VOLCANIC PLUMES AND PLUME DEPOSITS ON IO. P. E. Geissler, Astrogeology Program, U.S. Geological Survey, Flagstaff AZ 86001 USA.

Introduction: The Voyager spacecraft's discovery of enormous plumes reaching several hundred kilometers above Io's surface provided the first spectacular evidence of active volcanism beyond Earth. Io's volcanic activity is the most prodigious in the solar system, fueled by tidal heating generated by the gravitational grip of Jupiter. More than 400 volcanic paterae dot the surface of the satellite [1] but so far only a handful of these volcanic centers have been seen to produce plumes. Most plumes are associated with new lava flows that explosively vaporize existing surface ices of SO_2, but the largest plumes vent sulfur-rich gases from the interior of Io.

Plumes are important because they reveal clues to the composition of Io's interior [2-5] and details of the mechanisms of volcanic eruptions. They contribute to Io's rapid resurfacing, responsible for the erasure of the impact craters on the satellite's young surface. Ejection of dust from Io's largest plumes creates the dust streams that emanate from Io and pervade the jovian system [6]. The plumes also complicate the structure of Io's tenuous atmosphere and help sustain the neutral clouds and plasma torus.

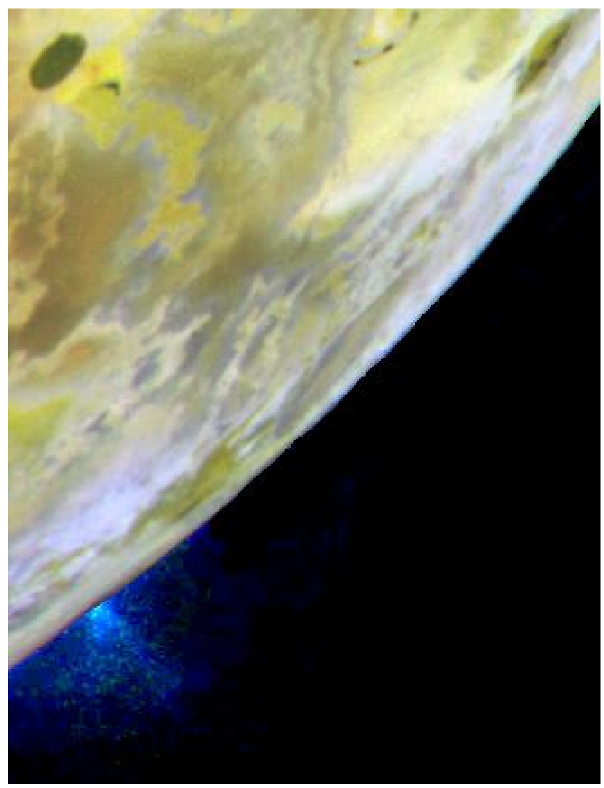
This talk will review what has so far been learned about Io's volcanic plumes from the observations of Voyager, Galileo and Cassini, and will highlight some of the remaining unanswered questions.

Dust Plumes: Dust plumes can be seen in daylight to have blue colors that contrast with the oranges, whites and reds of Io's surface. The color and opacity of dust plumes yields information on the dust grain size distributions and the dust deposition rates of the eruptions.

Most dust plumes tend to be small and dense, typically reaching heights of less than 100 kilometers. The archetype of this class of plumes is Prometheus, which has been seen actively fountaining SO_2-rich gas and dust at every favorable observing opportunity since the Voyager flybys. These plumes arise when hot silicate lavas flow over the icy SO_2-rich substrate. The morphologies of the smaller plumes range from fountain- to umbrella-shaped, with an optically thick core near the source region. Wispy filaments have been spotted in the dust streams from some plumes, suggestive of plume electrification [7].

A second class of plumes, exemplified by Pele, is rarer and more energetic than the first. These giant plumes are faint and difficult to see in reflected light, but typically form umbrella-shaped dust streams that reach heights of a few hundred kilometers. Pele's source appears to be an actively overturning lava lake that continually exposes hot lava and exhales sulfur-rich gases from Io's interior.

Preliminary calculations suggest that the deposition of frosts by the smaller, SO_2-rich plumes contributes significantly to Io's resurfacing [8]. Correlations between the record of volcanic eruptions during the tenure of Galileo and the flux of dust recorded by the spacecraft's Dust Detector suggest that ejection of dust from Io's most energetic plumes is chiefly responsible for the dust streams emanating from Io [6].



The July, 1999 eruption of Masubi lofted dust to a height of nearly 100 km. (Galileo orbit C21).

Gas Plumes: Gas plumes are prominent at night and during eclipses, when they display an ethereal glow produced by the stimulation of the gases by charged particles, similar to terrestrial aurorae. The spectra of the auroral emissions yield information on the makeup and abundance of the gases, as well as the intensity of the electrical currents that excite the emissions [9-11].

Molecular species such as SO_2 and S_2 produce strong ultraviolet and visible continuum emissions that impart a bluish hue to the visible aurorae. Atomic species, including O, Na, and K, produce line emissions at longer visible and near-infrared wavelengths that are diagnostic of their composition.

Only plumes near the electrical poles of Io (the subjovian and antijovian points) are in a position to be stimulated by the currents connecting Io to Jupiter. Exceptionally large plumes in other locations, such as the eruption of Tvashtar in late 2000, can sometimes be seen in emission because of the high density of emitting molecules.

Gas plumes extend much farther from Io's surface than their dusty counterparts, reaching heights comparable to the satellite's radius. The gases vented by adjacent plumes often combine to form a megaplume above the most active regions.

Some plumes such as Acala could be seen in emission but were invisible in daylight, confirming a prediction [12] of the existence of "stealth plumes" that are largely free of dust.

Plume Deposits: The deposits laid down by the plumes are observed through obvious changes in the appearance of the surface [8], the optical scattering behavior of frosts of SO_2 at visible wavelengths [13], and in maps of the abundance and grain size of SO_2 as determined by infrared spectroscopy [14].

Plume deposits can be annular, concentric or irregular in plan. The sizes, shapes and colors of the deposits divide into two categories, consistent with the two classes of plumes discussed earlier. Giant plumes produce enormous red rings up to 500 km in radius that are poor in SO_2 and may be dominantly made up of condensed sulfur. The smaller plumes produce SO_2-rich deposits that are typically less than 200 km in radius and are white or yellow in color unless contaminated with sulfur or silicates.

Galileo's monitoring of Io over a 5 year period showed that surface changes took place repeatedly near the sites of many smaller plumes, indicating the sustained flow of lava from these volcanic centers. Pele's giant deposits also altered repeatedly throughout the mission, and ephemeral giant red rings appeared in several unexpected locations.

Outstanding Questions: The genesis of the dust in Io's plumes remains a mystery. There exists the possibility of snowfall on Io – condensation of SO_2 snowflakes from the vapor phase as the plumes expand and cool – but the relative roles of condensation vs. lofting of existing dust particles are still unknown. The better spectral range and resolution of the Galileo and Cassini imaging observations (in comparison to Voyager data) can be used to improve our knowledge of the dust particle size distributions and deposition rates.

The broader problem of relating the observed properties of active plumes to the characteristics of the deposits they emplace has yet to be addressed. We must integrate diverse observations of thermal emission, gas plume morphology, dust plume characteristics, and surface deposits in order to obtain a more complete understanding of Io's enigmatic explosive eruptions.

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