UNDERSTANDING ERUPTIONS: HOW CAN WE DETERMINE WHICH VOLCANOES POSE THE GREATEST THREAT?

FOR MILLENNIA, HUMANS HAVE LOOKED UPON VOLCANOES WITH A SENSE OF AWE AND TERROR. NOWADAYS, WE HAVE A MUCH DEEPER UNDERSTANDING OF WHAT VOLCANOES ARE AND HOW THEY WORK. HOWEVER, PREDICTING WHEN AND WHERE AN ERUPTION IS GOING TO OCCUR IS STILL A CHALLENGE. **DR MICHAEL EDDY**, A GEOLOGIST FROM **PURDUE UNIVERSITY** IN INDIANA, USA, IS RESEARCHING HOW TO MAKE MORE ACCURATE PREDICTIONS ABOUT WHERE THE MOST VIOLENT ERUPTIONS ARE LIKELY TO HAPPEN

TALK LIKE A GEOLOGIST

PYROCLASTIC FLOW - a fast-moving mass of hot ash, gases and rock fragments

MAGMA - extremely hot liquid rock found under the Earth's surface. When it breaks through the surface in a volcanic eruption, it is known as lava

RHYOLITE MAGMA - a type of magma that has a very high silica content. When it cools, it hardens and becomes a kind of volcanic rock known as rhyolite

COMPACTION - a process in which granular materials are forced together by pressure from above, forcing any liquid between the granules to be expelled

VISCOSITY - a measure of how easily a substance flows. Substances with high viscosities are sticky and flow very slowly

RADIOACTIVE ISOTOPE - an unstable form of a chemical element that decays over time into a more stable form. The rate at which this decay occurs can be used to date substances that contain the isotope

SILICA - a natural substance containing silicon and oxygen that is found in most rocks, sand and clay

At the start of 2022, a submarine volcano in Tonga erupted in an explosion that was hundreds of times more powerful than the atomic bomb dropped on Hiroshima at the end of World War 2. This was the largest volcanic eruption recorded, so far, in the 21st century and it caused devastation throughout the Tongan archipelago and triggered a tsunami that surged across the Pacific Ocean. Eruptions like this have the potential to cause widespread disruption and even pose a threat to human life. Being able to predict when and where these explosive eruptions are likely to occur next could help nearby populations prepare for the worst.

Volcanic eruptions can vary dramatically in power, duration and frequency. The gentlest eruptions occur with minimal force and involve steady outpourings of lava that move slowly enough that they pose little threat to humans. In certain parts of the world, like Hawaii, these eruptions occur continuously and have even become popular tourist attractions. On the other hand, the most powerful eruptions can be deadly and unpredictable. These larger eruptions explode with immense power and can trigger tsunamis or pyroclastic flows, making them a much more potent threat to human life.

The geological processes that lead to these large eruptions are complex and can be hard to study, which makes the eruptions hard to predict. Dr Michael Eddy from Purdue University in Indiana is attempting to understand these processes by studying ancient, fossilised volcanoes.

WHAT CAUSES THE MOST EXPLOSIVE ERUPTIONS?

Volcanic eruptions occur when molten rock, or magma, is forced to the surface. The most powerful and explosive eruptions are often caused by rhyolite magmas which have a high silica content. The high levels of silica make rhyolite magma extremely viscous. Substances with a high viscosity, like honey, flow very slowly, while substances with a low viscosity, like water, flow easily. "This property matters," Michael says, "because high viscosity magmas trap gas bubbles as they begin to form, essentially creating a pressure bomb." As the magma rises to the surface, these bubbles of gas merge and eventually burst, which causes an eruption. As high-silica rhyolite magmas are highly viscous and contain lots of dissolved gas, they are, as Michael puts it, "prime culprits for explosive volcanic eruptions".

DR MICHAEL EDDY

Department of Earth, Atmospheric and Planetary Sciences, Purdue University, USA

FIELDS OF RESEARCH

Geology, Geochronology

RESEARCH PROJECT

Studying fossilised magma chambers to uncover the processes behind the planet's most explosive volcanic eruptions

FUNDER

National Science Foundation (NSF)

Unfortunately, the process that forms rhyolite magmas is still poorly understood. Rhyolite magma is normally formed in chambers in the uppermost part of the Earth's crust. In these chambers, the high-silica magma separates from magma that contains a high density of crystals. The process by which this separation occurs remains unknown and is the subject of Michael's research.

Currently, there are two models that could explain the separation. The simplest explanation is that the crystals sink to the bottom of the chamber and leave the high-silica magma closer to the surface. The other model involves a process known as compaction, in which the crystal-bearing magma is compressed under pressure. As compaction occurs, the high-silica magma is expelled upwards like water being squeezed out of a sponge.

WHY IS IT IMPORTANT TO UNDERSTAND THIS PROCESS?

These two models make two very different predictions about the characteristics of a magma chamber in the build-up to an eruption. Crystals can only sink if the magma chamber is dominated by liquid rock. On the other hand, compaction can only occur if the magma chamber is dominated by crystals. "Geophysicists can use seismic waves to determine whether the magma underneath a modern volcano is crystal-rich or liquid-rich," explains Michael. "Therefore, determining which of these processes leads to the production and eruption of high-silica rhyolite will help them decide which volcanoes pose the greatest hazard."

HOW DOES MICHAEL STUDY THIS PROBLEM?

In certain areas, the movement of rocks over long periods of time have caused ancient volcanoes to tilt, exposing fossilised magma chambers to the surface. "These areas allow us to look at fossilised magma reservoirs to determine whether crystal settling or compaction occurred," says Michael. He and his team then attempt to match the fossilised chamber with rhyolite eruption deposits on the surface to learn more about how conditions in the magma chamber might have affected the eruption.

Michael specialises in determining the age of rocks, and these skills come in handy when his team is trying to match a fossilised chamber with specific rhyolite deposits. "Showing that an eruption occurred at the same time that a fossil magma reservoir contained liquid is a key part of reconstructing ancient magmatic systems," explains Michael. He can determine the age of rock samples in a laboratory using a process called uranium-lead dating. As we know how long it takes for uranium to decay into lead, Michael can determine the age of a rock sample by observing the amount of uranium and lead present in it.

Michael also spends a lot of time outdoors conducting fieldwork. This involves mapping the different rock types within a field area and collecting samples for analysis. "This is fairly simple," he explains. "It involves breaking up rocks with a sledgehammer!" This mix of field and lab work poses a challenge to geologists like Michael as they need to be skilled in a range of different procedures and techniques. Because of this, Michael's team is made up of scientists who have a range of specialties from studying volcanic deposits to operating special instrumentation that analyses the chemical composition of minerals.

WHAT HAS MICHAEL'S RESEARCH TAUGHT US?

Preliminary findings from this project, along with other areas of Michael's research, suggest that the high-silica rhyolite magma is formed when the crystals sink to the bottom of a magma chamber. This implies that magma chambers dominated by liquid rock pose the greatest threat as they are the most likely to cause explosive rhyolite eruptions. Michael and his team are currently working in the Stillwater Range, in Nevada in the US, to determine whether high-silica magma is formed by the same process there.

If Michael's findings are confirmed, geologists may be able to make more accurate predictions about which volcanoes are going to erupt and how dangerous those eruptions might be. If a dangerous eruption is thought to be possible, then special instrumentation can be brought in to monitor the volcano. If these instruments indicate an imminent eruption, local populations can be evacuated before the eruption begins, emergency supplies could be sent to the area and backup communication systems could be set up. After the eruption in January 2022, communications between Tonga and the rest of the world were all but severed and it took days for humanitarian aid to reach the island nation. Having a warning system might have made all the difference. We will never be able to stop volcanic eruptions, but with more accurate predictions, we can be better prepared to deal with their consequences.

ABOUT GEOLOGY

Geology is the study of the physical structures and substances that make up the Earth, as well as the processes which have shaped these. It is a broad field that incorporates elements of practically all other scientific fields including physics, biology, chemistry and mathematics. As it encapsulates such a range of topics, geology is often sectioned into smaller, more specified disciplines. These include mineralogy (studying crystal structure), sedimentology (sediments, such as sand and clay), palaeontology (fossils) and volcanology (volcanoes), to name but a few.

Michael specialises in a field known as geochronology, which is the science of dating Earth materials, such as rocks, minerals and sediments, as well as geological events. Geochronologists determine the age of their samples by studying radioactive isotopes present within them. By observing the ratios of different isotopes, which decay at varying rates, they can make accurate predictions about the age of a sample. Geochronology plays a vital role in many aspects of geology and helps geologists understand the processes that shaped the Earth as we know it.

WHAT DOES A DAY IN THE LIFE OF A GEOLOGIST LOOK LIKE?

Because geology incorporates such a range of disciplines, the daily work of a geologist is likely to vary depending on what they specialise in and where they are in their career. Some geologists will spend a lot of time in the field, making observations, mapping field areas and collecting samples of rocks and minerals. On the other hand, some geologists will specialise in lab work and make use of cutting-edge research tools to analyse samples. Some geologists, like Michael, get the opportunity to work both in the field and in a laboratory. Michael says, "This approach suits my skills and interests very well and it is what drew me to the field initially."

WHAT RESEARCH OPPORTUNITIES WILL BE OPEN TO FUTURE GEOLOGISTS?

Because of geology's scope, there will be a range of opportunities for budding geologists. "Much of the technology that is used within our society requires elements that must be mined," says Michael. "Learning how to better find and safely exploit deposits of these elements will be an important opportunity for the next generation of geologists." Geologists will also continue to assess the risks posed by seismic and volcanic activity. More recently, geologists have begun investigating how the world will react to climate change.

EXPLORE CAREERS IN GEOLOGY

- The department of Earth, Atmospheric and Planetary Sciences at Purdue (**www.eaps.purdue.edu/outreach/index.html**) offers a variety of public outreach programmes within the state of Indiana.
- The department also communicates the most recent research results from its faculty through Twitter (**@PurdueEAPS**) which can be a great way to keep up-to-date with the latest geological research.
- The British Geological Society (**www.bgs.ac.uk/geology-projects/citizen-science**) has a number of citizen science projects that you can take part in to get involved in some real geology.
- Become a student member of The Geological Society (**www.geolsoc.org.uk/StudentMembership**) for free access to resources and events that can help prepare you for a career in geology.
- According to Salary.com, the average salary for a geologist in the US is around $64,000. (**www.salary.com/research/salary/listing/geologist-salary**)

PATHWAY FROM SCHOOL TO GEOLOGY

- Geologists must be proficient in mathematics, chemistry and physics, in addition to Earth science. Michael recommends that any budding geologists take as many courses in these areas as possible.
- A career in geology generally follows a bachelor's or master's degree in the subject.
- Michael also recommends that, whilst studying for your degree, you should contact companies that you are interested in working for. Sometimes, these contacts lead to internships and permanent employment.

HOW DID MICHAEL BECOME A GEOLOGIST?

WHAT WERE YOUR INTERESTS WHEN YOU WERE GROWING UP?

I've always been interested in history, both human history and the history of the Earth. In fact, I consider myself an Earth historian because my research helps tell the story of Earth's past. My fascination with the past was present even when I was a child, and from an early age, I collected fossils near my parent's home in North Carolina.

WHO OR WHAT INSPIRED YOU TO BECOME A SCIENTIST?

I was inspired to become a scientist by the educators I encountered in secondary school and at university. My science teachers seemed to understand the world in a way that was very appealing to me, and if they didn't already understand something, they had a method for trying to figure it out!

WHAT ATTRIBUTES HAVE MADE YOU SUCCESSFUL AS A SCIENTIST?

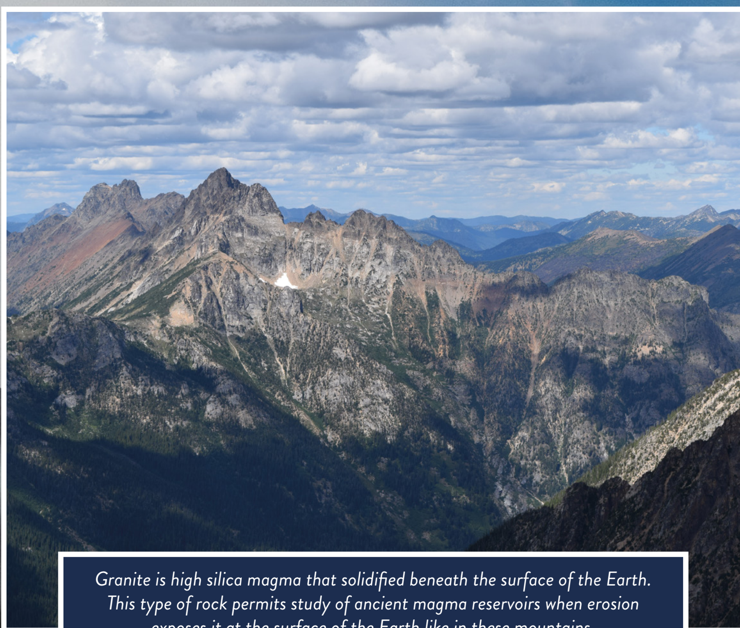
Technical skills in mathematics, physics or chemistry seem to always be highlighted when discussing the success of scientists. However, I think that an intense curiosity about the world and how it works is much more important to a scientist's success.

WHAT ARE YOUR PROUDEST CAREER ACHIEVEMENTS SO FAR, AND WHAT ARE YOUR AIMS FOR THE FUTURE?

I'm most proud of my contributions to scientific teams that have constrained things like the rates of volcanic eruptions and how the Earth's climate has changed in the past. Working in teams is one of the most rewarding parts of scientific research. I'm currently building my own research group at Purdue University and my ambition is to put together a team that has fun working on all sorts of geological research problems.

MICHAEL'S TOP TIP

Be curious about the Earth and its history. Ask questions about the Earth and try to find the answers!



Granite is high silica magma that solidified beneath the surface of the Earth. This type of rock permits study of ancient magma reservoirs when erosion exposes it at the surface of the Earth like in these mountains.