Institution: The Open University

Unit of Assessment: B7 Earth Systems and Environment Sciences

Title of case study: Citizen scientists and environmental volcanology

1. Summary of the impact

The longevity of volcano impact monitoring projects is a strong argument for the involvement of citizen scientists and volunteers. Professor Rymer and colleagues have run several long-term volcano projects in collaboration with the charity Earthwatch. Over 500 citizen scientists have collected geophysical and environmental data since 2000. The work has impacted on the lives of the volunteers, who are engaged and enthused by scientific research, park wardens in Nicaragua who continue to monitor long-term SO_2 release, and authorities in Costa Rica, Iceland, Italy and Nicaragua who use the citizen science data to mitigate the environmental effects of persistent volcanism.

2. Underpinning research

Professor Hazel Rymer has led a group studying hazards arising from both volcano eruption and gas release during persistent activity, providing important new insights into the processes occurring at shallow depth beneath persistently active volcanoes. A key aspect of the work has been the involvement of volunteer citizen scientists, and also engagement with local communities. The team has included Dr Steve Blake and Dr Mike Gillman, and colleagues from other institutions including Professor Corinne Locke (University of Auckland), Dr Hilary Erenler (Northampton University), and Dr Glyn Williams-Jones (Simon Fraser University). Dr Saskia van Manen, an independently funded Branco Weiss Research Fellow, is researching the impact on society of fluctuations in volcanic activity in Costa Rica and Nicaragua.

The Volcanology and Ecology Project
Citizen science fieldwork on volcanoes has been carried out almost every year since 2008. The environmental volcanology project integrates expertise in volcano monitoring, modelling and public engagement with the delivery of comprehensive hazard awareness, preparedness and mitigation. Professor Rymer has shown that unerupted magma can remain molten at shallow depths for many months, and that magma movements can be detected many years in advance of eruption; both are crucial to hazard mitigation since natural variations and persistent activity affect the local environment. High concentrations of gases at persistently active volcanic sites can cause heavy metal pollution (heavy metals such as lead, copper and zinc) of soil, water and the atmosphere. The implications for local people include a build-up of pollutants in their agricultural crops.

In recent years citizen scientists mapping the distribution of air plants within and around such volcanoes have found that the location of these plants mirrored results from the sulphur detection plates in indicating levels of gas deposition. This provides a new way for local communities to monitor gas flux from the volcano without the need for instrumentation and lab analysis.

The Microgravity and Volcano Hazards Project
Citizen science fieldwork was carried out on volcanoes in Iceland over a 20-year period 1993–2013. Recent work in Iceland has built upon the many earlier citizen science monitoring projects (e.g. Carbonne et al. 2010, 2011; Wooler et al., 2009; Williams-Jones et al., 2008; Gottsman et al., 2008), and is focused around the ongoing subsidence within the main caldera of Askja volcano in the north of Iceland. Ground deformation and micro-gravity data collected by citizen scientists and volunteers have been used to shed light on the processes responsible for unrest at this large, central volcano. Increased seismicity and net micro-gravity increases while the subsidence continued were the cause of considerable speculation in the period 2008–10. A 20-year gravity time series at Askja caldera shows a sharp contrast in behaviour at the caldera

centre compared with the margins. The observed reversal from long-term magma drainage to magma accumulation below the caldera centre identified by these new gravity data may be the first sign heralding the next phase of activity at Askja (van Dalfsen 2011).

3. References to the research

Publications with contributions from citizen science:

Williams-Jones, G., **Rymer, H**., Mauri, G., Gottsmann, J., Poland, M. and Carbone, D. (2008) 'Towards continuous 4D microgravity monitoring of volcanoes', *Geophysics*, vol. 73, no. 6, pp. 19–28. (45% contribution)

Gottsman, J., Camacho, A.G., Marti, J., Wooller, L. Fernández, J., Garcia, A. and **Rymer, H**. (2008) 'Shallow structure beneath the Central Volcanic Complex of Tenerife from new gravity data: implications for its evolution and recent reactivation', *Physics of the Earth and Planetary Interiors*, vol. 168, pp. 212–30. (10% contribution)

Wooller, L.K., van Wyk de Vries, B., Cecchi, E. and **Rymer, H**. (2009) 'Analogue models of the effect of long-term basement fault movement on volcanic edifices' *Bulletin of Volcanology*,doi: 10.1007/s00445-009-0289-3.

Carbone, D., Zuccarello, L., Saccorotti, G., **Rymer, H**. and Rapisarda, S. (2010) 'The effect of inertial accelerations on the higher-frequency components of the signal from spring gravimeters', *Geophysical Journal International*, doi: 10.1111/j.1365-246X.2010.04644.x.

Carbone, D., Zuccarello, L., Montalto, P. and **Rymer, H**. (2011) 'New geophysical insight into the dynamics of Stromboli volcano (Italy)', *Gondwana Research*, doi: 10.1016/j.gr.2011.09.007.

de Zeeuw van Dalfsen, E. **Rymer, H**., Pedersen, R., Sturkell, E., Sigmundsson, F. and Ófeigsson, B. (2013) 'Geodetic data shed light on ongoing caldera subsidence at Askja, Iceland', *Bulletin of Volcanology*, vol. 75, no. 5, pp. 709–22.

Grants:

2013: $100k awarded by SEG Foundation Geoscientists without Borders to Professor Hazel Rymer for a project entitled 'Developing integrated volcano monitoring and hazard mitigation programs at persistently degassing volcanoes'.

2008–13 £128k awarded by Earthwatch, The Centre for Field Research to Professor Hazel Rymer for a project entitled 'Environmental impact of persistently active volcanoes'.

2008–13: £46k awarded by Earthwatch, The Centre for Field Research to Professor Hazel Rymer for a project entitled 'Icelandic volcanoes'.

4. Details of the impact

Professor Rymer's group is developing the new area of environmental volcanology as citizen science, using a wide range of established and emergent geophysical, geochemical and bioassay tools to investigate the impact of chronic (background, persistent) volcanic activity on the local environment. A critical feature of the group is that it is part of an international network of collaborators working closely with local communities, government-run volcano observatories and universities in several countries. Citizen scientists volunteering to undertake measurements on volcanoes represent a major theme common to many of the studies.

Earthwatch is the charity that has collaborated with the OU on many of the recent citizen science expeditions. It offers untrained members of the public the opportunity to work in peer-reviewed research projects and has found that many returning citizens express very clear enthusiasm and report positive experiences. Nigel Winser, Executive Vice President (Observations) of the charity, commented:

> 'Your work over many years with these individuals fulfils Earthwatch's mission to engage people worldwide in scientific field research and education to promote the understanding and action necessary for a sustainable environment… These volunteers return and engage their wider communities – in schools, in business, with other academics and in the home – with their own outreach activities.'

The following are examples of the substantial impact this approach is having on the volunteers, policymakers and the local communities surrounding the persistently active volcanoes in Iceland and South America.

Citizen scientist observations at Askja volcano in Iceland suggest that magma has been accumulating beneath the caldera since 2007 and colleagues at the Nordic Volcanological Institute increased their surveillance of the area during the summer field seasons of 2009 onwards. The Open University team has collaborated with local volcano scientists in this area over several decades, and worked together with citizen scientists over much of that period. Professor Guðmundsson, Professor of Geophysics and Head of the Faculty of Earth Sciences, Reykavík, comments:

> 'The decades-long collaboration with the volunteer Earthwatch teams has been particularly valuable, since their contribution has led to fieldwork campaigns that is difficult to see how could have been carried out in any other way. Here are two important aspects that need to be considered. Firstly, the volunteer participation brings resources into research that would otherwise not be available. Secondly, the vast majority of all the volunteers that have participated in your Earthwatch projects act as proponents of science within the general public.'

More recently, the group's work at Poás volcano, Costa Rica, involved citizen scientists in predicting increased local environmental damage from 2009 and helped to inform the volcano observatory staff and National Park officials who restricted access by the public to the crater area during the degassing crisis of 2009–10, reducing the risk of injury. To mitigate against such hazards, operational guidelines for monitoring and responding to changes in volcanic degassing were put in place in Costa Rica and Nicaragua in 2009. These will be essential for establishing short-term responses to gas-related health emergencies, as well as medium-term land management policies to reduce the effect of degassing on human and agricultural activity. Both are of direct economic benefit to vulnerable communities.

The Open University group and several cohorts of citizen scientists have worked closely with the Nicaraguan government body tasked with volcano and environmental monitoring, and share all of the research results with them. Educational material has been provided from this project to the National Park Office and is now used in its visitor centre to inform the public about volcanic risk and environmental impact. In the past year work has begun with local farmers to study water quality with a view to advising on safety for agriculture. This has educated and trained the wardens within the National Park, who are now able to identify species of flora and fauna that can be used to monitor poisonous gas levels, and has allowed them to develop a more systematic recording of volcanic activity.

More generally, several volcano observatories have benefited from this research and the approach of using citizen scientists to both acquire data and help integrate and involve local communities. Several observatories and civil defence organisations and geological surveys have requested collaboration and advice. Training has also been requested and given to students from other higher education institutions (from the UK and elsewhere).

5. Sources to corroborate the impact

External sources corroborating impact:

1. Evidence from a blog of a colleague travelling with the Earthwatch trip to Nicaragua for a

project developing remote viewing and fieldwork and commenting on the project. http://projects.kmi.open.ac.uk/era/jawlan/

2. Earthwatch volunteering reflecting on the experience http://www.youtube.com/watch?v=s9GeR2u8-gg

3. Another Earthwatch volunteer reflecting on the experience http://www.youtube.com/watch?v=s9GeR2u8-gg

Beneficiaries who could be contacted to corroborate impact:

1. Executive Vice President (Observations), Earthwatch charity
2. Head, Faculty of Earth Sciences, University of Iceland (testimonial available on request)
3. Researcher, Volcanology, Volcanological and Seismological Observatory of Costa Rica
4. Park Ranger, Parque Nacional Volcán Masaya, (Masaya Volcano National Park)
5. Earthwatch volunteer