SPIRIT: OBSERVATIONS OF VERY VESICULAR BASALTS IN THE COLUMBIA HILLS, MARS AND SIGNIFICANCE FOR PRIMARY LAVA TEXTURES, VOLATILES, AND PALEOENVIRONMENT.

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Introduction: Extremely vesicular basalts encountered by Spirit within the Columbia Hills on the Gusev crater floor represent one of the more unusual lithologies of the Mars Exploration Rover mission. These basalts offer a unique potential for insight into the volatiles associated with martian volcanism, paleoclimate, and eruptive processes on Mars in general. Numerous examples of basaltic blocks also bear textures diagnostic of basal and possible upper quenched surfaces leading to the tantalizing possibility of extracting paleobarometric information [1] (past martian atmospheric pressure and climate).

On-going examinations of the unusual examples of highly vesicular basalt are continuing in an effort to (1) extract volatile and environmental characteristics at the time of emplacement, and (2) to ascertain whether near vent processes are required, or whether they represent a more widespread behavior of certain gas-charged lavas in the martian environment.

Significance of High Vesicularity: The significance of vesicles in understanding the volatiles paleoenvironment of Mars has been discussed briefly in previous reports [*1*]: Vesicles are “fossilized” bubbles (largely H_2O, CO_2, CO) [*2*,*3*,*4*] exsolved on ascent and decompression from the melt source and, isobarically, by crystallization of anhydrous minerals during initial solidification and crystal growth [*5*]. Bubbles in silicate melts grow through a combination of gas diffusion and by coalescence of two or more bubbles until solidification occurs. The gases themselves may originate through both juvenile and non-juvenile sources. Volatiles are known to be especially high in some alkali basaltic magmas [e.g., *6*]. The high alkali nature of the Inner Basin basalts [*7*] may be significant in this respect. Gases introduced in the shallow environment through interaction with any volatile saturated zone can also contribute to excess vesiculation as well, a process characterized by distinct ash-rich deposits (tuff

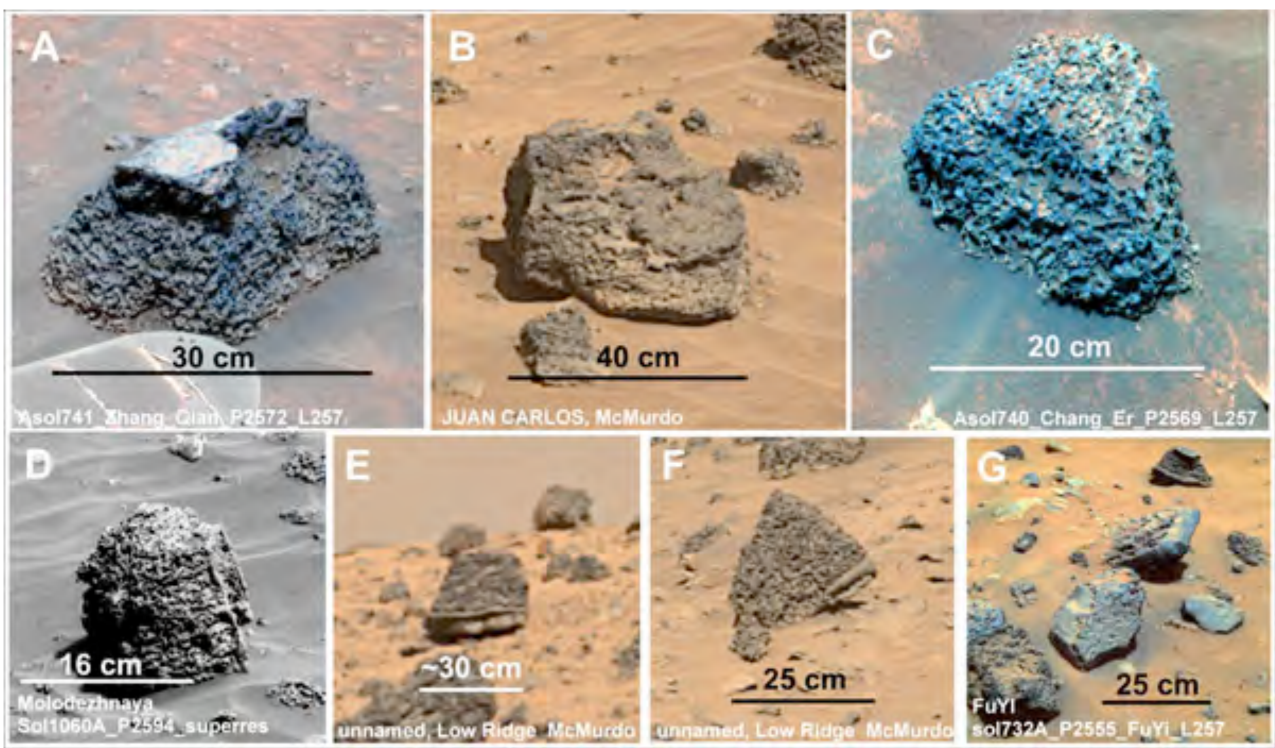

Figure 1. Examples of the three to four distinct vesicular basalts textures encountered during the traverse along Mitcheltree Ridge. A, D, E. F. and G all represent high vesicularities with boundaries of planar non-vesicular material. B is representative of the exterior of many irregular blocks “coated” with less vesicular material. C is representative of many small samples that have been extremely modified by wind-abrasion.

rings, maars). And because of the unique characteristics of basaltic eruption dynamics on Mars [*8*], a magma sufficiently enriched in juvenile volatiles, as suggested for the alkali basaltic compositions of the Inner Basin [*7*], may be difficult to distinguish from the case of non-juvenile enrichment in the shallow environment. Three small samples of vesicular basalt have been examined with one or more Athena instruments (Masada [A723], GongGong [A739], and Esperanza [A1059]). Wind abrasion was significant in all of these. APXS analyses imply primitive compositions consistent with very low viscosities. Retention of abundant gas bubbles at these viscosities implies abundant volatiles were present.

Observed Vesicular Basalt Samples: Between sols 633 and 805 Spirit descended from the summit of Husband Hill and entered the "Inner Basin". On its way to Home Plate it traversed the margins and interior of Lorre and Mitcheltree Ridges, broad topographic ridges on the valley floor. Some of the most vesicular basaltic rocks yet encountered on Mars occur within the Inner Basin along Mitcheltree Ridge and on Low Ridge south of Home Plate, the site of Spirit's winter campaign. These Irvine-class basalts appear to have been undermined by general deflation of softer sediments and are topographically inverted, i.e., they appear to cap Mitcheltree Ridge.

Textures and morphologies are diverse (**Fig. 1**). In addition to extreme vesicularity of rocks along Mitcheltree Ridge, many samples preserve fluidal textures or variations in vesicularity, tabular zones of low vesicularity, and potential quenched surfaces. The latter is of particular value because it may represent a surface that was in contact with the environment (eitherambient atmosphere or surface) at the time of formation.

Many fragments have migrated down slope, revealing characteristics of the interior of the original basalt. Orcadas (**Fig 2**) is note worthy because the near face preserves a textbook texture of a basal quenched surface. This rock was imaged with Pancam super resolution from two locations, as well as several orientations with Navcam.

Discussion. High vesicularities are of particular interest for several reasons. Vesicularity, the total vesicle volume per unit volume of dense matrix, within most lava flows agrees well with vesicularity estimates based on the ideal gas law [*9*]. Vesicularity at the surface of a lava flow is probably a function of initial lava vesicularity established by degassing during eruption equilibrating to a gas volume significantly less than that necessary for fragmentation (<70 percent) [*10*], i.e., by the eruptive process itself. Lava flows generally represent the degassed (equilibrated to less than 70% vesicularity) portion of the erupted magma.

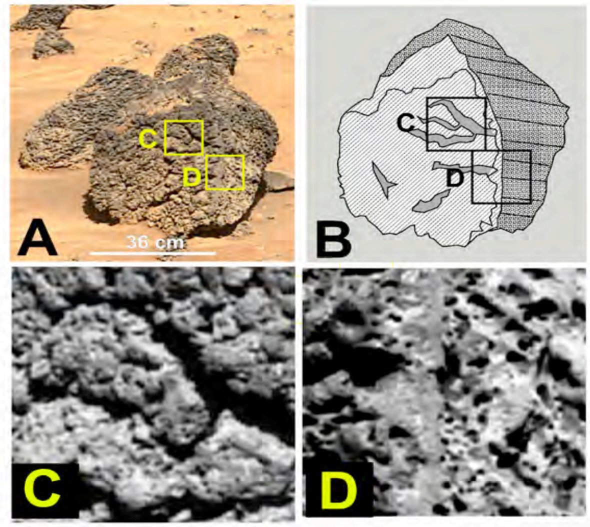

Figure 2. A. Orcadas, a basaltic block on the north flank of Low Ridge, Columbia Hills as imaged by Pancam. Part of the 360° "McMurdo pan". Facing side consists of basal quench texture (planar accordance and sub-polygonal patterns of scoriaceous knobs). **B.** Sketch showing general geometry of sample. Shaded sided is extremely vesicular. Near face contains basal fused "breccia" texture and low vesicularity. **C.** Basal quenched texture. From sol899 Pancam super resolution frame. **D.** Contact between the basal texture and interior basal vesicular zone. C and D are from sol899 Pancam super resolution frame.

Degassing is efficient and near-surface vesicularities are similar regardless of surface pressure [*1*], with the exception of vent-proximal materials. Vent-proximal parts of lavas, rootless flows, and agglutinates can be sufficiently cooled during fragmentation and transport, and of sufficient yield strength, to retain unusually large gas contents and extreme, nearly frothy, vesicularities. Secondary processes such as flowage and shear within semi-fluid frothy magmas of vent-proximal spatter and agglutinates, and accumulation of successively fluid clasts of variable gas content, can cause bubble collapse and result in retention of selvages of non-vesicular basalt within extremely vesicular partials of magma (such as that in Fig 1A, D, E, F, and G).

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