Could Siberian volcanism have caused the Earth's largest extinction event?

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The Siberian Traps were created about 250 million years ago by massive volcanic eruptions. The lava that covered the land formed flat plains as it cooled. Over the millennia, weathering has caused the rock to crack and wear, forming steep mountains. Some rock resists weathering, creating spires of rock. Photo: NASA Earth Observatory

Around 250 million years ago, at the end of the Permian geologic period, there was a mass extinction so severe that it remains the most traumatic known species die-off in Earth's history. Although the cause of this event is a mystery, it has been speculated that the eruption of a large swath of volcanic rock in Russia called the Siberian Traps was a trigger for the extinction. New research from Carnegie's Linda Elkins-Tanton and her co-authors offers insight into how this volcanism could have contributed to drastic deterioration in the global environment of the

period. Their work is published January 9 in *Earth and Planetary Science Letters*.

The end-Permian mass extinction saw the sudden loss of more than 90 percent of marine species and more than 70 percent of terrestrial species. The fossil record suggests that ecological diversity did not fully recover until several million years after the main pulse of the extinction. This suggests that environmental conditions remained inhospitable for an extended period of time.

Volcanic activity in the Siberian Traps has been proposed as one of the mechanisms that may have triggered the mass extinction. Gases released as a result of Siberian magmatism could have caused environmental damage. For example, perhaps sulfur particles in the atmosphere reflected the sun's heat back into space, cooling the planet; or maybe chlorine and other chemically similar nonmetal elements called halogens significantly damaged the ozone layer in the stratosphere.

The team designed experiments to examine these possibilities.

Led by Benjamin Black of the Massachusetts Institute of Technology, the group included Elkins-Tanton, formerly of MIT and now director of Carnegie's Department of Terrestrial Magnetism, Michael C. Rowe of Washington State University, and Ingrid Ukstins Peate of the University of Iowa.

The geology of the Siberian Traps is comprised of flood basalts, which form when giant lava eruptions coat large swaths of land or ocean floor with basaltic lava. This lava hardens into rock formations. The team investigated concentrations of sulfur, chlorine and fluorine (another halogen) that were dissolved in tiny samples of ancient magma found within basalt samples from the Siberian Traps. These small frozen droplets, which preserve a record of volcanic gases from the time of the

eruption 250 million years ago, are called melt inclusions.

Sulfur, chlorine, and fluorine gasses could have been released into the atmosphere from eruptions spewing out of large fissures, which is common in basalt flood formation. Plumes escaping from these cracks could have reached the stratosphere. If sulfur, chlorine, and fluorine made it to the upper atmosphere, these gasses could have cause a wide array of adverse climate events, including temperature change and acid rain.

Based on their findings, the team estimated that between 6,300 and 7,800 gigatonnes of sulfur, between 3,400 and 8,700 gigatonnes of chlorine, and between 7,100 and 13,700 gigatonnes of fluorine were released from magma in the Siberian Traps during the end of the Permian period.

They say more research on atmospheric chemistry and climate modeling is urgently needed to determine whether these gasses could have been responsible for the mass extinction.

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