Abstract

Silicic lava flows ($SiO_2 \geq 63$ wt%) remain less well constrained in terms of emplacement dynamics, flow style and resultant structures and flow geometry than basic lava flows. Although frequent in the geologic record, they are rare at human timescales, thus few of them have been observed while actively flowing. Hence understanding silicic lava flow dynamics mostly relies on the study of past, inactive flows. However such flows generally preserve internal structures and textures which can be used to infer some of their emplacement processes. A review of such studies allows for a compilation of common features of silicic lava flows, which include surface ridges, foliations, and folds. Different facies can also be distinguished based on their texture (i.e., vesicularity, density…). Flow chemistry and/or morphology allows for estimations of viscosity and velocity, with most silicic flows falling in the ranges 10^8–10^{12} Pa s and 1–100 m d^{-1}, respectively.

The morphology of silicic lava flows is an important parameter, both for inferring flow dynamics and for building and constraining lava flow emplacement models. After compiling an inventory of 140 fresh-looking silicic lava flows in the recent (mostly Holocene) geologic record, I used high spatial resolution satellite images on Google Earth to measure the morphological parameters, such as length, average thickness, area, and volume, for each identified unit. By focusing on lava flows only, and excluding lava domes, this morphological analysis reveals that silicic lava flows are much longer than previously thought (median length 3.2 km, close to that of basaltic flows). Length shows an inverse correlation with slope, and spans two orders of magnitude, from 140 m to ∼18 km. However, no relationship can be found with silica content (a proxy for rheology) and length suggesting that topographic controls outweigh rheological factors in determining the unit length, width and thickness.

Globally, and based on an extensive literature search, I can define two end-member types of flow: glassy, obsidian and crystal-rich. The former is characterized by different textural facies based on vesicularity and deformation structures such as flow banding and folds. The latter is characterized by an undeformed, massive lava "plug" over a thin basal shear zone and fault gouge. I define the morphologies and associated emplacement dynamics of each by carrying out two case studies: of the Pietre Cotte rhyolite flow for the former, and the Grande Cascade trachyte flow for the latter.

A first case study was carried out at the Pietre Cotte rhyolite flow (Vulcano, Italy), representing the glass-rich silicic lava flow subtype. Although the unit looks "simple", being a short (380 m long), single lobe of constant width (of 170 m), structural and

textural data reveal that it underwent a complex emplacement history characterized by a series of deformation events. I found evidence for extension (stretched vesicles, fracture planes, tension gashes), but also for compression both in ductile (i.e., folds) and brittle (i.e., ramps) regimes. In some cases, these deformation events have taken place at the same time, the changes in stress regime being driven by local variations in water content, strain rate, and/or temperature. Textures indeed show evidence for local degassing pathways, while a break in slope mid-way down the flank of the volcano on which the unit was emplaced may have promoted local increases in shear stress during lava emplacement.

A second case study was carried out at the Grande Cascade trachyte flow (Monts Dore massif, France). Here structural and textural data reveal a very different emplacement history. This 40 m thick, crystal-rich flow has a basal "breccia" layer which is similar to a fault gouge, or cataclasite, with very small (ash-sized) particles of ground-up lava and crystals. A 3 m thick shear zone above the breccia preserves well defined parallel shear planes, while the rest of the flow (the "plug"), constituting $\sim$90 % of the unit, is massive and undeformed, except from a vertical foliation inherited from the ascent phase within the conduit. I argue that the plug of the Grande Cascade flow "slid" over the basal breccia and shear zone, which accommodated most of the stress. This emplacement style could apply to other crystal-rich flows, and applies to the nearby Puy de Cliergue unit.

In conclusion, I found that the term "silicic lava flows" actually encompasses a wide diversity of flow types. They have a wide range of viscosities and velocities, and present very different shapes and morphologies. These differences actually correspond to different emplacement dynamics: glass-dominated flows (such as Pietre Cotte) do not flow in the same manner as crystal-dominated flows (such as the Grande Cascade). This stresses the need to refine the broad "silicic lava flows" effusive volcanism category into several sub-families, which do not necessarily share the same emplacement behavior and flow dynamics, and hence should be treated separately for modeling and hazard assessment.