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Natural Hazards · Volcanic Eruption

DANGEROUS WATER VAPOUR: PHREATIC ERUPTIONS

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First published: 2016, 22nd of November, Volume 3

Digital Object Identifier (DOI): https://doi.org/10.2312/eskp.051

Teaser

Phreatic eruptions often occur without any forewarning. Many were unprepared for the sudden eruption of Ontake volcano, Japan in autumn 2014.

Keywords

water vapour, phreatic eruption, ash column, pyroclastic flow, earth crust, earthquake, volcanic gases, volcanic buildings, magma quality, evacuation, warning signal, surveillance data, monitoring systems, early warning signs

Ontake volcano (Japan) and its shrines is a popular spot for tourists and pilgrims. Especially in good weather, many people can be in the proximity of the crater, which was fatal for almost 60 visitors in September 2014. A sudden explosion produced an ash column and a pyroclastic flow; most victims however were claimed by the large number of rock fragments ejected from the crater.

Japanese volcanoes are amongst the best monitored volcanoes world-wide – so why could the people on the summit not be warned and evacuated in time? Volcanic eruptions are generally heralded by various signals that are associated with the ascent of new magma through the Earth's crust: Earthquakes and Earth vibrations, so called volcanic tremor, changes in the composition of volcanic gases and the inflation of volcanic edifices are some of the most reliable precursors for an imminent eruption. How much time passes between the first signals and the onset of an eruption depends on the respective volcano and its individual dynamics, which depend for example on the magma composition and local crustal structures. In the case of the Ontake eruption, the first occurrence of volcanic

tremor preceded the eruption by only 11 minutes – by far not enough time for an evacuation. Additionally, a single tremor is not a uniquely identifiable precursor for an eruption. Further signals, such as an inflation of the summit, could only be identified in the monitoring data and associated with the eruption in hindsight analysis.

Ascending magma usually generates signals in our monitoring systems. However, no magma was involved in the Ontake eruption, which caused the lack of precursory signals. But how can a volcano erupt without lava? Groundwater-bearing layers (aquifers) can be found in many volcanic areas. Those who have visited a geyser (e.g. "Strokkur" in Iceland) know that water, too, has explosive potential. When water vaporises, its volume increases significantly. The sudden volume expansion caused by a simultaneous vaporisation of a large quantity of water can thereby lead to a steam-driven explosion.

How do steam-driven eruptions work?

A common mechanism for steam-driven explosions at volcanoes – so-called phreatic or hydrothermal eruptions – is the sudden depressurization of hot water. As is known, the boiling point of water is 100 °C, however this is only valid under normal atmospheric pressure. At higher pressures, as they prevail at depth in the Earth, water is liquid at higher temperatures. When sufficiently hot, pressurized water is depressurized, its temperature is suddenly above the boiling point and it therefore abruptly vaporises. Depending on the amount of water, as well as temperature and pressure conditions (among other things), the resulting explosion can be violent enough to fragment surrounding rock and thereby produce ash columns and pyroclastic flows. One exemplary process causing such a depressurization is a landslide removing load from an underlying aquifer. In volcanic areas, aquifers are commonly heated by the residing magma at depth, forming hydrothermal systems that often contain both steam and liquid water. Due to the elevated temperatures many such systems are potential origins of hydrothermal explosions.

In the case of the Ontake eruption, a large amount of water vapour escaped from the hydrothermal system at depth and made its way to the surface. This lead to a pressure decrease in the hydrothermal reservoir, which in turn caused the explosive vaporisation of the remaining water in the system and thereby the eruption.

The moral of the story: even apparently quiescent, inactive volcanoes can suddenly erupt without forewarning. While the intensities of phreatic eruptions are generally rather small in comparison to their magmatic counterparts, they still pose a threat especially to visitors in the proximity of the crater that is not to be underestimated.

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Cite as

Strehlow, K. (2016, 22nd of November). Dangerous water vapour: phreatic eruptions. *Earth System Knowledge Platform* [www.eskp.de/en/basic-knowledge], *3*. doi:10.2312/eskp.051