VOLCANOLOGY AND GEOLOGY: AN EXPLOSION OF POSSIBILITIES

PROFESSOR STEPHEN SELF HAS BEEN STUDYING VOLCANOES FOR MORE THAN 40 YEARS. IN THAT TIME, HE HAS VISITED VOLCANOES ALL AROUND THE WORLD AND EVEN TAKEN NOTES WHILE STANDING UNDER THE ASH FALL OF A VOLCANIC ERUPTION. HERE, WE LOOK AT THE STUDY OF ANCIENT FLOOD BASALT ERUPTIONS AND EXPLOSIVE SUPER-ERUPTIONS

TALK LIKE A VOLCANOLOGIST

Super-eruption – a volcanic eruption that has a measure of 8 on the Volcanic Explosivity Index and also magnitude 8 on the global magnitude scale for eruptions (in kg).

Volcanic Explosivity Index – a relative measure of the explosiveness of volcanic eruptions. Steve was part of the team that devised the Index.

Super-volcano – a volcanic centre that has had a super-eruption at some point.

Ancient flood-basalt eruptions – eruptions that occurred many millions of years ago, with known volumes of individual lava flows exceeding 2,000 cubic kilometres (km^3).

Caldera – a large bowl-shaped volcanic depression that measures more than one kilometre in diameter. Calderas are almost always formed by the collapse of the top of a volcanic edifice.

Magma – molten or partially molten rock below the Earth's surface from which igneous rocks form.

Lava – magma that emerges as a liquid onto the Earth's surface.

Pyroclastic flows – a mixture of hot magma/magmatic fragments, gases and entrapped air that moves at high speed in thick clouds across the ground. The ultimate geologic hazard!

Volcanic winter – a reduction in global temperatures that is caused by volcanic droplets of sulphuric acid and water obscuring the Sun.

As you walk along the street to the shops, take the bus to see a friend, or lie on the beach on holiday, you could be forgiven for not realising just what has gone into creating the Earth's surface. It is said that more than 80 percent of the Earth's surface – both above and below sea level – is of volcanic origin. Over hundreds of millions of years, gaseous emissions from volcanic vents formed the Earth's earliest oceans and atmosphere. Not only have countless volcanic eruptions produced mountains and plains around the world, they have supplied the very ingredients needed to evolve and sustain life.

In human terms, explosive volcanic events that led to the phenomena detailed above occurred so long ago as to almost seem to belong to a different planet. And it is true that even in geological terms, most of these events occurred over geological eons.

While many super-eruptions are associated with mass extinction of life through (geologic) time, a series of flood-basalt eruptions that took place 15-17 million years ago in the Columbia River Basalt Group did not – even though these ancient flood-basalt eruptions produced an unimaginable ~210,000 km^3 of lava in the Pacific Northwest of the United States. Fortunately for all of us, another eruption of this type is not expected on Earth for a few million years.

WHAT IS AN EXPLOSIVE VOLCANIC SUPER-ERUPTION?

Professor Stephen Self has dedicated his life to the study of ancient flood-basalt eruptions and explosive volcanic super-eruptions. As a volcanologist, his research has taken him all around the world, from some of the most remote regions on Earth, through to the inside of active volcanoes.

Explosive super-eruptions can be the size of flood-basalt eruptions, producing upwards of 1,000,000,000,000,000 kg (10^{15} kg) of magma, equivalent to ~ 1,000 km^3 of ash (enough to bury a large city like London to a depth of 500 m (1,640 ft)).

WHEN DID THE LAST SUPER-ERUPTION OCCUR?

Around 26,500 years ago. It was the Oruanui eruption of Taupo Volcano in New Zealand. It generated approximately 430 km^3 of pyroclastic flow deposits from 530 km^3 of magma. It is worth noting that this is the youngest super-eruption yet known – it is entirely possible that volcanologists like Steve may discover a younger one.

Of some concern is that it was once thought that super-eruptions occurred every 100,000 years or so, but the latest study using extreme-value

statistics puts the likelihood of an occurrence at one every 17,000 years. That could mean we are effectively 9,500 years overdue. It is important to remember, however, that averages like these cannot be taken as a statement of fact.

HOW LIKELY IS IT THAT WE'LL EXPERIENCE A SUPER-ERUPTION IN OUR LIFETIME?

Fortunately, it is still extremely unlikely that a super-eruption will occur in our lifetime. Having said that, it is impossible to know when one will take place and where it will occur. Of course, this is one of the reasons that volcanologists monitor known super-volcanoes – to chart whether there is an increase in activity or any other warning signs. However, it is possible that there are super-volcanoes on Earth yet to be discovered which, again, forms part of a volcanologist's day job.

HOW DESTRUCTIVE ARE SUPER-ERUPTIONS?

This rather depends on the particular super-eruption, although it is worth noting that any impacts will likely be indirectly destructive. If you were to live in the caldera, then everything will collapse in and pyroclastic flows will wipe out an area of up to 30,000 km^2 (a radius of 100 km) around the caldera.

Most damage to the planet will occur in the years afterwards, though. Immediately after the super-eruption starts, there will be ash fallout, which will impede our ability to fly in aeroplanes. Later, there could be follow-on effects such as climate change – these effects could last for decades, if not centuries.

WHY IS IT IMPORTANT TO STUDY SUPER-ERUPTIONS IF THEY ARE A RELATIVELY RARE EVENT?

"We can learn a lot by studying the extremes of phenomena, particularly when we know that the Earth will definitely experience a super-eruption at some point in the future," explains Steve. "Studying super-eruptions can give us early warnings for future generations – it is worth noting that an eruption of 8 on the Volcanic Explosivity Index would cause devastation equal to that of a very large meteorite (a bolide) hitting the Earth – and the frequency of super-eruptions is much greater!"

HOW DO YOU STUDY SUPER-ERUPTIONS?

Steve and his team trace ash deposits, which sometimes occur across continents (the spread of ash can be extremely wide). They then try to determine whether the ash deposits are from the same super-eruption and estimate the volume and mass of the deposits. Ultimately, the work of a volcanologist studying super-eruptions is centred on putting together a historical picture of the eruption – it is time-consuming work, but filling in the gaps of our knowledge is always important.

There are about 20 known super-volcanoes on Earth. Below, we list two and detail their most recent super-eruptions.

TOBA

Toba is an ancient volcano located in Sumatra, Indonesia. Around 74,000 years ago, a super-eruption expelled up to 5,000 km^3 of ash. It is thought to be the largest volcanic eruption in human history (as opposed to recorded in human history) and one of the biggest ever known to scientists. Some scientists believed it sent the planet into a severe ice age, which almost caused the extinction of modern humans, but this point is highly disputed.

YELLOWSTONE

Perhaps the most well-known super-volcano to people in the Western world, Yellowstone is mostly situated in the northwest corner of Wyoming in the US. Its caldera measures approximately 55 x 75 km and was initially formed over three eruptions, the first of which occurred approximately two million years ago. It currently supports lots of geysers and hot-springs.

Here, you can see part of the Toba caldera and lake.

PROF STEPHEN SELF

Volcanologist, Faculty of Earth and Planetary Science, University of California, Berkeley, USA

FIELD OF RESEARCH

Volcanology and Geology

RESEARCH

Steve's interest in volcanoes spans more than 40 years. Much of his work is concerned with lava-producing super-eruptions (which occurred on Earth millions of years ago) and explosive super-eruptions (which can and will occur again during the human species' lifespan).

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PATHWAY FROM SCHOOL TO VOLCANOLOGY AND GEOLOGY

Volcanology is part of the field of geology, so you cannot have the former without the latter. The subjects you need to take at school, college and university to study volcanology and geology do have some overlap but volcanology is such a niche field, that it is perhaps better to focus your attention on geology initially and see if you can narrow the focus down to volcanology at a later date.

"The field of volcanology does not employ that many people, with between 2,000 and 2,500 people around the world considering themselves volcanologists – the number of members of the International Association of Volcanology and Chemistry of the Earth's Interior (IAVCEI)," explains Steve. "To become a geologist, you should study a broad range of subjects, including mathematics, physics, chemistry, geology and physical geography, biology and statistics."

WOULD STEVE RECOMMEND A CAREER IN GEOLOGY?

Yes. Steve believes it is a wonderful career for a range of different reasons. "It really is a great field to work in," says Steve. "You learn to look after the planet, you get to explore remote and/or beautiful regions around the world, you often work outdoors (if that's your thing), and the work is usually varied!" So, if all of that sounds of interest, you should certainly be embarking on a career in geology!

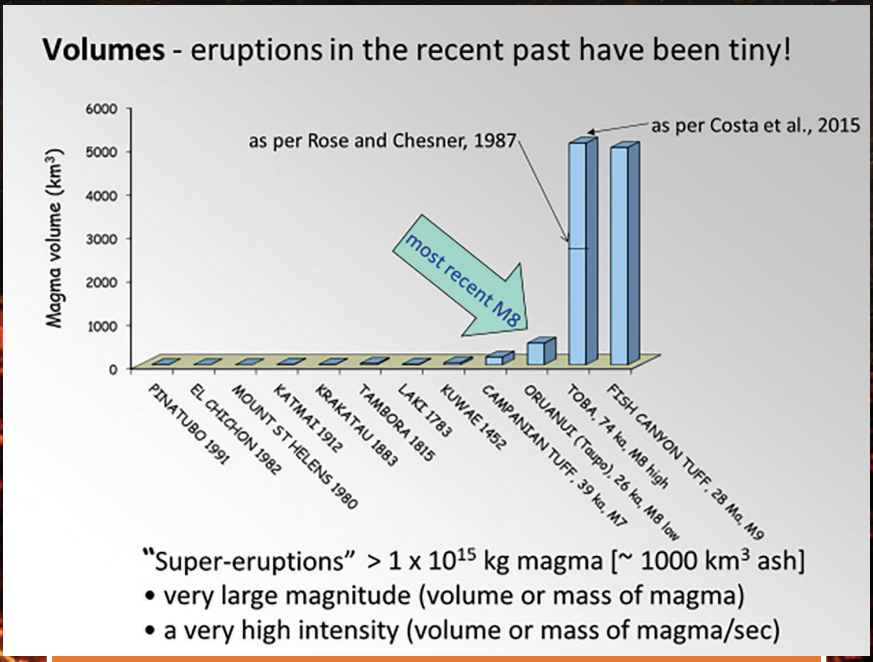
DO I NEED A DEGREE IN VOLCANOLOGY TO WORK IN THIS AREA?

Again, this rather depends on the pathway you take. There are many volcanologists who began with a geology degree and do not have a PhD in geology. However, it is worth considering the fact that there are jobs at all levels, from degree-level, to masters-level, through to PhD-level.

Even a non-geology degree can be OK, but an Earth science, geophysics or environmental science degree is best. In truth, the path is not always linear – there are many different routes to begin a career as a geologist or volcanologist. It is up to the individual to forge their own path in a way that works best for them.

HOW TO BECOME A VOLCANOLOGIST

- The Environmental Science Organisation has a wealth of information on volcanology as a vocation. It explains in great detail what a volcanologist does and includes information on the education requirements. https://www.environmentalscience.org/career/volcanologist
- Volcanologists earn an average of US$90,890 per year, with the highest 10% earning around $187,200 and the lowest 10% earning around $48,270.
- The job demand for volcanologists is expected to grow 16% in the next 10 years – faster than the average profession.



ka = thousand years (kilo annum); Ma = million years (mega annum); km³ = cubic kilometers
Toba could well be the second known M9 eruption, based on the latest estimates!

HOW DID PROF STEPHEN SELF BECOME A VOLCANOLOGIST?

WHAT DID YOU WANT TO BE WHEN YOU WERE YOUNGER?

The first thing I wanted to be was a steam locomotive driver, but then steam went away and was gradually superseded by electric and diesel locomotives. It was around the age of 12 that I became interested in geology and decided I wanted to become a geologist.

WHO OR WHAT INSPIRED YOU TO STUDY VOLCANOLOGY?

I used to read books about geography and geology from the local library – and I was naturally drawn to volcanoes for some reason. However, I never thought I would end up studying them – I just wanted to be a regular geologist hunting for minerals or oil.

Also, my mother rented rooms out to two London university students beginning from when I was about 11. One was studying chemistry (and ended up marrying my elder sister, but that's another story), while the other studied geology. I was very interested in him and the work he was doing – he went on field trips, which sounded great to me. He never tired of answering my questions! His name was Philip Sproston and he sadly died quite young.

YOU HAVE STUDIED VOLCANOES FOR MORE THAN 40 YEARS. WHAT HAS BEEN THE HIGHLIGHT OF YOUR CAREER SO FAR?

There have been so many highlights over the years! Managing to get to Mount Tambora, a remote volcano in Indonesia, in 1979 – to undertake the first modern study of the great 1815 eruption. Going to Antarctica for seven weeks as part of a remote field mapping team was a brilliant experience – it had nothing to do with volcanoes, but it was a unique experience nevertheless. Standing in the ash fall of the 1973 Iceland volcanic eruption at Heimaey and taking notes was also a highlight, as was seeing Toba in Indonesia – the site of the immense super-eruption 74,000 years ago.

HAVE YOU EVER BEEN INSIDE AN ACTIVE VOLCANO? WHAT IS IT LIKE? DOES IT FEEL DIFFERENT TO A DORMANT VOLCANO?

There are active volcanoes, which are defined as those that might erupt again, based on several criteria. However, when they are not erupting, they are classed as dormant, so being inside active volcanoes like that, such as Yellowstone or Etna – when they're not producing lava flows – is not much different to being in or on a dormant one.

Then there are actively erupting volcanoes, which of course are extremely dangerous!

The safest is Kilauea, Hawaii, where one could go right up to the active lava flows (until the eruption shut down about a year ago). That is something I have done frequently.

There are also volcanoes such as Heimaey, and Etna, which erupts almost every year it seems! I have actually been close to both during eruptions and I can tell you that it is pretty exciting! You just have to be aware of what you are doing, what is coming next, and avoid getting too near the vents.

IF YOU COULD GO BACK IN TIME, WHAT WOULD YOU SAY TO YOURSELF WHEN YOU WERE A TEENAGER?

Be better at maths, physics and chemistry, not just geology and geography! I struggled with the basic STEM subjects, but no one ever explained why the STEM courses were so essential.

FINALLY, WHAT SHOULD PEOPLE DO IF THEY HAPPEN TO BE CLOSE TO A VOLCANO ERUPTING?

Move away – quickly!

STEVE'S TOP TIPS

1. Study hard and learn at all times. You should be prepared to take STEM courses (science, technology, engineering and mathematics), because they essentially underpin many other subjects.

2. Take chances – if you are embarking on a career in geology or volcanology you should be prepared to live abroad, particularly as there are geological topics of interest all around the world.

3. Grasp the opportunities that you are given, whenever you are given them. It is important to apply for scholarships and fellowships if you can; this will help expand your potential and perhaps give you opportunities you would not otherwise be given.

Kilauea volcano in Hawaii. Steve has visited this volcano to see its active lave flows many times.