Tying down eruption risk

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200 years after the eruption of Mount Tambora, the eruption volume remains poorly known, as is true for other volcanic eruptions over past millennia. We need better records of size and occurrence if we are to predict future large eruptions more accurately.

On 10 April 1815, the volcano Mount Tambora, on Sumbawa Island in Indonesia, erupted violently. The event was the most disastrous volcanic eruption in recent history. More than 60,000 deaths on Sumbawa and neighbouring islands alone are attributed to the eruption[1]. But the worldwide suffering and deaths (caused indirectly) continued into the following year as a result of volcanic-induced cooling. This fatality approximation must therefore be an underestimate.

The Tambora eruption has been assigned a magnitude[2] of 6–7, yet the precise size of the eruption is still under scrutiny. In a giant eruption, like this one 200 years ago, the land surface can collapse into the empty magma chamber once its contents have been ejected. The resulting caldera provides an indirect estimate of the eruption size (Fig. 1). Tambora is probably the largest caldera-forming eruption of the last few centuries, at least since 1257 when the Samalas eruption on neighbouring Lombok Island occurred[3]. But the volume of the Samalas eruption is poorly constrained, too. Going back 3,600 years, the Minoan eruption of Santorini[4] in Greece may have formed a bigger caldera than Tambora's and was probably larger in magma volume. And the Kikai eruption that occurred offshore from Japan 7,300 years ago was almost certainly larger[5].

We argue that constraining the size and recurrence times of these giant eruptions is more than scientific curiosity; we need these answers to more accurately predict when the next one might happen.

Restricted assessment of recurrence

Determining the recurrence time of the largest, most catastrophic eruptions is particularly difficult because they are so rare. Traces of these eruptions can sometimes be found in ice cores, but the volcanic source is not always obvious. Without an identified source volcano or clear ice-core evidence, it is highly doubtful whether we can calculate an eruption recurrence interval with precision.

The Samalas eruption is testimony to this point. Ice-core evidence[6] for a giant eruption at this time has been available since the 1990s, yet the source volcano was only discovered[3] in 2012. Similarly, the submarine Kuwae caldera in Vanuatu, which erupted in 1452 and may be in the same size range as the 1815 Tambora eruption, was only discovered in the mid-1990s because of the coincidental, but independent, discoveries of a relatively young caldera and a volcanism-induced acidity spike in ice-core records[7].

Only eruptions that emitted large volumes of sulphur will generate acidity layers in ice cores. And the amount of erupted ash — combined with the ash dispersal pattern and extent of core sample area — will dictate whether ash from an eruption shows up in an individual core. Thus, many more magnitude 6–7 eruptions may not be recognized in existing records[8].

The statistical models used to assess volcanic hazards rely on information about the timing and volumes of past events[4]. If there are several eruptions missing from our records, the statistics for predicting the likelihood for future events of this size would change significantly.

Taking into account under-reporting of eruptions in past records[9], estimates of the recurrence interval for Tambora-size eruptions range from 780 years for low-end approximations[10] of the eruption size (magnitude 6.9), to about 1,500 years for a magnitude 7 estimate[11], to 5,000 years for the largest volume estimate[12,13] of magnitude 7.1.

Volume estimates impeded

Approximations of eruption size are often based on reconstructions of the dispersal patterns of the ash and pumice, or tephra, because these patterns give clues to the amount of erupted material and the power with which it was ejected. However, reliable records are simply not available, partly because explosively distributed deposits are remarkably widespread. During eruptions, ash, pumice and hot gases can be ejected upwards into the atmosphere in an eruption column and outwards along the volcano flanks in the form of a pyroclastic flow. Tephra often falls or flows into the sea, where it is redistributed by ocean currents, so the ash layers recovered in deep-sea cores may not reflect the primary thickness. And when tephra is deposited on land it is rapidly eroded: for example, 60% of the pyroclastic flow deposits erupted by Mount Pinatubo in 1991 were remobilized in certain areas within three to five years of eruption[14].

Recent estimates of the volume of magma erupted from Tambora during the April 1815 event range from 30 to 50 km^3. The eruption style included both an eruption column that injected material into the stratosphere and pyroclastic flows that shed material onto the volcano flanks, often synchronously. Much of the ash fall occurred at sea[15], so we may never know the true erupted volume. Although the size of the caldera gives some indication of the amount of magma ejected, calderas are prone to rapid filling, wall collapse during the eruption, and other processes that quickly change the primary dimensions. Also, coalescence with previous calderas is common. The 1815 eruption was not the first explosive event at Tambora and two earlier eruptions[15] may have contributed to a caldera that was enlarged in 1815.

Reinvigorate research

Large eruptions can have devastating impacts that last beyond the generally short-lived ejection of volcanic tephra. The year after the eruption in Indonesia, Europe and northeastern North America experienced unusually cold summer months with frequent frosts, in what has been termed the year without a summer[16]. The cool temperatures have been attributed to the Tambora eruption, the best-known case of a volcanically induced climate cooling event[16]. The sulphur gases released during the highly explosive eruption are thought to have caused an increase in stratospheric sulphate aerosols[13] and net cooling. Climate simulations[17] show that the eruption could have reduced global temperatures by 1 ± 0.1 °C. Worldwide precipitation also decreased. The cold climate was responsible for widespread crop failures, leading to high food prices and serious famine in Europe and North America, as well as crop failure in parts of Asia.

Given the widespread and devastating impacts of this eruption, there is a surprising paucity of volcanological studies on Tambora. Virtually no field research has been conducted there since the 1980s because Tambora is extremely remote and inaccessible, so a difficult place to do field work. Additionally, no thorough geochronological analysis of Tambora's eruption deposits has been performed. It thus remains unclear how large a typical eruption of Tambora might be and when the next large eruption may occur. The answers to these questions, on Tambora and many other volcanoes, are essential to aid prediction of Earth's next magnitude 6–7 eruption.

The current global volcanic eruption record is incomplete and difficult to interpret. It is high time for a systematic exploration of all the available eruption archives — ice cores, ocean sediments, remotely sensed caldera volumes and geochronological analysis of eruption deposits — so that we have a better chance to understand potential future hazards.

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Figures

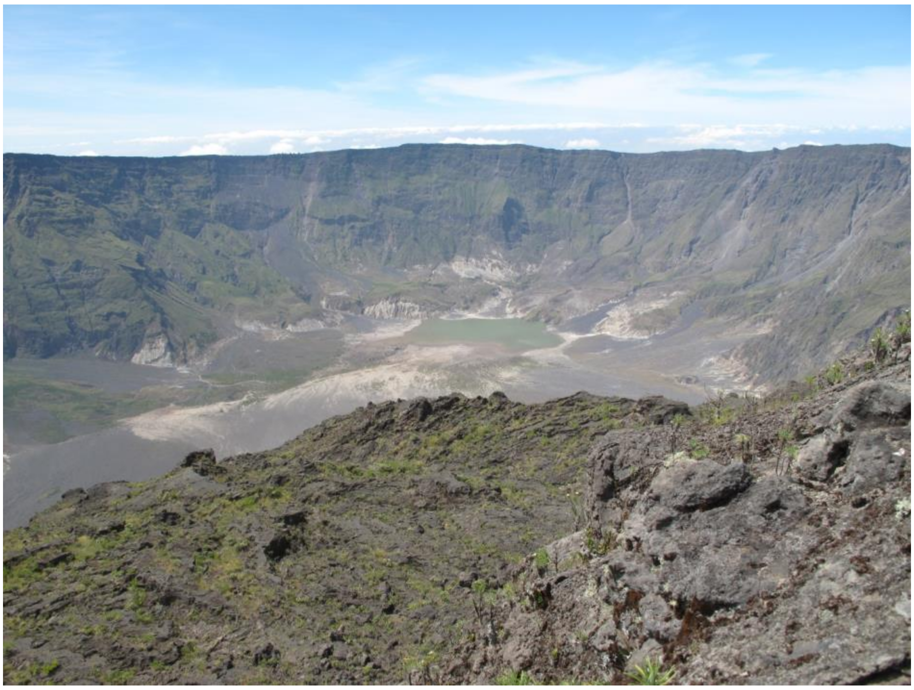

Figure 1. The Tambora caldera: The eruption of Tambora in 1815 created a 6.5-km-wide and more than 1-km-deep caldera. Erupted products form the top of the caldera wall, as seen in the foreground, and an ephemeral lake and a cone from a small post-1815 eruption lie on the caldera floor.