Whodunit? Determining the source and climatic forcing of unidentified volcanic eruptions from ice core archives

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In partnership with BGS

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Key Words	**1. Volcanoes, climate, isotopes, tephra, ice cores**

Overview

The history of volcanic eruptions is challenging to reconstruct because the geological record of eruptions is often incomplete. This makes it difficult to determine the frequency and impacts of large volcanic events, with implications for governments and businesses (e.g. aviation and insurance industries).

Sulfate layers in polar ice cores provide a continuous high temporal resolution record of global volcanism (e.g. Gao et al., 2008; Sigl et al. 2015). The study of these sulfate layers can provide important insights into the frequency and climatic forcing of volcanic eruptions. However, most sulfate layers recorded in the ice cores have not been attributed to a known source volcano. Even in last 2000 years only 6 of the 25 largest volcanic eruptions have been matched to a known event. A further challenge is that the magnitude of the sulfate peak, which is commonly used to infer the magnitude of the eruption, can be complicated by local eruptions (proximal to the ice sheet), which disproportionately contribute sulfate to the ice. New approaches are urgently needed to accurately determine eruption magnitude, where the source was located and its climate forcing potential.
To tackle these uncertainties, this studentship will use a two-pronged approach. Sulfur isotope analyses of ice core sulfate will be used to evaluate the eruption magnitudes (in terms of plume height) and tephra geochemistry will identify the source volcano.

Multiple sulfur isotope analyses will be used to evaluate whether the ice core sulfate was formed in the stratosphere, thus providing a means of distinguishing large tropical eruptions from local eruptions (e.g. Baroni et al., 2007; 2008). Furthermore recent work (Lin et al 2018) suggests that there is an altitude dependence of $\Delta^{33}S$ in stratospheric sulfate, which if true would provide a means of constraining the plume height of past volcanic eruptions. Ash particles (tephra) identified in ice cores have been successfully linked to large tropical events (e.g. Samalas, Lavigne et al., 2013) thousands of kilometres away. To pinpoint the source of a given eruption recorded in the ice, geochemical data (major and trace elements) from the tephra will be combined with age information and compared to large-scale geochemical compilations. This will allow the student to discriminate between different volcanic settings and identify the most likely eruptive source.

The student will apply these complementary geochemical techniques to key unknown volcanic events recorded in ice cores over the past 200,000 years. Since the eruption source location and plume height strongly control the spatial extent and residence time of sulfate aerosols in the atmosphere, this new information will be used to evaluate the climate impact of each eruption. These novel analyses will significantly improve global volcanic hazard assessments and in doing so, will help prepare society for future eruptions.

Methodology

Ice cores will be sampled from repositories in Grenoble and Copenhagen. Sulfate concentration will be measured by ion chromatography (IC) at the University of St Andrews and sulfur isotopes will be measured by MC-ICP-MS at the University of St Andrews in the STAiG laboratories. This project will benefit from close collaboration with Prof Siwan Davies at the University of Swansea, where the student will learn to process ice samples to find microscopic tephra. Major element composition of the tephra will be measured by electron microprobe at the Tephra Analysis Unit (University of Edinburgh), and trace elements on tephra will be measured by laser ablation ICP-MS at the STAiG laboratories. Analysis, attribution, and interpretation of tephra results will be in close collaboration with Prof Siwan Davies (Swansea) and Dr Sam Engwell (BGS) who provides expertise on ash dispersal in past volcanic eruptions.

Timeline

Year 1: Literature review, ice core sampling, training in clean laboratory methods and mass spectrometry at the STAiG laboratory. Travel to Swansea for tephra sampling from the ice core samples. Major element analyses of tephra by electron microprobe on initial samples. Trace element analysis of tephra by laser ablation.

Year 2: Ice core sulfate concentration by ion chromatography and $\Delta^{33}S$ isotope measurements by MC-ICP-MS at St Andrews. Finish major and trace element analysis of tephra. Analysis of data, and draft initial paper(s).

Year 3 to 3.5: Finish remaining ice core sample measurements, finalize data sets, prepare written manuscripts and write thesis.

Training & Skills

The student will gain specific training in geochemical laboratory techniques including ion chromatography, mass spectrometry, and clean lab chemistry, as well as training and expertise in volcanology, climate science, atmospheric chemistry, and isotope geochemistry. The student will be trained and work with MC-ICP-MS, laser ablation ICP-MS, and electron microprobe. The student will also be trained in the use of Matlab to process and analyse data. Furthermore, over the course of the PhD the student will gain transferable skills such as scientific writing, statistics and data analysis, and problem-solving, as well as time management and working towards a long-term goal.

References & Further Reading

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