STUDIES OF VESICLE DISTRIBUTION PATTERNS IN HAWAIIAN LAVAS

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Basaltic lava flows are generally vesicular, many of them highly so, and the broader facts relating to vesicle distribution have long been established; few detailed studies have however yet been made with a view to determining how and when vesicles form in the cooling history of the lava, explaining vesicle shape and size distributions, and gaining enough understanding to employ vesicles as a geological tool. Various avenues of approach exist by which one may seek to gain a better understanding of these ubiquitous structures and make a start towards developing a general theory, and three such avenues have recently been explored.

One avenue involves the study of pipe vesicles; these are a well known feature of lava flows and are narrow (3-15 mm) pipes which occur near the base of many pahoehoe flow units. They have often been attributed to the rise of steam into a lava where it flows over marshy ground. A new interpretation is that they develop at a time when the cooling lava has acquired a yield strength of a few tens of N m^{-2} and is almost static; bubbles a few cm wide are big enough to rise through such lava, but complete closure behind the rising bubbles is prevented by the yield strength, and each pipe therefore survives as a bubble trace. Larger but related features are vesicle cylinders, in which parcels of relatively low-viscosity melt plus bubbles rise diapirically through the lava. These structures have an origin broadly similar to that of pipe vesicles

A totally unexpected feature of pipe vesicles is their confinement, at the studied Hawaiian localities, to lavas on depositional slopes of 4° or less. They are thus sensitive paleoslope indicators of great potential when studying the paleogeography of lava accumulations. The proposed explanation is that a pipe vesicle survives only if the bubble of which it is a trace rises fairly steeply through the lava: that is, if the lateral lava flow rate is comparable with or less than the bubble ascent-rate. This condition is best realized if the lava stands on a horizontal or near-horizontal surface. Pipe vesicles and vesicle cylinders thus enable us to document the rheological condition and relative flow velocity of lava at a late stage in its cooling history.

Another avenue of approach is that presented by the distinctive "spongy pahoehoe" facies of lava that is common in distal locations on Hawaiian volcanoes. Spongy pahoehoe is characterized by a high content and rather uniform distribution of vesicles having a high degree of sphericity. The vesicle size systematically increases inward to reach a maximum in the center of the lava flow-unit. The bilateral symmetry of vesicle distribution and size above and below the horizontal median plane indicates that the vesicles formed in near-static lava, and their rise was prevented by the yield strength which the lava at that time possessed. Earlier, olivine crystals where present had settled through the same lava at a time when it lacked a yield strength. The vesicles in spongy pahoehoe thus belong to a generation formed late in the cooling history of the lava, and probably represent gas released by crystallization of the lava.

Various relationships show that early-formed vesicles were eliminated by flowage from spongy pahoehoe before the present vesicle population developed. Application of this idea of vesicle elimination by flowage explains one outstanding feature of some aa lavas, namely, the fact that vesicles are almost totally absent from distal-type aa. These studies of vesicles thus enable us to investigate the gas budget in lava flows.

A third avenue of approach is that of the study of gas blisters in lava. Gas blisters are voids, which can be as much as tens of meters wide, where the lava split along a vesicle-rich layer and the roof was up-arched by gas pressure. It has proved possible to distinguish gas blisters from lava tubes (which have similar dimensions), and among blisters to distinguish between those related to early-formed vesicles, and those related to late-generation vesicles.

One unexpected feature is that the distribution of gas blisters and tubes has utility when assessing how much erosion of a volcano has occurred. This is because they are rather transient features which soon either become infilled or collapse when the load of lava overburden exceeds about 30 meters. In the case of the Koolau volcano on Oahu, the presence of gas blisters and tubes establishes that the well-known cuestas above Honolulu and Waikiki are remnants of the original volcano surface, from which only a negligible amount of rock has been eroded.

These studies of vesicles are not yet finished. Vesicles hold great promise as a means of assessing the changing rheological condition of lava, they are sensitive indicators of the times and amounts of gas loss, and they have utility as paleoslope, lava facies, and erosion-depth indicators. A start has now been made to realize their potential.