Now we know how super-volcanoes blow

Geoffrey Mohan, Los Angeles Times, 1-6-14

Scientists have figured out how and why massive pools of magma such as the one lurking beneath Yellowstone National Park blow sky-high in volcanic super-eruptions.

The rare catastrophic events can spew thousands of times more material than the eruption of Mt. St. Helens in 1980, or of Mt. Pinatubo in 1991, and can bury a large city several miles deep.

But how these enormous forces are unleashed remained an unpredictable mystery, with some geologists speculating that earthquakes might touch them off.

The culprit, however, appears to be deceptively simple – the buoyancy of the magma exerting pressure on the chamber roof, like a balloon inflated under water, according to two studies published Monday in the journal Nature Geoscience.

That mechanism differs from the driving force behind most volcanic eruptions -- a relatively quick injection of magma causing high pressure quickly vented to the surface -- the researchers found.

“It’s a little bit like if you blow in a tiny balloon, you can blow it up so fast that it can explode,” said volcanologist Luca Caricchi of the University of Geneva, lead author of one of the studies. “This would be a parallel for smaller eruptions that are triggered by the injection of magma.”

But no amount of blowing would explode a hot-air balloon, so the pressure behind eruptions of huge magma reservoirs had to come from something else, volcanologists suspected.

“Because magma is less dense than the crust, this provides the same pressure that you have when you push an air balloon below water,” Caricchi said. “The air balloon you put below water is less dense than the water around it. The parallel for magma chambers is the magma being less dense than the crust that is sitting around the chamber.”

While Caricchi’s team resorted to more than a million computer runs of a mathematical model, another team cooked up its own magma recipe and brought it to the European Synchrotron Radiation Facility in Grenoble, France.

They put it in a diamond and platinum capsule surrounded by graphite and squeezed it between two anvils to obtain temperatures and pressures of about 36,000 times Earth’s atmospheric pressure at sea level, and more than 3,000 degrees Fahrenheit.

“Once we created the right pressure and temperature conditions we basically took an X-ray image, the same as an X-ray image of your hand,” said Swiss Federal Institute of Technology geochemist Wim J. Malfait, lead author of another of the studies published Monday.

Armed with the density calculation, the researchers showed that buoyancy could create an over-pressure on the roof of a magma chamber some 100 to 400 times Earth's atmospheric pressure at sea level, which would be sufficient to start cracking open the lithosphere.

The study was the first to experimentally calculate the density of such granitic magma -- most studies have looked at basalt, Malfait said.

Because of the depth, pressures and temperatures involved, most of what we know about magma reservoirs has to be inferred from seismic waves. For instance, last month, researchers at the University of Utah used seismology to map Yellowstone’s magma chamber and found it was some 55 miles long, 18 miles wide, and as much as 9 miles deep. They estimated it could explode with 2,000 times the force of Mt. St. Helens.

But seismic wave data can’t determine the density of magma, which is critical for estimating pressure.

Among the additional factors that will have to be studied is the flux of magma in various areas of Earth, Caricchi added. Few areas on Earth are believed to have the kind of flux sufficient for super-volcano formation, and other conditions also have to align to bring on the eruptions, he said.

"It’s a very strict set of conditions that can lead to super-eruptions," Caricchi said. "This is why they are not likely. They’re essentially errors of nature.”

Caricchi's group also estimated the upper limit of magma chamber volume at nearly 8,400 cubic miles. Only about 10-20% of that magma would likely erupt, but that would would match the largest known super-eruption, about 28 million years ago near La Garita, Colo., according to Caricchi.

Placing an upper limit on super-eruptions could help scientists estimate their recurrence with a smaller margin of error, he said.

“I cannot tell you if tomorrow Vesuvius is going to erupt, but I can tell you what the probability of an eruption to occur at Vesuvius is in the next 100 years,” with such a model, Caricchi said. “That is not bad.”