Volcanic plumbing provides clues on eruptions and earthquakes

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The eruption of Mount St. Helens in 1980. Credit: Austin Post, USGS

Two new studies into the "plumbing systems" that lie under volcanoes could bring scientists closer to understanding plate ruptures and predicting eruptions—both of which are important steps for protecting the public from earthquake and volcanic hazards.

International teams of researchers, including two scientists from the University of Rochester, have been studying the location and behaviour of magma chambers on the Earth's mid-ocean ridge system—a vast chain of volcanoes along which the Earth forms new crust.

They worked in the tropical region of Afar, Ethiopia and the subarctic country of Iceland—the only places where mid-ocean ridges appear above sea level. Volcanic ridges (or "spreading centers") occur when tectonic plates "rift" or pull apart. This happens when magma (hot molten rock) injects itself into weaknesses in the brittle upper crust, erupting as lava and forming new crust upon cooling.

"These conclusions would not have been possible without the multi-disciplinary expertise of the researchers taking part in these studies," said Cynthia Ebinger, professor of geophysics at the University of Rochester.

The studies, published in Nature Geoscience, reveal new information about where magma is stored and how it moves through the geological plumbing network.

Magma chambers work like plumbing systems, channelling pressurized magma through networks of underground "pipes." Finding out where magma chambers lie and how they behave could help identify early warning signs of impending eruptions, according to the researchers.

By analyzing images taken by the European Space Agency satellite Envisat, scientists were able to measure how the ground moved before, during, and after eruptions. Also, Ebinger and Manahloh Belachew, also from the University of Rochester, operated an array of seismographs that provided the depth and detailed time control to gauge the fracturing of the earth and the flow of magma from multiple eruptions in Afar. Using these data, the international team built and tested computer models to find out how rifting occurs.

The team of scientists discovered that the ground started "uplifting" (elevating) four months before the eruption, due to new magma increasing pressure in one of the underground chambers. They hope the ground movement will prove to be precursory signals that are fundamental to predicting eruptions.

In an extensive study of eruptions in Afar and Iceland—two vastly different environments—Ebinger and Belachew found remarkable similarities, with many events occurring within a short space of time. They identified multiple magma chambers positioned horizontally and vertically, allowing magma to shoot in several directions. Earthquake patterns were used to track the migrating magma as it inflated cracks, and to map the rupture of faults above the miles of propagating magma injection zones. The combined data sets show that separate magma chambers fed single eruptions.

A sequence of eruptions in Afar from 2005 to the present is part of an unusual period of volcanic unrest in Ethiopia, and is enabling scientists to learn more about magma plumbing systems at spreading centers. Most spreading centers are about a mile under water at the bottom of the ocean, making detailed observations extremely challenging.

"Our studies in Ethiopia open the door to new discoveries of multi-tiered magma chambers along submerged mid-ocean ridges worldwide," said Ebinger. "We also found that magma movement and faulting during intense episodes create much of the characteristic rift valley topography, where narrow lowlands are found between mountain ranges."

When magma intrudes into a region it generates earthquakes, according to Belachew, a Ph.D. candidate. "The detailed relations of the earthquake sequences in both time and space allow us to track the movement of magma and associated fault rupture with unprecedented detail," he said.

Tim Wright, from the University of Leeds' School of Earth and Environment, heads the international Afar Rift Consortium. "The dramatic events we have been witnessing in Afar in the past six years are transforming our understanding of how the crust grows when tectonic plates pull apart," said Wright. "Our work in one of the hottest places on Earth is having a direct impact on our understanding of eruptions from the frozen volcanoes of Iceland."

Provided by University of Rochester