Research shows why there's a 'sweet spot' depth for underground magma chambers

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A new study reveals why the magma chambers that feed recurrent and often explosive volcanic eruptions tend to reside in a very narrow depth range within the Earth's crust. The findings, published in *Nature*

Geoscience, could help scientists to better understand volcanic processes the world over.

The research makes use of computer models that capture the physics of how magma chambers, reservoirs in the crust that contain partially molten rock, evolve over time. The models showed that two factors—the ability of water vapor to bubble out of the magma, and the ability of the crust to expand to accommodate chamber growth—are the key factors constraining the depth of magma chambers, which are generally found between six and 10 kilometers deep.

"We know from observations that there seems to be a sweet spot in terms of depth for magma chambers that erupt repeatedly," said Christian Huber, a geologist at Brown University and the study's lead author. "Why that sweet spot exists has been an open question for a long time, and this is the first study that explains the processes that control it."

Depths of six to 10 kilometers generally correspond to pressures of about 1.5 kilobars on the shallow side and 2.5 kilobars on deep side. The models showed that at pressures less than 1.5 kilobars, water trapped within the magma forms bubbles readily, leading to violent volcanic explosions that blast more magma out of a chamber than can be replaced. These chambers quickly cease to exist. At pressures more than 2.5 kilobars, warm temperatures deep inside the Earth make the rocks surrounding the magma chamber soft and pliable, which enables the chamber to grow comfortably without erupting to the surface. These systems cool and solidify over time without ever erupting.

"Between 1.5 and 2.5, the systems are happy," Huber said. "They can erupt, recharge and keep going."

The key to the models, Huber said, is that they capture the dynamics of both the host crust and of the magma in the chamber itself. The ability

of deep magma chamber to grow without erupting was fairly well understood, but the limit that water vapor exerts on shallow magma chambers hadn't been appreciated.

"There hadn't been a good explanation for why this habitable zone should end at 1.5 kilobars," Huber said. "We show that the behavior of the gas is really important. It simply causes more mass to erupt out than can be recharged."

Huber says the findings will be helpful in understanding the global magma budget.

"The ratio of magma that stays in the crust versus how much is erupted to the surface is a huge question," Huber said. "Magma supplies CO2 and other gases to the atmosphere, which influences the climate. So having a guide to understand what comes out and what stays in is important."

More information: Optimal depth of subvolcanic magma chamber growth controlled by volatiles and crust rheology, *Nature Geoscience* (2019). DOI: 10.1038/s41561-019-0415-6 , nature.com/articles/s41561-019-0415-6

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