VESICULARITY AND FRACTURE SPACING OF ROCKS ON DEGRADED LAVA FLOWS: APPLICABILITY TO ESTIMATES OF ATMOSPHERIC DENSITY ON EARLY MARS.

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Introduction: A study of rocks on older terrestrial lava flows supports a characteristic correlation between rock shapes, rock dimensions, and rock surface textures. Small rocks tend to have numerous small vesicles and are more rounded than larger rocks, whereas larger rocks tend to be more angular, and contain fewer and larger vesicles. The case can be made for a similar distribution of fractures and textures for the surface of Mars from previous landed science missions [*1, 2, 3, 4*]. The correlation may be a result of two depth dependent effects: (1) joint spacing in lava flows arisng from deviatoric stress in cooling crusts and (2) vesicularity changes following the hydrostatic influences predicted from the gas law [4, 5]. Documenting the dimensions and vesicularity of rocks encountered in future landed science missions may enable order-of-magnitude estimates of early atmospheric density.

Terrestrial Data: Planetary analog studies have focused on relatively young lava flows that retain primary flow morphologies. But the normal process of degradation associated with mechanical weathering rapidly alters most lava flow surfaces. Degradation of lava flows in arid settings on Earth (and Mars) in the absence of fluvial erosion, occur through freeze-thaw and thermal cycling, and from the flux of aeolian materials in and out oif the surface. These infuences tend to reduce the relief on lava surfaces. Typical older lava surfaces are characterized by relatively flat to rolling topography and scattered rocks and fines.

Data for many flow surfaces show that vesicle abundance in surface rocks commonly decreases and vesicle size increases proportionately with the size of the block. Vertical outcrops show that fracture spacing characteristically increases with depth and that blocks are probably derived from previously jointed outcrops. A survey of possible mechanisms for generating the observed depth dependent fracture spacing concludes that the fractures that define individual rocks of vesicular texture are the result of deviatoric stresses in the crust of lava flows. The stresses arise from motions associated with inflation and deflation of the flow interiors (Figure 1). The separation of fractures scales with the thickness of the crust at the time of deformation. In contrast, the fractures characteristic of lava flow interiors is defined by cooling stresses that result in the more widely recognized patterns of jointing in dense lava flow interiors ("columnar jointing"). As a result, fractures common to vesicular rocks may generally differ in distribution from those of non-vesicular rocks.

Discussion. Vesicle dimensions within lava flows are a function of initial lava flow volatile retention,

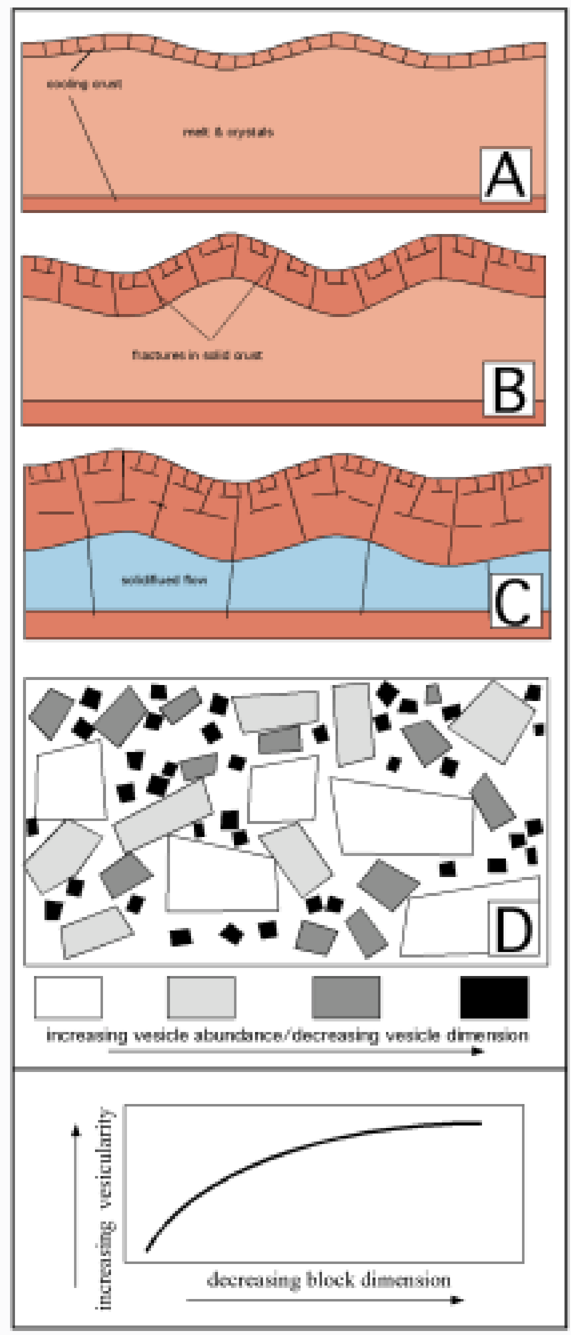

Figure 1. A, B, C. Hypothesis for the development of joint spacing in lava flows that increases with depth. D. The distribution of blocks derived from disrutiopn of the flow section in along joint planes. C. Note that the smaller fragments will characteristicaly have more small vesicles. The corresponding general depth-vesicularity curve could be reconstructed from D.

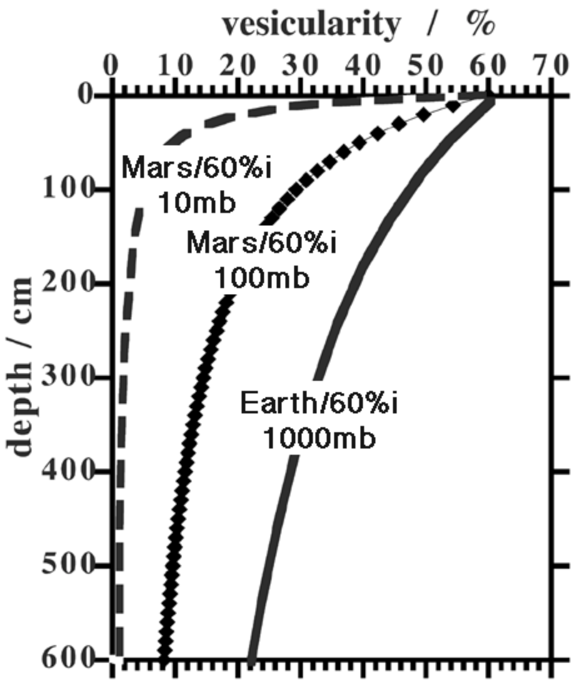

Figure 2. Vesicularity profiles for lava flows of similar initial vesicularity on Earth and Mars.

pressure at the crust-melt interface, and rate of solidification (time available for bubble coalescence) [*6*]. The gas law controls the vesicularity at a given level within a lava flow. Because the pressure that satisfies the ideal gas law has both atmospheric and hydrostatic terms, differences in vesicularity are expected to be relatively sensitive to differences in atmospheric pressure in the upper lava section [7*; 8]*.

The atmospheric pressure of Mars is two orders of magnitude less than that on Earth, and terrestrial lava volatile abundances (~0.05 wt.%) in martian lavas would yield significantly higher vesicularities than that observed. Instead, volatile abundances approaching equilibrium degassing are likely, or several ppm. For similar initial vesicularities, the vesicularity versus depth curve for martian lavas under current atmospheric density is predicted to result in a much thinner vesicular zone and more vesicle-free interior. Higher atmospheric pressures will result in a different vesicle distribution in surface rocks (Figure 2.) This is a potential means of documenting the broad characteristics of martian atmospheric pressure during the early history when many plains lavas were emplaced.

Application of this method depends on knowledge of vesicle depth distributions. Likely data for Mars landed science missions, is instead rocky debris. Outcrops and lava vertical sections will be rare. In addition to the overall rock-size-vesicle density population, the vesicle distribution function in single blocks may contain some information about the relative depth. For example, a single rock in Pathfinder rover image data (Souffl) (Figure 3) exhibits the characteristic curved distribution function typical of the lower part of an upper vesicular zone [4].

Conclusions. Block size is found to be related to fracture spacing developed from deviatoric stresses in cooling lava crusts The mutual depth dependence of block size and vesicularity enables three important constraints on rocks observed on surfaces: (1) for a given rock derived from disruption of a lava flow surface the relative original position of the rock within the pre-disturbed lava section may be estimated; (2) measurements of vesicle size and abundance placed in the context of depth enable estimates of vesicularity-depth distributions; and (3)general vesicularity- depth relations may be compared with models of vesicularity based on the ideal gas law enabling constraints on the initial volatile abundances and on the relative magnitude of the atmospheric pressure at the time of emplacement. For Mars, the latter may be one of the few ways to estimate the climatic conditions during the early geologic history, an important goal of current research on Mars.

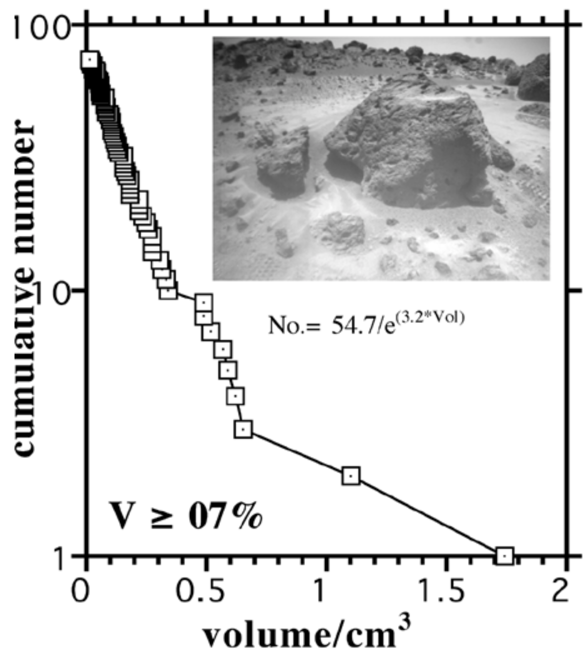

Figure 3. Vesicle distributions in single blocks such as Souffl (pathfinder) . The vesicularity is relatively low for a block of this dimension. Without additional data, however, the overall depth-dependence cannot be established in order to construct curves as in Figure 1.

References. [1] *Sharp and Malin, Geol. Soc. America Bulletin*, 95, 1398-1412, 1984; [2] *Garvin et al., The Moon and Planets*, 24, 355-387, 1981; [3] *Much et al,. Jour. Geophys. Res.*, 82, 4452-4467,1977;[4] *Crumpler, Lunar Planet Sci.*, XXX, 2001; [5] *Crumpler et al., Lunar Planet Sci.*, XXVIII, 1999; [6]*Sahagian et al., Bull. Volcanol.*, 52, 49-56, 1989; [7]*Cashman and Kauahikaua, Geology*, 25, 419-422, 1997; [8] *Sahagian and Maus,Nature*, 372, 449-451, 1994.