E^3 PhD studentship proposal

Elucidating the Earliest Colonists of Land

Supervisors: Professor Charles Cockell[1], Dr Claire Cousins[1], Dr John Stevenson[2]
1 – School of Physics and Astronomy, Univ. of Edinburgh (c.cockell@ed.ac.uk)
2 – School of Geosciences, Univ. of Edinburgh

1: Project summary (30 words max- for advertising)
This project will investigate the earliest colonists of volcanic environments, elucidate their role in establishing biogeochemical cycles and revealing how Precambrian land masses might have been colonised.

2: Project rationale
This project will investigate the characteristics of the earliest colonists of lava flows. Newly formed lava flows provide a substrate for a wide range of microbial colonists. Initial data from us (Kelly *et al*., 2014) showed that within 2 to 4 months, the Eyjafjallajökull lava flow in Iceland (erupted in 2010) was rapidly colonised by chemolithotrophs – organisms that use iron, sulfur and other inorganic elements and compounds as a source of energy. The study of older lava flows shows that this community eventually changes into one that uses organic compounds for energy, such as from photosynthesis or organic material delivered onto the lava flow. In this project we will use microbial culturing and molecular methods to elucidate the metabolic capabilities of organisms on fresh lava flows.

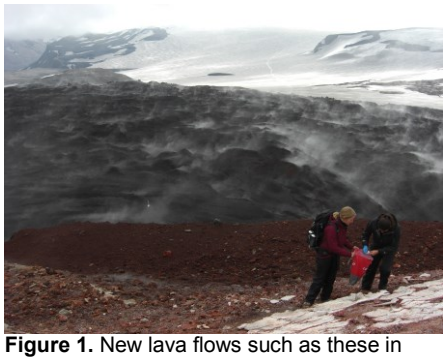

Figure 1. New lava flows such as these in Eyjafjallajökull, are colonised early by chemolithotrophs. This project seeks to elucidate how these biogeochemical cycles become established.

The scientific motivation of this work is to understand how newly formed subaerial basaltic crust is colonised and how biogeochemical cycling of key elements in the biosphere such as nitrogen and carbon becomes established.These data will give us more fundamental insights into how new ecosystems and biogeochemical cycles are established in any disturbed or even human-altered environment. The work has implications for elucidating what sorts of organisms might have colonized the land masses of Precambrian Earth before there was large-scale availability of carbon compounds from photosynthesis. It will also yield new insights into the habitability of basaltic environments on Mars and whether these environments could have provided energy and nutrients for life.

This interdisciplinary PhD proposal will link the extensive and pre-existing expertise in the geobiology of volcanic environments (Cousins) and the microbial ecology of basaltic environments (Cockell) with expertise in physical volcanology (Stevenson) to study the major biogeochemical cycling activities of microorganisms on lava flows. This doctoral project will address key questions in geosciences:

1) What organisms are the earliest colonists of newly formed subaerial basaltic environments?
2) What role do these microbes play in fixing nitrogen and carbon in newly formed environments and thus establishing land-based biogeochemical cycling?
3) How quickly do these communities become established and how do their metabolic capabilities change over the first few months of colonization?
4) What do these communities tell us about the earliest colonists of continental land masses during the Precambrian or the habitability of extraterrestrial basaltic environments such as Mars?

3: Aims and Methodology
Samples: The applicants have existing frozen samples from Eyjafjallajökull that can be used to initiate the project. We would then target newly formed lava flows in Iceland such as Holohraun (Bárðarbunga) to obtain fresh samples for analysis. During the PhD project we

would keep open the possibility of visiting newly formed lava flows if they become available. Samples are collected aseptically for the microbiological aspects of the project with samples also collected for geochemical analysis.

Analytical approach:

Several approaches will be taken to investigating the samples:

1) Microbial enrichment cultures will be used to attempt to isolate and characterise organisms on the fresh lava flows. Media will be used to select for chemolithotrophs (specifically sulfur and iron utilising organisms) and heterotrophs (using organic carbon). We will also isolate and enrich organisms capable of fixing or cycling nitrogen. The purpose of these enrichments is to identify the major metabolic capabilities of the organisms on the lava flows and specifically to identify the major pathways of carbon and nitrogen that are established on new lavas.

2) DNA will be extracted from the field samples by standard molecular methods to investigate the microbial communities inhabiting the new lava flow samples. This will be done in conjunction with the Edinburgh sequencing facility (Edinburgh Genomics). This will be correlated to geochemical data of the fresh lava (major elements, trace elements, N and P availability etc,), and will identify the most commonly utilised genes involved in carbon and nitrogen cycling within these communities.

3) Lab-based microcosms will be established in which newly formed lava is colonised by innocula obtained from old lava flows and the atmosphere to investigate which organisms establish active metabolism within the lava flows first and how the communities develop over time. Some of these microcosms will be augmented with nitrogen and carbon to study how the communities are expected to develop as more N and C become available in later stages.

Timeline:

Year 1: Literature review. Begin isolation and enrichment of organisms from existing Eyjafjallajökull samples. Collect new samples and carry out molecular analysis of the samples.

Year 2: Examine geochemistry of samples and prepare new enrichments and isolation procedures based on detailed geochemical information. Set-up and sample microcosms. Paper writing.

Year 3: Carry out culturing and molecular analysis of enrichments. Interpret data in a global context. Thesis and paper writing,

Year 4: Completion and further papers.

4: Research Training

We are seeking a microbiologist with proven interest and experience in the laboratory. A comprehensive training programme will be provided comprising both specialist scientific training and generic transferable and professional skills. The student will receive training in microbiology (aerobic and anaerobic culturing), molecular biology, lava flow emplacement and sterile sample collection. The project offers an extremely exciting opportunity to learn interdisciplinary field and laboratory techniques by working alongside the supervisors in microbiology and igneous petrology. These skills are highly transferable to many career choices. Leaving the PhD with microbiology and geology methods expertise would particularly lend itself to an earth scientist seeking to pursue research.

5: Further reading/ references

Cockell, C.S., Olsson, K., Herrera, A., Meunier, A. 2009. Alteration textures in terrestrial volcanic glass and the associated bacterial community. *Geobiology* 7, 50-65.

Kelly L, Cockell CS, Herrera-Belaroussi A, Piceno Y, Andersen G, DeSantis T, Brodie E, Thorsteinsson T, Marteinsson V, Poly F, LeRoux X. 2011. Bacterial diversity of terrestrial crystalline volcanic rocks, Iceland. *Microbial Ecology* 62, 69-79.

Kelly LC, Cockell CS, Thorsteinsson T, Marteinsson V, Stevenson J. 2014. Pioneer Microbial Communities of the Fimmvörðuháls Lava Flow, Eyjafjallajökull, Iceland. Microbial Ecology, DOI 10.1007/s00248-014-0432-3

Olsson-Francis K, Simpson AE, Wolff-Boenisch D, Cockell CS. 2012. The effect of rock composition on cyanobacterial weathering of crystalline basalt and rhyolite. *Geobiology* 10, 434-444.

Summers S, Cockell CS, Kelly LC, Whiteley AS. 2013. Land coverage influences the bacterial community composition in the critical zone of a sub-Arctic basaltic environment. 2013, *FEMS Microbiology Ecology* . doi: 10.1111/1574-6941.12167.