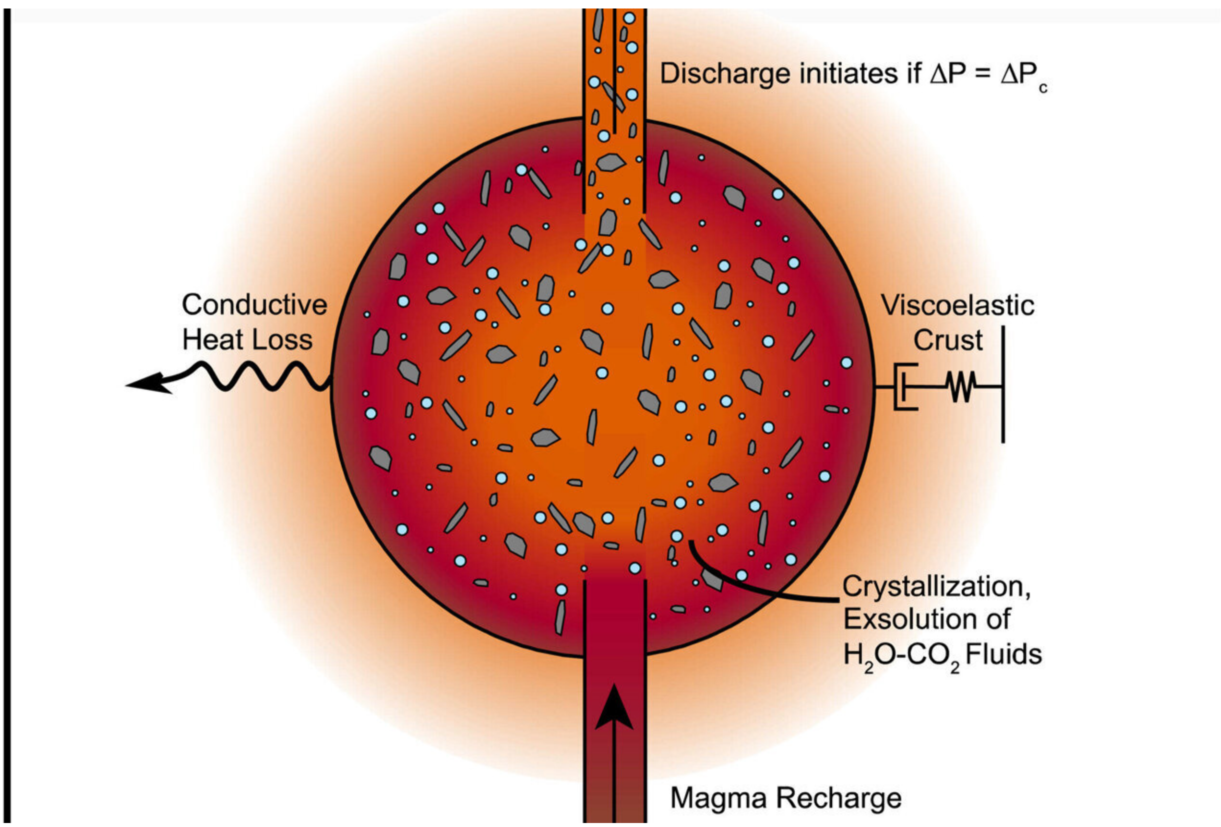
Melting Antarctic ice sheets may be causing larger volcanic eruptions

January 12 2025, by Hannah Bird



Schematic of the thermomechanical magma chamber model with simulated ice unloading from this study. Transparent arrows represent ice unloading as a decrease in the ice layer thickness over time. Credit: *Geochemistry, Geophysics, Geosystems* (2024). DOI: 10.1029/2024GC011743

Melting ice sheets are often considered synonymous with climate change in the media, with evocative images of lone polar bears floating on ever-shrinking rafts of ice. While impacts such as sea level rise and salinity changes are commonly reported, one lesser-known consequence is the effect on volcanoes.

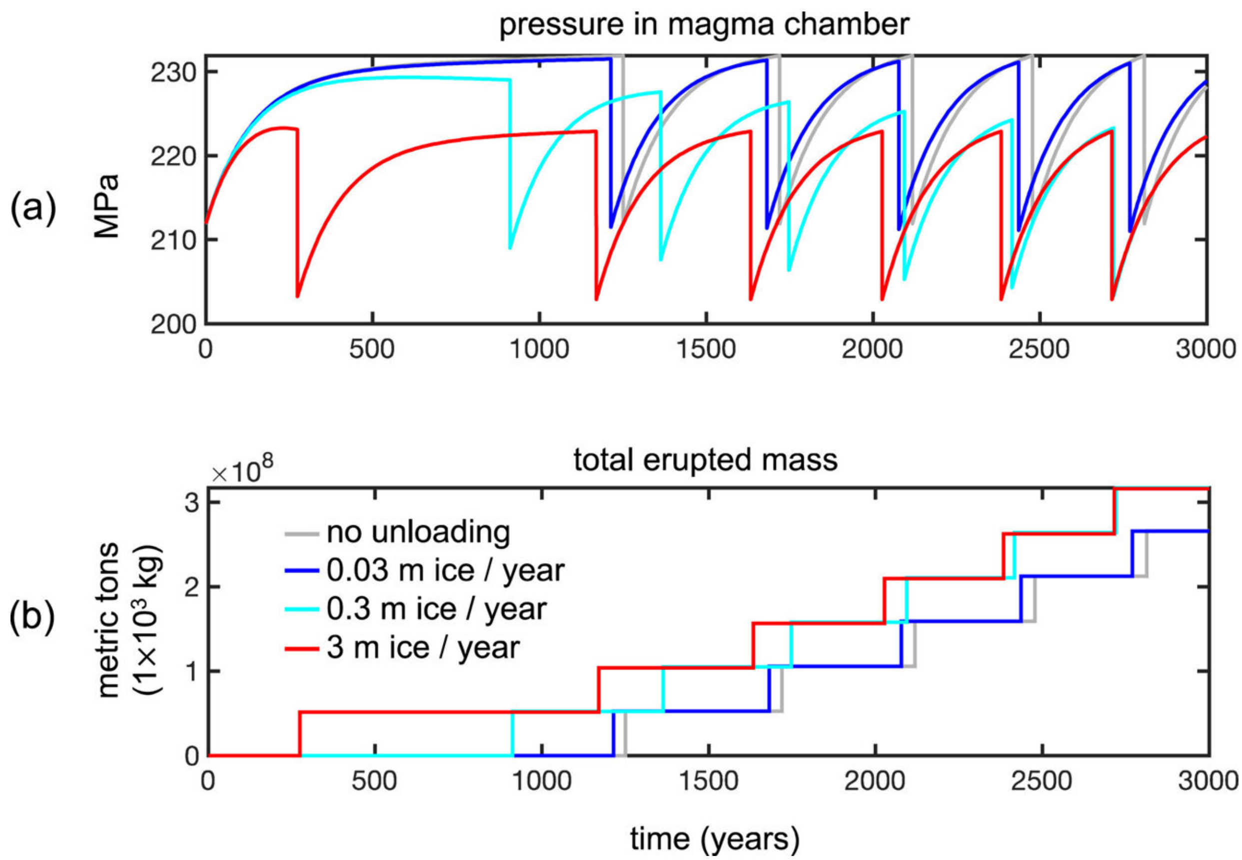
During deglaciation, melting of kilometers-thick ice sheets reduces the mass weighing down the land, which leads to uplift. This alters the pressure inside magma chambers lying below the Earth's surface, causing volcanic eruptions.

Research, published in *Geochemistry, Geophysics, Geosystems*, suggests that mass unloading due to melting of Antarctic ice sheets (isostatic rebound) is triggering eruptions of greater frequency and magnitude in the West Antarctic Rift System, one of Earth's largest volcanic provinces with over 100 eruptive centers.

Ph.D. researcher Allie Coonin, of Brown University, and colleagues investigated the interaction of glaciation and volcanism over the last two planetary glacial cycles (within the last 150,000 years).

To do so, they used a thermomechanical magma chamber model and simulated a shrinking West Antarctic Ice Sheet through inputting specific pressure decreases exerted on the underlying rocks and magma chamber.

They further explored how the reduction of this confining pressure allows the magma chamber to expand volumetrically, with associated overpressurization and expulsion of volatiles (here when dissolved water and carbon dioxide form gas bubbles) from basalt magmas affecting the trajectory of future eruptions.



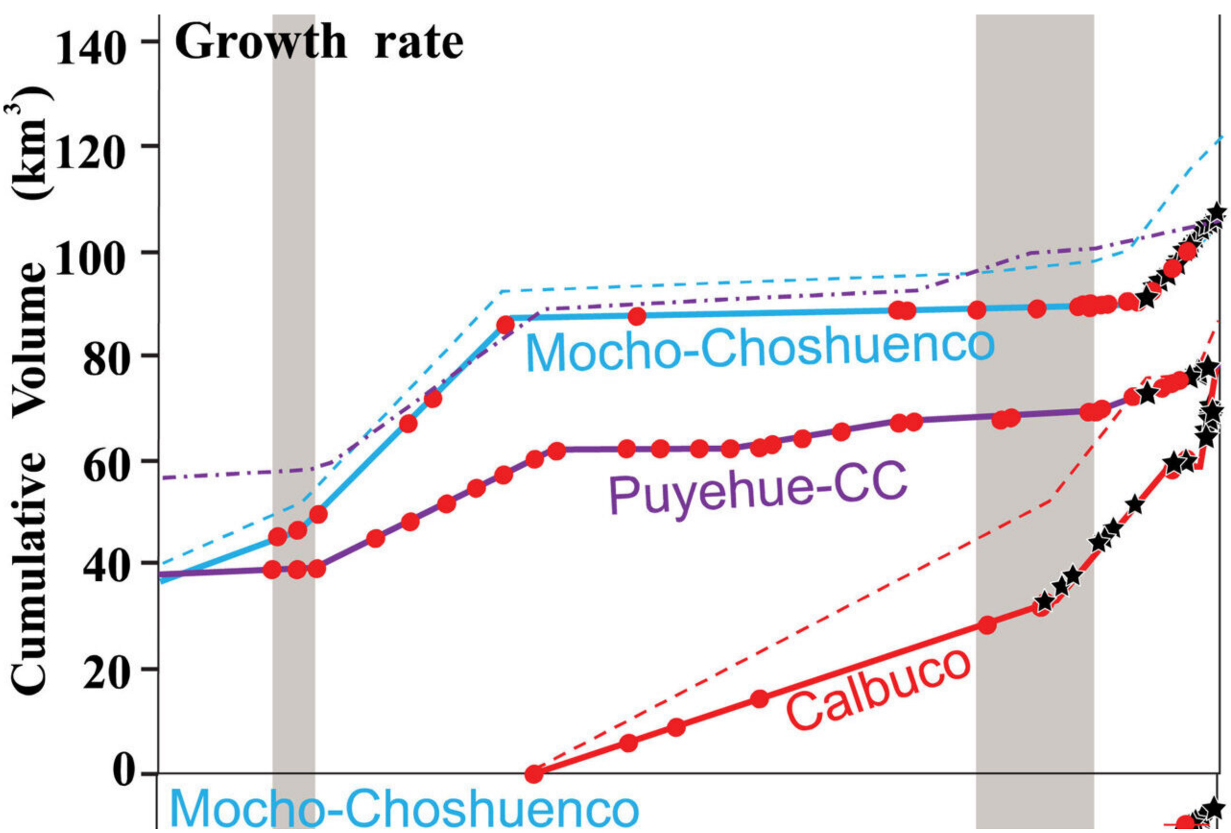
Results of modeled pressure changes in magma chamber in response to different rates of ice mass unloading and the equivalent mass of erupted magma over 3,000 years. Credit: Coonin et al., 2024.

Exploring magma chambers of different sizes, the research team found that the larger the magma chamber, the more susceptible to the effects of ice mass unloading and that unloading rate is the critical factor, with the highest investigated rate of ice loss being 3m/yr.

Furthermore, when testing magma chambers undersaturated in volatiles, the scientists identified that ice mass unloading sped up the process of first volatile expulsion (initiating the first stages leading to an eruption) by tens to hundreds of years.

This means that eruptions occurred that may not have if the unloading had not induced changes in the magma chamber, resulting in greater cumulative release of magma over that chamber's lifetime.

To test their findings, Coonin and colleagues turned to volcanic deposits from the Andes mountains in South America. Here, the Patagonian ice sheet grew to 1,600m thick on top of the Southern Volcanic Zone 18,000–35,000 years ago. They identified a correlation between ice mass unloading during deglaciation at the end of the Last Glacial Maximum (~18,000 years ago) with increased eruptive activity from the Calbuco, Mocho-Choshuenco and Puyehue-Cordon Caulle volcanoes.



Records of cumulative volume erupted from three volcanoes in the Andean Southern Volcanic Zone, corresponding to glacial cycles over the last 150,000 years. Credit: Coonin et al., 2024.

Such unloading-induced volcanism can lead to an unhelpful positive feedback loop, as when melting ice alters magma chamber pressurization to cause an eruption, the resulting event melts more ice, which could trigger another eruption. In particular, the West Antarctic Ice Sheet is grounded below sea level, so as sea level rises due to the melting ice, it becomes further submerged and accelerates retreat.

Complicating matters even more are the impacts of rising carbon dioxide levels causing global warming and ice albedo feedbacks, whereby melting ice sheets reduce the amount of incoming solar radiation reflected back out to space (there is less 'white' reflective surface compared to 'dark' surface to absorb), which warms the atmosphere and exacerbates melting.

The researchers note that even if anthropogenic warming ceased immediately, the effects of ice mass unloading that the West Antarctic Rift System has already experienced will still affect volcanic behavior here for thousands of years to come.

Therefore, understanding the sensitivity of this ice mass unloading of the West Antarctic Ice Sheet on magma chambers has important implications for being able to accurately predict future consequences on Earth's interconnected geological systems.

More information: A. N. Coonin et al, Magma Chamber Response to Ice Unloading: Applications to Volcanism in the West Antarctic Rift System, *Geochemistry, Geophysics, Geosystems* (2024). DOI: 10.1029/2024GC011743