POLICY FORUM: DISASTERS

Volcano Fatalities—Lessons from the Historical Record

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More than 400 fatal volcanic eruptions have been documented, averaging 2 to 4 such events per year in recent decades. Despite deficiencies in the historical record, its lessons can help reduce fatalities in the future (*1–3*).

The human impact of eruptions through the last seven centuries (panel A) is clear and worrisome. Fatal eruptions are far more likely to be retained in the historical record. We believe that much of the increase shown in the figure is real, and that it is linked to global population increase and not to eruption frequency worldwide, which has been roughly constant through recent centuries.

Causes of historical fatalities are frequently not stated, and accurate numbers of fatalities are often difficult to obtain, even for contemporary eruptions. The historical record may provide nothing more than words like "several" or "many." We have assigned numbers to such words (*4*), recognizing that these approximations may be far from the truth. Only 2.6% of the 274,443 fatalities considered here are based on these approximations. We feel it is important to look at the number of fatal events as well as the fatalities themselves. This approach reduces the influence of a few major eruptions (panel B) and is less dependent on how many people happened to be in the wrong place at the wrong time.

Volcanoes kill people in a remarkably large number of ways (*1, 5*) (panel C). Pyroclastic flows (hot ash clouds that sweep downslope at hurricane speeds) have claimed the most lives. However, the most common killer in fatal eruptions is tephra, which includes all fragmental material thrown from volcanoes, killing mainly by collapse of ash-covered roofs (the most deaths) or by projectile impact (by far the largest number of fatal tephra accidents). Tephra is a more tractable hazard than pyroclastic flows, tsunami, and mudflows, although these causes understandably have received the most attention. Improved building codes and education are relatively easy solutions to prevent roof collapse. Keeping climbers away from active summits (and their unpredicted projectiles) is more difficult. Our data suggest that increased attention should be paid to tephra (*6*), and perhaps also to other agents, such as lava or gas, which have a significant fatality recurrence rate.

Where possible, we have tried to capture the time delay between an eruption's start and its fatalities (panel D). Data for total fatalities and fatal events yield the same two conclusions. First, the dangers during an eruption's early hours are huge. Many lives are lost in the first 24 hours, when the element of surprise is strongest. Research and monitoring of precursory phenomena are essential to reducing such fatalities. Second, danger persists well after the eruption's first month. Nearly two-thirds of the fatalities and half the fatal events have taken place more than 1 month after the eruption's start. Current crises involving long-running eruptions include volcanoes in Mexico, Ecuador, and Montserrat.

Shortly after an eruption's start, crisis awareness runs high. Residents often need little urging to evacuate. After many weeks, however, complacency increases, an attitude of "we've learned to live with it" develops, and a desire of evacuees to return home grows stronger. Cynicism toward scientists and authorities may increase, and scientists themselves begin to experience burnout. Our data should provide a warning to resist the temptation to think that the worst is over. History tells us that it may not be.

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References and Notes

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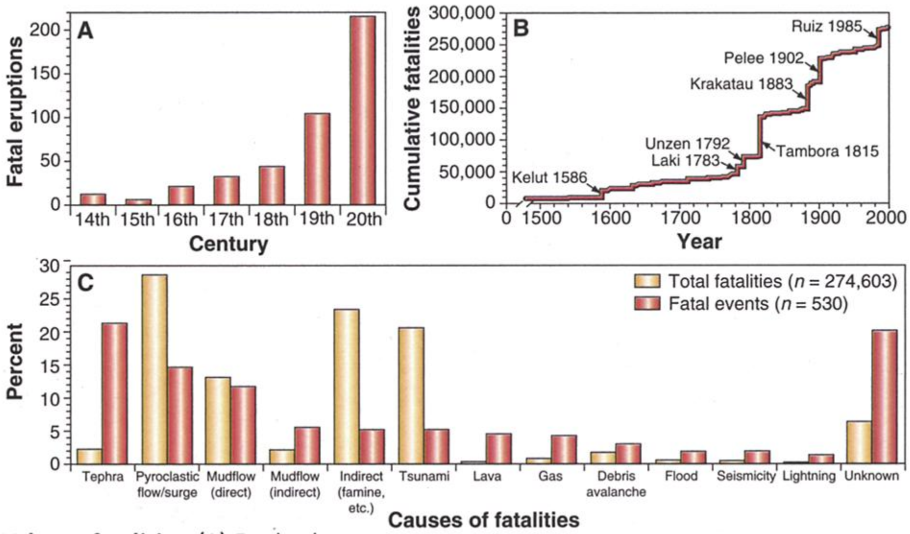
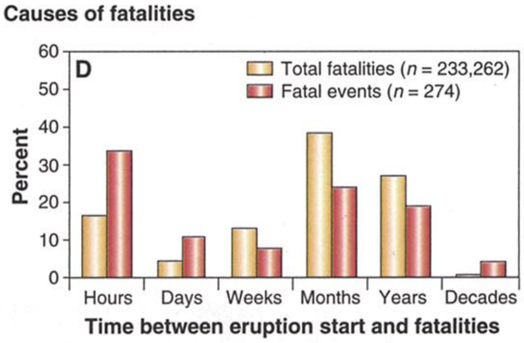
2. Smithsonian Institution, *Global Volcanism Network Bull.* **19-24**, (1994–99).
3. J.-C. Tanguy, C. Ribière, A. Scarth, W. S. Tjetjep, *Bull. Volcanol.* **60**, 137 (1998).
4. Each word used to enumerate fatalities is followed below (in parentheses) by its frequency of occurrence in our sources and the conservative number we have assigned to it in italics. "Few" (2) and "some" (1), *3*; "several" (7), *5*; "unknown" (69), *15*; "many" (29), *100*; "hundreds" (1), *300*; "thousands" (1), *3000*. The "unknown" cases are clearly the most problematic, and for this figure, we have used the median of all 304 eruptions that list specific fatality numbers. For the "many" cases, we have reasoned that this word would not be used for numbers <10 or >10,000, and the median for known fatalities in that range is a nice round 100.
5. H. Sigurdsson, B. F. Houghton, S. R. McNutt, H. Rymer, J. Stix, Eds. *Encyclopedia of Volcanoes* (Academic Press, San Diego, 2000).
6. In July 2000, L.S. and four other volcanologists were injured by an explosion at the summit crater of Semeru, Java's highest volcano. Two Indonesian colleagues, Asep Wildan and Mukti, were killed. This accident tragically underscores the lesson that active craters must be avoided unless the scientific gain (and mitigation of public risk) outweighs the risk.
7. We thank C. Newhall, R. I. Tilling, R. Wunderman, and J. F. Luhr for discussion and comment.





Volcano fatalities. **(A)** Fatal volcano eruptions per century. **(B)** Cumulative volcano fatalities since AD 1. The seven eruptions that dominate the record, all claiming 10,000 or more victims, are named. These account for two-thirds of the total and heavily influence studies based on number of fatalities alone. **(C)** Cause of volcano fatalities since AD 1. In some eruptions, fatalities result from more than one cause. **(D)** Time delay (where known) between eruption start and fatalities.