Analyzing Volcanic Hazards at Yucca Mountain

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Los Alamos researchers have also been involved in analyzing the probability and consequences of volcanic activity at the Yucca Mountain repository site. The possibility of such activity must be considered because a dozen small volcanoes lie within 20 kilometers of the mountain. All but one are within Crater Flat, a region of alluvium-filled basins to the southwest of Yucca Mountain. The twelfth, and youngest, volcano lies farther south at Lathrop Wells (Figure 1). Six of the volcanoes have erupted within the last 1 million years; the other six, within the last 4 million years.

The major goal of our volcanism studies has been to assess the probability that volcanic events will disrupt the potential repository during the 10,000-year waste-isolation period. For this assessment, we have studied the area's volcanic activity over the last 5 million years to determine its patterns. The likelihood of a volcano disrupting the repository is expressed as the annual probability of such an event over the 10,000-year period. In its simplest form, the probability is calculated by multiplying the area's recurrence rate of volcanism (volcanic events per year) by the site's intersection ratio (repository area divided by the area in which volcanism occurs), taking into account uncertainties in each value.

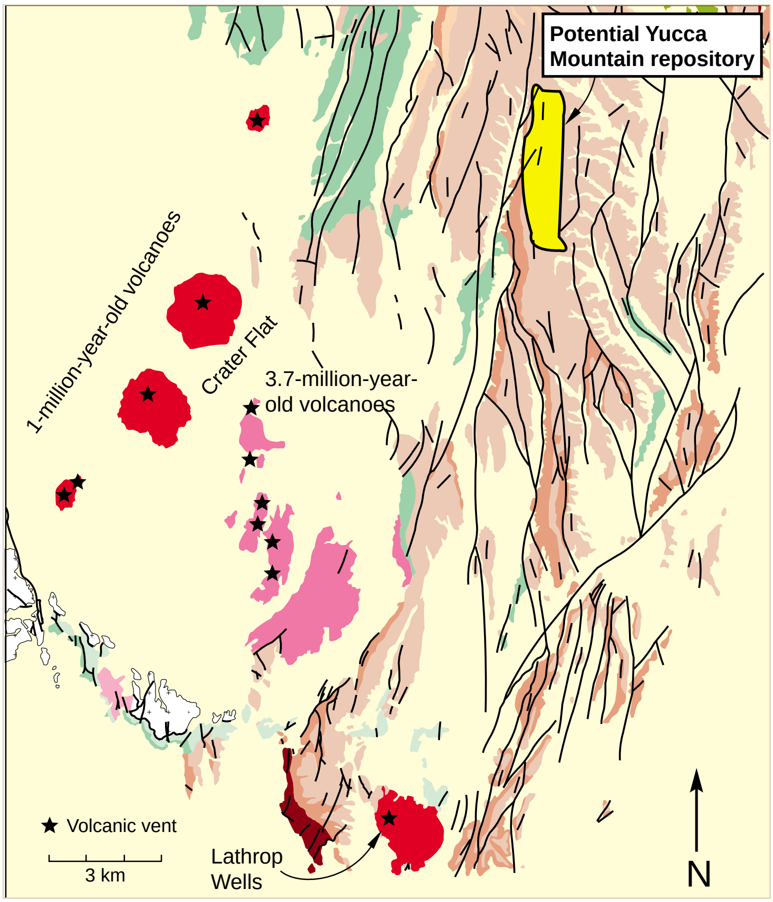

Figure 1. Volcanoes Near Yucca Mountain

A dozen volcanoes are within 20 km of the potential repository site. Six have been active within the last million years; the other six, within the last 4 million years. The youngest volcano, at Lathrop Wells, is 75,000 years old.

Volcanism Near Yucca Mountain. Volcanoes can be generally characterized as either basaltic or rhyolitic. Basaltic lava tends to flow easily because it erupts at high temperature and contains little silica; at the point of eruption, it often forms large scoria cones. Rhyolitic lava is more viscous and flows less readily because it erupts at lower temperatures and contains more silica. It usually erupts explosively, producing thick welded ash deposits such as those that form Yucca Mountain.

Episodes of basaltic eruptions have occurred in the Yucca Mountain region over the past 11 million years and have been the only form of volcanism since the last rhyolitic eruptions some 7.5 million years ago. The eruption mechanisms of these basaltic volcanoes have ranged from effusive (low energy) to strombolian (violent). The youngest volcano, at Lathrop Wells, evidences the full range of activity. Lava flows that surround most of the cone attest to effusive events, while finely fragmented and highly vesicular rock attests to violent eruptions that may have spewed volcanic ash several kilometers into the air.

Probability of a Volcanic Disruption. The first Los Alamos estimates of the likelihood of volcanic activity at the repository site were made in 1980; the probability was put at about 10^{-8} events per year (Figure 2, Crowe and Carr 1980 data). This probability was at the NRC's cutoff point for concern—i.e., a lower probability would eliminate volcanism as a regulatory issue. More recent studies sponsored by the DOE, NRC, and State of Nevada have generally bounded the disruption probability as lying between 10^{-9} and 10^{-7} events per year, while presenting alternative models of volcanism in the area and alternative statistical methods of calculating its probability.

Since volcanism near Yucca Mountain over the past million years has been relatively infrequent, one analytical approach is to estimate an upper limit on its threat by calculating the disruption probability of a repository placed within a more active basaltic field. The Cima Crater in central Nevada and the Lunar Crater in the Mojave Desert have been used for such comparisons (Figure 2). This method suggests a maximum disruption probability of ~5×10^{-6} events per year for the repository.

In 1995 and 1996, the DOE convened a panel of ten experts in the fields of physical volcanology, volcanic hazards, geophysics, and geochemistry to assess the mountain's vulnerability to volcanic disruption. The panel's goal was twofold: to arrive at a defensible probability distribution for volcanic disruption that reflected the latest understanding of volcanic processes in the Yucca Mountain region and to determine the uncertainty in that prediction.

Each of the ten experts independently arrived at a probability distribution. Their aggregate distribution spanned about three orders of magnitude (see lower graph of Figure 2). The mean value of this distribution was 1.5×10^{-8} events per year, with a 90 percent confidence interval between 5.4×10^{-10} and 4.9×10^{-8} (PVHA results in Figure 2). This mean value translates to a probability of about 1 in 7000 that the repository would be disrupted by volcanic activity during its 10,000-year isolation period. The panel's mean value confirmed earlier Los Alamos estimates from DOE-sponsored studies (e.g., Crowe et al. 1995).

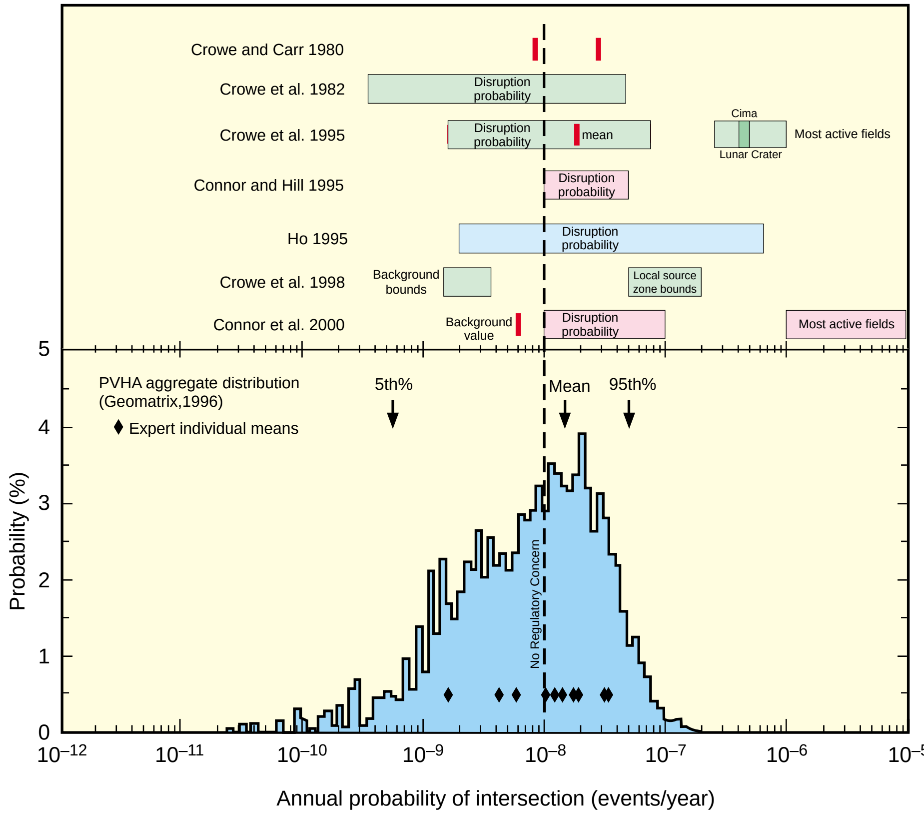

Figure 2. Probability of Future Volcanic Activity at Yucca Mountain

A number of researchers have analyzed the likelihood of a volcano disrupting a repository at Yucca Mountain. Their probability point estimates (single lines) and ranges (rectangles) are compared here with estimates made by a panel of experts convened by the DOE to assess the hazard (PVHA distribution). The ranges labeled "Most active fields" and "Local source zone bounds" represent upper bounds for the probability and assume that the repository is placed in an active volcanic field. The background bounds and value represent lower bounds that assume the repository does not lie in an active volcanic field but lies in a region that produces only sporadic eruptions. Most estimates put the disruption probability at a little greater than 10^{-8} events per year, which translates to a 1 in 7000 chance that volcanic activity could occur during the repository's 10,000-year waste isolation period.

Consequences of a Volcanic Disruption. For a full risk assessment of volcanic activity at Yucca Mountain, the probability of a disruption must be weighted with its consequences in terms of public exposure to radiation. Analysis of the consequences examines such issues as magma rise, intrusion geometry at shallow depths, hydrothermal activity, and potential eruption of nuclear waste.

A recent study of the Lathrop Wells cone sponsored by the NRC reported high xenolith abundance in some strata (xenolith is underground rock that broke off and became entrained in the magma). If true, such abundance would imply that a large amount of repository debris could be ejected were a similar volcano to penetrate Yucca Mountain. However, there is insufficient data to constrain the xenolith content of the volcano as a whole, and the study may have overestimated its abundance. Ongoing work at Sandia National Laboratories and at Los Alamos is addressing the interaction between rising magma and repository tunnels as they are specified in the current design. ■