented products would be accelerated to greater speeds than on Earth which, together with the low atmospheric density and low gravity which enhance the atmospheric trajectories of erupted pyroclasts, ensures a wide dispersal of the material.

Given that factors appear to conspire to produce explosive volcanism on Mars, why are so many indications of effusive volcanism present? One possibility is that flow-forming magmas were essentially volatile free. This may be a result of extreme volatile depletion in the source region. However, evidence from SNC meteorites suggests the possibility of a significant amount of water in the parent magmas [6-8]. Under favorable conditions, magmatic gases may alternatively have been lost during magma storage or transport at shallow crustal levels. However, while these are possible mechanisms for gas loss, it is unlikely that they would have operated in *every* eruption on Mars. This is certainly not the case on Earth where explosive eruptions of basalt are common as lava fountains, even though terrestrial conditions are not as favorable for magma fragmentation as those on Mars.

Numerical modeling of the processes involved in basaltic lava fountain eruptions has revealed that lava fountains analogous to those on terrestrial basaltic volcanoes may not commonly have operated on Mars [4,9]. Typical terrestrial lava fountains are weakly explosive, ejecting large clasts to relatively short distances; lava flows and spatter deposits are common products. The gas driving the eruption is likely to decompress to atmospheric pressure in the vent, accommodated by flaring of the conduit [10]. If this were the case on Mars, however, the density of the gas would be so low that it could not support clasts greater than ~1 cm in size out of the vent. The great majority of clasts would be much finer than typical lava fountain products, which would promote a more vigorous style of eruption, possibly similar to plinian-style activity on Earth.

However, reconsideration of the processes involved during explosive eruptions on Mars suggests that complete decompression of the emerging fluid is unlikely for almost all feasible combinations of magma volatile content and mass flux (very low contents and fluxes would be required). For higher values of these quantities, the fluid is likely to emerge at pressures far exceeding that of the ambient atmosphere as a result of restriction of lateral expansion of the gas by the conduit walls. The most extreme case of vent overpressure occurs when conduit walls are vertical: choked flow occurs, in which the exit velocity is limited to the local sonic velocity [10].

In cases when the gas-particle mixture emerges overpressured, results of theoretical modeling indicate that clasts much larger than 1 cm can be ejected. Figure 1(a) shows the exit pressure and velocity in the erupting fluid for cases such that (1) flow is choked and (2) flow is able to expand somewhat during ascent (accommodated by vent flaring). Curve (3), for comparison, shows the unrealistic case of flows decompressed to atmospheric pressure: this is unlikely to be achieved within the conduit. Despite the fact that the eruption velocity is lower for greater exit pressures, it is the product of the gas density and the square of the gas-clast relative velocity (ρu^2) that is critical for determining clast ejection, since a clast will just be ejected when the upward drag force exerted on it by the gas ($1/2 C_d A \rho u^2$, where C_d is the drag coefficient) just exceeds the downward gravitational force (mg) acting on a clast of cross-section A and mass m.

EMPLACEMENT OF VOLCANIC MATERIALS ON MARS; FAGENTS S.A.

Figure 1(b) shows the largest clast that can be ejected in each case, provided clasts of these sizes are produced by the fragmentation process. This assumption remains open to debate since the effects of planetary environment on fragmentation processes are essentially unknown. Nevertheless, Figure 1 serves to illustrate that the greater pressure (and hence density) in an emerging flow is capable of supporting much larger clasts out of the vent.

Above the vent the overpressured, supersonic flow will decompress to atmospheric pressure through a complex series of shocks. Large clasts will rapidly decouple from the gas and fall close to the vent. The insignificant cooling undergone by large clasts during short trajectories, together with associated high pyroclast accumulation rates, is likely to produce spatter-fed lava flows analogous to those that form around lava fountains on Earth. Finer material may be incorporated into a convecting column above the supersonic decompression region and distributed over much wider areas. Thus it may be anticipated that lava flows may form in explosive basaltic eruptions, simultaneously with the production of eruption plumes. Ash deposits associated with lava flow source regions have not commonly been identified on Mars, although many young flows have obscure vent regions [11-13]. In addition, processes may have operated to subdue or redistribute this material. For example, eruptions from Tharsis volcanoes may have contributed fine material to the Stealth region [14-16]. Further detailed numerical modeling of the above-vent flow processes and the subsequent dispersal of pyroclastic material will place more quantitative constraints on the conditions required for lava flow formation, and on the fate of fine material introduced into the martian atmospheric circulation.

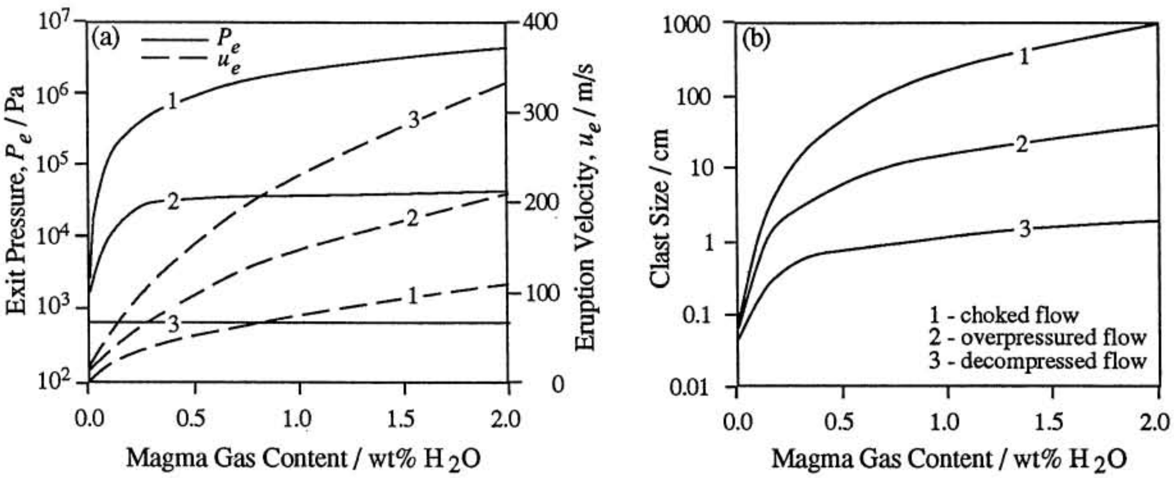

Figure 1. (a) Maximum ejectable clast size as a function of magma gas content for planetary conditions on Mars. Each curve illustrates the results for a spherical clast of density 1000 kg m^{-3}. Clast sizes are smaller for greater densities and lower degrees of sphericity. (b) Pressure (left axis, solid curves) and eruption velocity (right axis, dashed curves) of emerging volcanic fluid. For both graphs 1=choked, highly overpressured, sonic flow (vertical conduit walls); 2=overpressured supersonic flow (for which the conduit is allowed to flare outwards somewhat towards the surface); 3=values that would be attained if the flow was able to decompress to atmospheric pressure (unlikely to happen within the conduit). Each curve shows the results for a magma mass flux of 10^6 kg s^{-1}; each quantity plotted is somewhat reduced for lower mass fluxes.

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