Modelling magma propagation on Earth versus Mars (DAGGER)

ABSTRACT FOR THE GENERAL PUBLIC

The Tharsis volcanic province on Mars holds some of the largest known volcanoes in our Solar System but is also marked by straight valleys of hundreds of kilometres long. Such valleys have steep walls several hundred meters high and are found in association with volcanic terrains as well as on other rocky planetary bodies, including Mercury, Venus, and the Moon. At active volcanoes on Earth, similarly shaped valleys are formed when molten, hot rock ascends from a few tens of kilometres depth and deforms the crustal rocks. This magma either solidifies in the shallowest one to five kilometres of the crust or goes on to the surface to erupt. When the shape of the magma intrusion is long and high, but its thickness is narrow, the planetary surface is extended and fails along faults that form the observed straight valleys that connect the top of the magma intrusions to the surface. This failure of the crust coincides with the occurrence of large numbers of earthquakes on Earth. The InSight mission to Mars measured so-called ‘marsquakes’ below Cerberus Fossae, one such valley, and this finding suggests that the Martian crust either still holds liquid magma or is still relaxing and actively deforming after magma intrusion in the past tens of millions of years.

Just as on other planetary bodies, it is impossible to collect the geological and geophysical observations on Mars that help us understand magma emplacement mechanisms on Earth. Numerical models can be used instead to understand magma intrusion processes. For volcanoes on Earth, to obtain useful results for volcanic eruption forecasting rapidly, most existing numerical models of magma emplacement simplify the way rocks respond to magma injection. Mostly, the models ignore the actual fracturing of rocks during deformation. However, geological observations have shown that different fracturing mechanisms affect overall deformation patterns differently. As a result, the impact of simplifying rock behaviour on the modelled magma intrusion characteristics is poorly understood, even more so for the Martian crust heavily damaged by meteorite impacts. A new model is now necessary to study magma injection in the fractured crust of rocky planetary bodies to help understand the magmatic sources of ground deformation and seismic activity on Earth and Mars, including at Cerberus Fossae.

The DAGGER project will use an innovative approach to numerically model deformation and fracturing caused by magma emplacement in fractured rocks. Geological measurements and imaging from Uncrewed Aerial Vehicles, i.e. ‘drones’, from magma intrusions and fracture networks in Iceland will be used to study the model behaviour for a range of rock types. In this way, the research team will gain a deep understanding of the effects of fracture networks and a range of rock strengths on how magma emplaces under the gravitational conditions of Earth versus Mars. Then, by systematically simulating realistic geological conditions in the Martian crust, it will be possible to test different scenarios of how marsquakes could form below magma-induced valleys such as Cerberus Fossae. By resolving this outstanding question in the current geological state of Mars, the project will allow us to investigate the controls on different deformation mechanisms around magmatic intrusions at volcanoes on Earth as well.

In summary, the DAGGER project will develop a new, complex model of how thin sheets of magma emplace in the shallow crust of rocky planets. This model will help understand if recently measured marsquakes mean that Mars may still be volcanically active and will contribute to more robust modelling of magma intrusion events on Earth, with important implications for volcanic hazard management efforts.