Ductile and brittle processes of permeability development and outgassing during hybrid explosive-effusive activity at Cordon Caulle, Chile (2011-12)

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After initial Plinian to sub-Plinian phases of activity, the 2011-12 eruption of Cordon Caulle, Southern Chile, transitioned into a months-long period of ash jetting and Vulcanian blasts, with effusion of a voluminous obsidian lava flow. Ejected pyroclasts ranged from fine tube-like pumiceous ash to large (<3 m) bombs of dense obsidian. Field campaigns before, during, and after the eruption allow us to describe the shallow conduit that fed the eruption using direct observations of activity and features of the pyroclasts.

The vent complex and site of lava effusion was represented by two loci of Vulcanian blasts within a single tephra cone. These loci each consisted of clusters of long-lived sub-vents that expressed correlated shifts in eruption intensity, indicating the presence of partially connected and/or branching zones of high permeability within the upper conduit. Sub-vents ejected the tube-like pumiceous ash, with porosity (39-67 %) and anisotropic Darcian permeability (3.1×10^{-15} m^2 perpendicular to fabric to 3.8×10^{-11} m^2 parallel) indicating that the permeable networks consisted of highly sheared, tube-like bubbly magma. These contrasted with the low porosity (17%) and nul permeability of bombs ejected to hundreds of metres from the vent in Vulcanian blasts. Residual H_2O content of ash (0.14 wt%) and bombs (0.2-0.25 wt%) indicate pyroclast degassing to near-atmospheric pressures. Together, the pyroclasts demonstrate that both ductile and brittle processes of permeability development and gas transfer were important.

Ash textures and modeling indicate the onset of permeability by ductile processes of shear-enhanced bubble coalescence in the upper 1 to 1.5 km of the Cordon Caulle conduit. Textures in pumices collected early in the eruption indicate a significant role for shear localization in the ductile development of permeability, which we extrapolate to the hybrid activity. Bombs of tube pumice collected after the eruption indicate that the ash represents fragmented parts of larger bodies. Ongoing work aims to reconcile the very low H_2O equilibration pressures of the ash (< 1 MPa) with the considerably higher overpressures (5.7-12.5 MPa) theoretically required to fragment melt with the measured porosity and permeability.

Ash jetting and Vulcanian blasts show that ductile processes were not sufficient to accommodate degassing, and additional brittle (e.g., fragmentation) events assisted in gas transfer to the atmosphere. Brittle processes of gas transfer are examined through the frequency of Vulcanian blasts recorded during the eruption, as well as in textures of dense-to-breadcrusted, tuffisite vein-bearing obsidian bombs collected afterwards. Ductile and brittle processes combined to permit the open-system degassing required for hybrid explosive-effusive activity.