PETROGRAPHIC TEXTURES AND INSIGHTS INTO BASALTIC LAVA FLOW EMPLACEMENT ON EARTH, THE MOON, AND VESTA. R.C.F. Lentz[1] and G.J. Taylor[2]; [1]Department of Geological Sciences, University of Tennessee, Knoxville TN 37996-1410; rlentz@utk.edu, [2]Hawaii Institute of Geophysics and Planetology, University of Hawaii, Honolulu, HI 96822.

Introduction: Basaltic petrographic textures are strongly influenced by the conditions and processes during eruption and flow emplacement. Crystallization and nucleation are both effected by variables such as eruption and strain rate, as well as degrees of insulation, degassing, and undercooling. Conversely, the progress of crystallization can effect the emplacement process: for example, substantial crystallization will increase viscosity and yield strength, greatly affecting the rheology of the lava and its behavior during emplacement. This intimate relationship between crystallinity and the eruptive process prompted us to compare petrographic textures in terrestrial, lunar and eucrite basalts in an effort to reveal details of volcanic processes on these extraterrestrial bodies.

Hawaiian Pahoehoe vs. 'A'a: The two dominant types of terrestrial basaltic lava flows, pahoehoe and 'a'a, are marked by different emplacement histories and distinctive petrographic textures [1]. Pahoehoe is associated with low eruption rates (<5 m^3/s; [2]), strain rates [e.g. 3], and viscosities. The fluid lava generates a smooth, continuous crust which insulates the flows and allows for the formation of internal tube systems for long distance transport of lava. Inflation causes originally thin lobes (typically 10-30 cm thick) to grow many meters thick as new lava is injected beneath the solidified crust. In comparison, 'a'a is associated with higher eruption rates (>5-10 m^3/s; [2]), viscosities, and strain rates [3,4]. Typically, 'a'a is transported in open channels with vigorous enough flow that an insulating roof cannot develop. Cooled chunks of clinker and disrupted crust are often mixed into the interior of the 'a'a, causing cooling throughout the flow [5].

The differences in the petrographic textures between pahoehoe and 'a'a are clearly linked to their emplacement histories. Pahoehoe is characterized by a subophitic, intergrown network of medium-sized pyroxene and plagioclase laths, with fine-grained pockets of late-stage minerals interstitial to the two main phases (Fig. 1a). In contrast, 'a'a displays an almost porphyritic texture, with a fine-grained groundmass of pyroxene and plagioclase and fewer, larger grains of plagioclase and pyroxene (here called "microphenocrysts") (Fig. 1b). Internal heat and fluidity in pahoehoe flows leads to fewer crystal nuclei and favors the growth of larger grains. In 'a'a, the internal cooling throughout the flow during transport and emplacement favors early production of many crystal nuclei and, ultimately, growth of the fine groundmass with fewer larger grains. The fact that 'a'a flows are more crystalline than pahoehoe has been recognized for many years [1]. However, quantitative studies have usually been limited to freshly quenched samples [e.g. 6, 7] rather than fully crystallized ones from flow interiors [8], which are more appropriate for extraterrestrial comparisons.

Methods: Several samples from the flow interiors of Hawaiian tholeiitic and alkalic basalts are used in this study to establish, quantitatively, the distinction between pahoehoe and 'a'a. The aim is to apply the same analytical techniques to lunar basalts and noncumulate eucrites to evaluate the general emplacement conditions of those flows. We use two parameters to distinguish textures of the samples: modal volume percent of grains < 10μm, and the ratio of plagioclase vol% to pyroxene vol% (for grains >10μm).

Preliminary Quantitative Results: Terrestrial basalt samples are clearly separable using the criterion of vol% < 10μm (Fig. 2). Pahoehoe samples all exhibit only minor amounts of fine-grained material, found in interstitial pockets, averaging 4-12 vol%. The alkalic basalt has the greatest percentage of fine material at 17 vol%, but this is still clearly less than that found in the 'a'a flows. 'A'a samples typically have 50-75 vol% of the section represented by a fine-grained groundmass (Fig. 2). Preliminary data on grain number density support these differences, suggesting at least a fourfold difference between the flow types.

The other parameter shown in Figure 2 is the ratio of plagioclase to pyroxene in the >10 μm fraction. For the tholeiitic compositions, this is also a clear distinguishing characteristic, with pahoehoe samples having subequal proportions of the two phases, while 'a'a has twice as much plagioclase as pyroxene at the microphenocryst-size range. This parameter does not distinguish the three alkalic basalt samples measured so far (Fig. 2). Examination of more samples is necessary to determine if these low plag/pyx ratios of the alkalic 'a'a are representative.

To date, we have analyzed four noncumulate eucrites and three lunar basalt samples (one KREEP, two aluminous mare basalts). (Typical plagioclase-poor mare basalts are unsuitable for comparison because they are so different in composition from the terrestrial analogs.) Texturally, the eucrites and lunar basalts bear a closer resemblance to terrestrial pahoehoe than 'a'a, and this is born out by the quantitative measurements (Fig. 2). In both parameters, the extra-terrestrial basalts plot quite clearly with the Hawaiian pahoehoe samples, although they do range lower in the plag/pyx ratios (down to 0.7). Interestingly, the KREEP basalt (15386) plots closer than the other lunar samples to the terrestrial pahoehoe samples and has the closest bulk composition and liquidus viscosity to a typical Hawaiian tholeiite.

Implications: These results suggest that these eucrite and lunar samples were most likely emplaced in a manner similar to pahoehoe flows, that is, under conditions of extended insulation with low rates of nucleation. Most likely, the eruptions were associated with low effusion rates and low viscosities. In the case of Vesta, the presumed eucrite parent body, possible eruption rates of 0.1-3 m^3/s per meter of fissure have been suggested [9], which for long fissures (10-50 m) would imply total effusion rates more typical of 'a'a flows, counter to our results. However, vestan gravity is sufficiently low that even with high eruption rates, the lava could be flowing slowly enough that lower strain rates and viscosities would help maintain pahoehoe-like characteristics. Alternatively, some eruption centers must have been narrow, <5-10 m.

Figure 1. Typical Hawaiian basalt textures for a) pahoehoe (XPL) and b) 'a'a (PPL) flows. FOV is 1.7 mm in both.

Many studies have concluded that lunar mare basalts were emplaced at high eruption rates (e.g., 10,11). Our data suggest that at least some aluminous mare basalts were emplaced like pahoehoe flows, hence at low eruption rates. Apollo 15 KREEP basalts, which are associated with the Apennine Bench Formation [e.g. 12, 13], also appear to have formed pahoehoe flow fields. If additional data are consistent with results so far, the implication is that ancient lunar basalts (KREEP, aluminous mare) had magma production and delivery rates much lower than mafic mare basalts.

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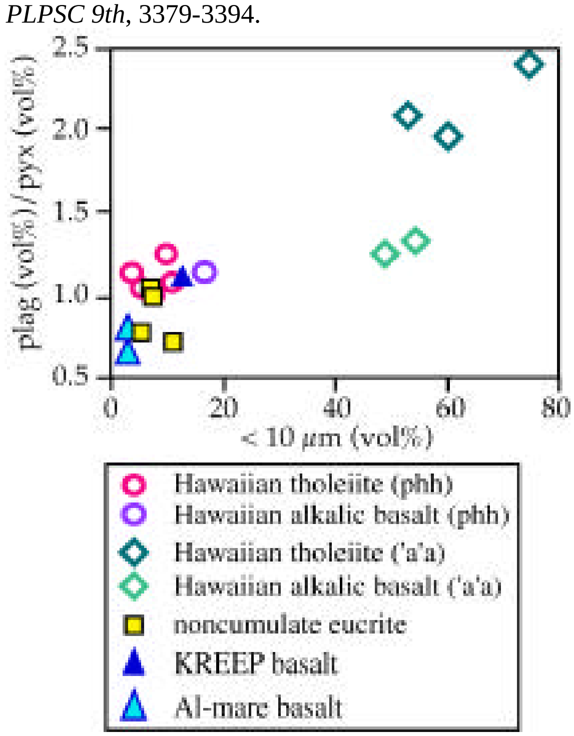

Figure 2. Distribution of basaltic flows by quantified textural parameters. Note that the plagioclase and pyroxene vol% represent those >10 µm. Hawaiian pahoehoe and 'a'a are easily distinguishable. Eucrites and lunar basalts fall in the terrestrial pahoehoe field.