



Open Research Online

Citation

Fox-Powell, Mark G.; Stephens, Ben; Batty, Claire; Aldis, Angus; Hammond, Sam; Barton, Tim and Gladding, Toni Chemical fractionation in terrestrial geysers: implications for cryovolcanic plumes at ocean worlds. In: AbSciCon 2024, 5-10 May 2024, Providence, RI, USA.

URL

<https://oro.open.ac.uk/99526/>

License

None Specified

Policy

This document has been downloaded from Open Research Online, The Open University's repository of research publications. This version is being made available in accordance with Open Research Online policies available from [Open Research Online \(ORO\) Policies](#)

Versions

If this document is identified as the Author Accepted Manuscript it is the version after peer review but before type setting, copy editing or publisher branding

Chemical fractionation in terrestrial geysers: implications for cryovolcanic plumes at ocean worlds

Mark G. Fox-Powell¹, Ben Stephens¹, Claire Batty¹, Angus Aldis¹, Sam Hammond², Tim Barton², Toni Gladding³

¹*AstrobiologyOU, The Open University, Walton Hall, Milton Keynes, UK (mark.fox-powell@open.ac.uk)*

²*School of Environment, Earth and Ecosystem Sciences, The Open University, Walton Hall, Milton Keynes, UK*

³*School of Engineering and Innovation, The Open University, Walton Hall, Milton Keynes, UK*

Introduction: Cryovolcanic plumes, such as the plumes of Enceladus, offer a unique opportunity to probe the chemistry and potential habitability of subsurface oceans beyond Earth. Cassini observations at Enceladus have implied that salt-rich ice grains in the plumes originate as aerosolized droplets of ocean fluid, and therefore may contain a record of ocean chemistry [1]. However, it is not clear to what extent the composition of these aerosolized droplets, and the resulting ice grains, reflects the composition of the underlying fluid reservoir.

We investigated the composition of aerosol plumes originating from geysers and actively bubbling geothermal springs in Iceland, to better understand the relationship between aerosols and source fluid chemistry. Geothermal springs provide compelling natural laboratories for studying plume aerosols, with fluid chemistries relevant to ocean worlds and a wide range of aerosol ejection mechanisms. In contrast to plume aerosols at Enceladus, geothermal aerosols on Earth emerge from accessible fluid reservoirs, offering the opportunity to interpret plume composition in the context of known fluid chemistry that produced them.

Methods: Fluids, gases and aerosols were sampled at two locations in south-west Iceland: the erupting Strokkur geyser at Geysir, and a system of bubbling springs at Ölkelduháls. Aerosols were sampled in 30-minute increments with a Bertin Instruments Coriolis μ aerosol sampler at 300 liters air min^{-1} . Aerosol flux was monitored across three size fractions (diameters ≤ 10.0 , ≤ 2.5 and ≤ 1.0 μm) during sampling intervals using a Turnkey Osiris Particle Enumerator. Elemental compositions of aerosol and spring samples were analyzed by inductively coupled plasma-mass spectrometry and optical emission spectroscopy. In ongoing work, we are characterizing volatile and semi-volatile compounds with gas-chromatography mass spectrometry.

Results and Discussion: Aerosol abundances downwind of geothermal springs were 2-4 orders of magnitude higher than background levels, showing that geothermal springs are prolific local sources of aerosol. Mass spectrometric analyses of plume aerosols revealed notable deviations from source fluid composition in both major and minor chemical species (Fig. 1). In particular, at Strokkur, the Si:Na and S:Na ratios were depleted up to 3 orders of magnitude in aerosol samples relative to the geyser source fluid. Furthermore, the extent of this depletion increased with distance. Mo and

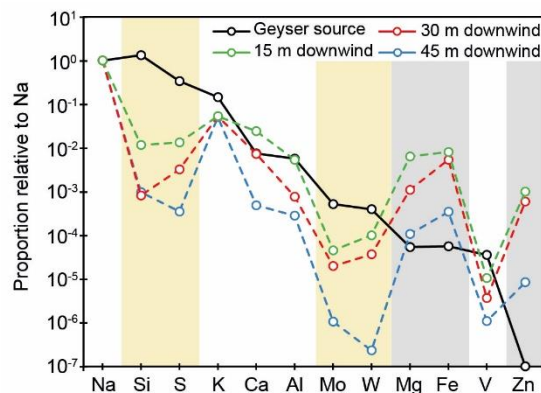


Figure 1. Elemental composition of source fluid and plume aerosols at Strokkur geyser. Shaded yellow and grey boxes highlight elemental depletions and enrichments in the aerosol, respectively.

W showed similar depletions. As larger droplets are observed to decrease in relative abundance with distance, this changing composition may reflect a changing size distribution of droplets, with the smallest droplets, which are transported furthest, representing the greatest extent of depletion. Similar fractionations have been observed in marine aerosols [2]. By contrast, some elements, including Fe and Zn, showed marked enrichment in aerosols relative to the source fluid, the magnitude of which decreased with distance. In this presentation, we will outline chemical and physical mechanisms that may be responsible for producing the observed fractionations.

Our results show that ejection of aerosols in natural geyser plumes on Earth can lead to pronounced chemical fractionation between plume aerosols and source fluid reservoirs. These fractionations were expressed in both major and minor species that could be important tracers of geochemical and biogeochemical processes, and thus of primary interest to space missions aiming to reconstruct source fluid chemistry from plume measurements at ocean worlds.

This work offers a natural analogue perspective on how the physical processes in cryovolcanic eruptions may influence the composition of ejected materials, with implications for interpreting data from Cassini and from future missions that aim to sample plume materials, such as Europa Clipper.

References: [1] Postberg F. *et al.* (2009) *Nature* 459, 1-4; [2] Salter, M. E. *et al.* *Geophys. Res. Lett.* 43, 8277–8285 (2016)