Insights into the origins and composition of cryovolcanic plume particles from natural and experimental analogues

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Cryovolcanic plumes are high-priority targets for missions such as Europa Clipper and JUICE due to their potential to deliver material from subsurface liquid reservoirs of ocean-bearing icy satellites to space. Data from the Cassini mission suggest that ice grains in the plumes of Enceladus likely originate as aerosols produced via bubbling of volatiles at a liquid-vapor interface [1]. Using an integrated field and experimental approach, we are investigating aerosolization dynamics and size-dependent composition of aerosols produced under a wide range of conditions relevant to cryovolcanic plume formation, with the aim of constraining the possible composition of ice grains ejected to the altitude of spacecraft fly-throughs. Findings will enable new insights into existing data from Enceladus and can be leveraged to help predict plume behaviour and composition at other planetary bodies with active plumes, such as Europa.

Field programme: We are investigating the geochemistry and microbial content of aerosol plumes originating from geothermal springs in Iceland, which are useful natural laboratories for studying plume aerosolization scenarios due to icy moon-relevant fluid chemistries and hydrothermal gas input [2]. Our data show that Icelandic geothermal springs are prolific local sources of aerosols, with aerosol fluxes tightly controlled by gas dynamics. Furthermore, we have found that microbial cells are present in the aerosol, indicating that biomass can be ejected by bubbling of hydrothermal gases, with promising implications for the possible transfer of biosignatures into cryovolcanic plumes. Spring aerosols show preferential loss of some inorganic elements relative to source fluids. Our data allow us to quantitatively compare a given aerosol sample to the aerosol source, establishing the extent to which biogeochemistry can be faithfully reconstructed from the aerosol sample and how this varies with distance.

Experimental programme: Field data are complemented with controlled experiments using a purpose-built experimental plume aerosol facility. This facility allows us to conduct detailed investigations of size-dependent flux and composition of aerosols produced under conditions relevant to the plume-formation regions at icy satellites. Aerosols are generated in a temperature and pressure-controlled reaction vessel, and physically separated into 14 size fractions with diameters between 0.01 and 10 µm, which are recovered for downstream analyses. Preliminary data from our plume aerosol facility show that contrasting bubble dynamics can result in dramatically different aerosol size distributions, with implications for the observed size distributions at Enceladus. Ongoing work is investigating the efficiency of transfer of organics into plume aerosols under biological and non-biological scenarios.

Integrating our field and experimental analogue approaches allows us to explain size-dependent differences in aerosol composition observed in natural samples, and extend these insights to pressure-temperature conditions relevant to plume formation regions on icy bodies. Ultimately findings will contribute to a predictive understanding of the origins of plume particles that can be applied to cryovolcanic plumes at the Galilean Moons and elsewhere.

References: [1] Postberg F, *et al*. *Nature*. (2018) 558 (7711):564-568; **[2]** Fox-Powell MG, *et al*. (2018) *Earth Planet. Sci. Lett*. 498:1-8