Volcanic jets, plumes and collapsing fountains: evidence from large-scale experiments, with particular emphasis on the entrainment rate.

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The source conditions of volcanic plumes and collapsing fountains are investigated by means of large-scale experiments. On experiments, gas-particle jets issuing from a cylindrical conduit are forced into the atmosphere by a variable mass flow rate. Dense jets (high particle volumetric concentration) generate collapsing fountains whose height scales with the squared exit velocity. This is consistent with Bernoulli's equation and means that kinetic energy is transformed into potential energy without loss against friction with the atmosphere. The dense collapsing fountain, on hitting the ground, generates an intense shear flow similar to pyroclastic density currents. Dilute hot jets (low particle volumetric concentration) reach a height much smaller than that resulting from Bernoulli's equation, meaning that part of the kinetic energy is lost through friction with the atmosphere. This causes a significant air entrainment and dilution, which leads to the formation of a buoyant column (plume) resulting in particles settling from its margin, similar to pyroclastic fallout. By means of the functional relationship between the initial densiometric Froude number and normalized height, the scaling of experiments is compared with data of the recent fluid-dynamics literature.

In order to assess the different entrainment rate between collapsing fountains and plumes, experiments were investigated by quantitative video analysis. Results show that dense collapsing fountains are formed only when air entrainment is not significant. Cold dilute experiments result in an entrainment coefficient of about 0.06, which is typical of pure jets in fluid-dynamics. Hot dilute runs result in an entrainment coefficient of about 0.11, which is typical of plumes.

An initial densiometric Froude number of 3 sets the limit between dense collapsing fountains and dilute jets-plumes. We use this value for obtaining a diagram of the stability fields of pyroclastic density currents and pyroclastic fallout.