APPROACH, METHODS AND RESULTS OF AN INDIVIDUAL ELICITATION FOR THE VOLCANISM EXPERT JUDGMENT PANEL

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APPROACH, METHODS AND RESULTS OF AN INDIVIDUAL ELICITATION FOR THE VOLCANISM EXPERT JUDGMENT PANEL

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Probabilistic volcanic hazard assessment (PVHA) of future magmatic disruption of the Yucca Mountain site was completed as a participating member of the volcanism expert judgment panel conducted by Geomatrix Consultants for the Department of Energy. The purpose of this summary is to describe the data assumptions, methods and results of the elicitation and to contrast this assessment with past volcanism studies conducted for the Yucca Mountain Project. In previous studies, we have attempted to establish a range of probabilistic estimates of magmatic disruption using multiple alternative models that are permissive with the limited record of basaltic volcanic events. No attempt was made to discriminate or weight alternative models with respect to plausibility of magmatic processes or suitability to the tectonic setting of the region. Thus probability distributions for magmatic disruption of the site represent “consensus” distributions of all possible alternative models. In contrast, individual elicitation by the members of expert judgment panel members are allowed to incorporate preferred judgments in the assumptions required for probabilistic assessments, and to weight alternative models used to establish recurrence rates and disruption probabilities. This elicitation represents the input of one panel member; all the elicitation are integrated through a process of aggregation conducted by the Geomatrix methodology team.

Late Miocene and younger basaltic volcanic activity has occurred non-uniformly in space and time in the Yucca Mountain region (YMR), probably from partial melting of hydrous lithospheric mantle that may or may not be associated with low rates of extension. Two cycles of small volume basaltic volcanism postdate voluminous Miocene silicic volcanism associated with the Timber Mountain caldera complex; the youngest cycle of basaltic activity (< 5 Ma) is emphasized in the PVHA.

Multiple observations concerning the tectonic and volcanic history of the YMR are especially relevant to PVHA. Tectonic activity has waxed in the YMR since the Miocene. Concomitantly there has been a large decrease (> factor of 30) in the erupted volume of basaltic magma since the Pliocene accompanied by a possible slight increase in the frequency of volcanic events. Post-Pliocene basaltic volcanic activity in the YMR is typical of the less active, interior parts of the Great Basin. There has been time-space migration of basaltic volcanism during the Pliocene and Quaternary characterized by a southwestward migration of eruptive sites. Past sites of volcanic activity can be used to define zones of more likely future volcanic activity, but individual sites of past events are poor predictors of sites of future events. Ascent of basaltic magma may be facilitated by deep seated structural features and volcanic centers are more common in alluvial basins than range interiors probably because the former represent sites of continuing but low rates of extension.

The PVHA for the Yucca Mountain region requires: (1) identifying zones of preferential occurrence of future volcanic activity, (2) developing methods to estimate the recurrence rate(s) of events in the zones, (3) estimating the disruption rate for the zones and (4) applying these data to the Yucca Mountain site. Identification of zones of volcanic activity is accomplished through assessment of the distribution of volcanic events using event-distribution models (weighting 40%) and structural-tectonic models (weighting 60%). Regional background models are also used but are not integrated into the elicitation; they do however, provide a basis for assessing probability bounds. Event-distribution models are established through systematic examination of patterns of the distribution of basalt centers for intervals of 1.15, 5.05 and 9.05 Ma. The preferred event-distribution models include the Plio-Quaternary (not including the basalt of Buckboard Mesa) and Quaternary models of the Crater Flat Volcanic Zone4,5 (weighting 80%), the distribution area of the younger Postcaldas basalt6 (weighting 0.15), and the distribution area of the Postcaldas basalt7 (weighting 0.05). The structural-tectonic models include Plio-Quaternary and Quaternary pull-apart models8 (weighting 60%), Walker-Lane structural models (weighting 25%), and northeast-trending structural models (weighting 15%). The probability of magmatic disruption of the Yucca Mountain site must be > than background rates for the southern Great Basin and YMR (1.4 to 3.3 x 10^-9 events yr^-1 and ≤ upper
Recurrence rates are estimated primarily through counts of volcanic events for intervals corresponding to recognized volcanic cycles in the YMR. Volcanic events are defined as the formation of a new volcanic center, or a cluster of volcanic centers. There is uncertainty in the event counts because of a limited data base of past volcanic events in the YMR, ambiguities in geochronology, spatial, and geochemical data and the possibility of hidden or undetected events. Uncertainty is accommodated by treating the event counts as probability distributions and estimating minimum, most likely, and maximum event counts. Undetected events are assessed only in the maximum event counts. The judgment is made from a combination of extensive geophysical data and from constraints on the physical processes of magma ascent that it is very unlikely for volcanic events with dimensions comparable to a cluster of volcanic centers or the Lathrop Wells center to be undetected. Moreover, the likelihood of an undetected event increases with increasing age of the center but the sensitivity of undetected events on PVHA decreases with increasing age of the volcanic event.

Two questions must be considered with respect to the distribution of volcanic events in a defined zone: (1) What constraints can be placed on the distribution of events in the zones, and (2) what is the nature of the boundary of the zones? The judgment is made that the location of future events within zones cannot be strongly constrained using the record of Pli-Quaternary volcanic events in the YMR. This is based on the observation that while there are general patterns to the distribution of volcanic events, the sequence of events is random with respect to jump lengths and jump directions. There may be a slight tendency toward a southwest drift of events through time and an oscillation of locations between northwest and southeast poles but the location of any one event does not significantly constrain the location of a succeeding event. Thus smoothing or cluster models are not used and events are randomly located in volcanic zones. The boundaries of volcanic zones are defined using different criteria (for example, event distribution, geophysical data, topography) and their locations are treated as fuzzy or uncertain. To include this uncertainty in the PVHA, the event locations are randomly distributed within zones and feeder dikes associated with the events are allowed to extend across zone boundaries.

There has been considerable discussion of the relative merits of homogeneous and nonhomogeneous Poisson temporal models for PVHA. However both models give nearly identical results and their differences are judged not to be significant to the PVHA; homogeneous Poisson temporal models are used in this elicitation.

The lengths and orientation of dike systems associated with volcanic events are critical data assumptions for the PVHA. Dike orientations for the elicitation are based on a combination of observations from the geologic record of directions of alignment of clusters of volcanic centers, fissure alignments in volcanic centers and the local stress field. Dike orientations are inferred to be bimodal and each mode is treated as a triangular distribution with most likely values of N20°E (weighting 80%) and N20°W (weighting 20%). Dike lengths are established from a combination of theoretical constraints, observations of cluster lengths of volcanic centers in the YMR and observations at eroded basalt centers. Dike lengths are treated as a triangular distribution (minimum = 0.3 km, most likely = 3.5 km, maximum = 7.0 km, weighting = 60%) and as a normal distribution (mean = 3.5 km, standard deviation 3.0 km).

The size of a repository and the affected area of disturbance of a repository can be treated as continuous variables and included in evaluations of the probability of magmatic disruption. Alternatively, the effects of these variables can be constrained by assigning fixed areas for the repository and the repository-disturbance zone and estimating the probability of magmatic disruption by assigning a dimension equal to the length of feeder dikes to the location of a surface volcanic event. Disruption of the specified area would occur if a volcanic event occurs near that area and feeder dikes extend from the event to the area. A critical variable for these calculations is the half-length of a feeder dike if the volcanic event is centered on the dike length, or some increment of the dike length if the volcanic event is randomly located along the dike length. These calculations can be accomplished using an analytical solution (this elicitation) or through simulation modeling.

The 50th percentile value estimated for the probability of magmatic disruption of a repository at the Yucca Mountain site for this elicitation is $1.2 \times 10^{-7}$ events yr$^{-1}$. In contrast the estimated 50th percentile value from the most recent summation of PVHA for the Yucca Mountain Project$^1$ is $1.8 \times 10^{-6}$ events yr$^{-1}$ and uses equally weighted alternative recurrence and disruption models. These numbers are virtually identical given the uncertainty of the PVHA and the weightings assigned for this elicitation have only a limited effect on the probability estimates. Probability estimates for elicitation by other panel members may show more sensitivity to model weightings dependent on the assumptions and choices of temporal and spatial models of basaltic volcanism. But more importantly, revised probability estimates for the Yucca Mountain site continue to be within the range of probability bounds established in the early 1980's.$^5$
REFERENCES


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