Geochronology of the Aeolian Islands (S. Italy): new constraints on hazard mitigation and tectonic evolution

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The full details of this project on the IAPETUS2 webpage (www.iapetus2.ac.uk) will be available shortly. To apply for this position, use the following link www.gla.ac.uk/ScholarshipApp

For further information please contact: Rob Ellam (SUERC, University of Glasgow) Rob.Ellam@glasgow.ac.uk. The project student will join the Caledonian Geochronology & Geochemistry Research Group (www.scottishisotopes.co.uk) and be based fulltime at SUERC (https://www.gla.ac.uk/research/az/suerc/)

PROJECT SUMMARY:

The main aim of this studentship is to provide the best yet reliable chronology for the eruption history of the Aeolian Islands, Southern Italy. For the active volcanoes (Stromboli and Vulcano) the new information will inform volcanic hazard planning but geochronology for these and the other extinct volcanoes on other islands (Alicudi, Filicudi, Lipari, Salina and Panarea) this will be the first state-of-the-art attempt to develop an absolute chronology for Aeolian volcanism. Most radiogenic geochronometers (e.g. Ar-Ar) were only suited to dating material older than a few million years.

Radiocarbon could date wood fragments engulfed by relatively low temperature pyroclastic deposits but, until the advent of accelerator mass spectrometry, required sample sizes of a few grammes. U-series isotopes operate over the correct timescale, but when ages have been generated, they tend not to be eruption ages because the processes that set the isotopic clocks predate eruption.

The Cassignol or unspiked K-Ar method was developed specifically to date young volcanic rocks. The method relies on tiny proportions of radiogenic ^{40}Ar, sometimes less than 1% of total Ar. However, the Cassignol method has tended to produce conflicting ages and does not deliver high precision; it is not unknown for authors to present data that are less precise than the actual age e.g. 1.8 +/- 3.0 k.y. (Gillot & Cornette, 1986) which is clearly not fit to purpose. Consequently, the Cassignol method has not been widely embraced by the geochronological community.

Recent advances in Ar-Ar mass spectrometry have achieved performance in two respects: (i) Ar-Ar is now able to date much younger rocks and (ii) the precision on those ages is greatly improved. Now, with absolutely state-of-the-art instrumentation, we can date rocks that are a few tens of k.a. old with a precision of a few hundred years. The youngest rocks we have dated are only a few thousand years old and, critically, we have demonstrated concordance with radiocarbon and luminescence dating. There is now a seamless transition from the radiocarbon working age range (0-50 k.y.) to that of Ar-Ar (k.y. – Ga).

Reliable volcanic chronologies can be (literally) vital to the populations of habited volcanoes. The seven Aeolian Islands are calc-alkaline to potassic subduction-related volcanoes. They define an island arc from Stromboli in the east to Alicudi in the west. However, in the centre of the arc, three islands, Vulcano, Lipari and Salina, are aligned roughly north-south. These three islands appear to be located along a rift bounded by the Tindari-Letojanni faults (Barberi et al, 1994).

Objective 1: Hazard Mitigation

Stromboli has been in persistent eruptive activity for at least 1000 years. The type locality for strombolian activity, it typically erupts from one of three active craters within the main crater which is offset from the summit of the mountain. Typically, the eruptions involve columns of volcanic bombs and most of the new material lands on the extremely steep Sciara del Fuoco (stream of fire). However, every few years, most recently 2002, 2003, 2007, 2013-14, 2019 activity increases and Stromboli erupts a fully fledged lava flow. The main hazard is probably not the volcanic eruptions which tend to be contained within the Sciara del Fuoco but collapse of the Sciara itself . In 2002 a major collapse induced a tsunami (Chiocci et al., 2008) that did around £600,000 worth of property damage. Fortunately, there were no casualties because the event occurred on December 30th. Stromboli has only about 400 permanent residents but in high summer the population swells to 10,000 . However, if the Sciara del Fuoco, which extends to 700m below sea-level were to be breached it could expose a magma chamber, thought to contain about 15000 Km^3 of magma to seawater which would trigger a catastrophic eruption.

Vulcano is the type locality for vulcanian eruptions; an explosive type of volcanic eruption that occurs when the pressure of entrapped gases in a relatively viscous magma becomes sufficient to blow off the overlying crust of solidified lava. The last eruption occurred in 1888-90 and some of its larger volcanic bombs litter the Fossa di Vulcano cone. Prior to 1888, volcanism was focussed on the Vulcanello isthmus which erupted periodically from 183 B.C. to 1550. Several older calderas make up the rest of the island. Fumarolic activity is intense at Vulcano, so much so that there was once sulfur mining and the miners were the main casualties of the 1888 eruption. Clearly, Vulcano remains a volcanic hazard. Again, the permanent resident population is small (c. 250) but Vulcano is a tourist attraction and day excursions from the Sicilian mainland are very popular. The 1888 eruption completely changed the demographic of the island as the major land-owner, James Stephenson sold off his land and abandoned the island, never to return.

Both islands are heavily monitored by remote instrumentation for changes in volcanic gas emission etc. that may be precursors to major eruptions. However, a better knowledge of the lengths and periodicity of the various ancient volcanoes will inform hazard assessment models.

Objective 2: Absolute Age Determinations

With the advent of high precision Ar-Ar geochronology being extended to young volcanic rocks and the increased availability of small sample ^{14}C by accelerator mass spectrometry (AMS) and the new positive ion mass spectrometry (PIMS) method it is, for the first time, possible to build a detailed chronology. Hitherto, the only constraints on the absolute age and duration of the various volcanic centres have been stratigraphic position and relatively imprecise K-Ar ages, although more modern Ar-Ar dates are emerging. This project will revolutionise understanding of the history of the Aeolian Islands. While it seems a large task to date all the islands, some of the smaller islands are characterised by relatively few

lava flows, bear in mind that only the summits of large volcanic edifices are exposed above sea-level e.g. Stromboli is a similar size to Etna but the latter is founded on land whereas Stromboli sits in 2000m of sea.

Objective 3: From Chronology to Tectonics

With greatly improved chronology it will also be possible to address some puzzling tectonic questions. In particular, the student will assess whether the suggested migration of magmatism from west to east along the arc is genuine. There seems no obvious reason why typical arc magmatism shouldn't be simultaneous along the arc. However. The Aeolian islands are not a typical island arc; there is no longer oceanic crust between Africa and Europe in Sicily although there is a Wadati-Benioff zone. Maybe, what we are seeing is post-subduction rift-related magmatism operating on a subduction modified mantle? Similarly, the age of magmatism along the roughly N-S Tindari-Letojanni rift zone is important. It has been suggested that there is an age progression from Salina through Lipari to Vulcano as the rift propagates to the south. Ellam (1986) already recognised a progression towards ever more acid volcanism on Vulcano with time. Maybe the Vulcano system is in its "death throes"? If so, it might be possible to predict where and when the next phase of rift-related magmatism might occur.

METHODOLOGY:

Guided by published maps of the volcanic stratigraphy that readily identify individual lava flows and pyroclastic units, the student will collect whole-rock samples from all the Aeolian Islands. The student will also try to find fossil wood in pyroclastic deposits which might prove suitable for radiocarbon dating. We anticipate involvement from Italian volcanologists who know these volcanoes well (e.g. Mauro Rossi and Lorella Francalanci) and have assisted us in previous field work. The student will learn preparation techniques e.g. rock powder preparation and mineral separation. Basic elemental and isotope analytical methods e.g. XRF, ICP-MS and mass spectrometry. The student will be fully trained to identify material likely to yield precise Ar-Ar and ^{14}C dating and to carry out sample preparation and analysis for both chronometers. XRF analyses are likely to be carried out (by the student) under the informal supervision of Prof. J. G. Fitton (a longstanding Collaborator of RME).

TRAINING

The student will receive training in volcanic fieldwork, analytical geochemistry (elemental and isotopic analysis) and geochronology (Ar-Ar and ^{14}C); the NERC analytical Facilities regularly offer courses in these areas and the student would be expected to attend those. However, much of the training will be hands on in the laboratory. The student will be registered as working with radioactive substances (essential in processing Ar-Ar samples) and will complete the examined radiation safety course at the University of Glasgow (UoG). The student will also use lasers and be required to complete the UoG laser safety course. A range of other transferable skills courses is available at UoG and the student will be expected to develop a portfolio of transferable skills. In addition, it would benefit the student to learn basic spoken Italian.

STUDENT

The project requires a student from a geological background who has a desire to combine field observations with precise and accurate laboratory measurements (geochemistry and geochronology). Experience of field mapping, numerically literate and demonstrable ability to work with isotope data are key. The student will be immersed in the Caledonian Geochronology & Geochemistry Research Group at the Scottish Universities Environmental Research Centre (SUERC), which currently includes 6 PhD students, 2 post-doctoral researchers and 4 research technicians. Working with CASE partners Thermo Scientific will allow the student to get direct experience in the mass spectrometer industry, including high precision design of cutting-edge instrumentation. During the course of the PhD the student will spend 3 months in Bremen, Germany and 2 months at Purdue University.

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