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MODELING POTENTIAL TEPHRA DISPERSAL AT YUCCA MOUNTAIN, NEVADA

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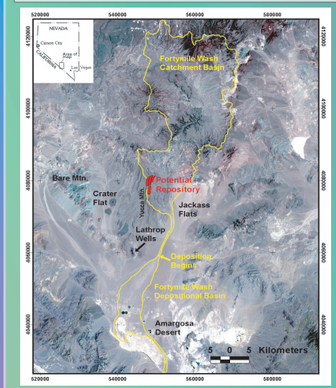
1. INTRODUCTION

Quaternary basaltic volcanoes exist within 20 km [12 mi] of the potential radioactive waste repository at Yucca Mountain, Nevada, and future basaltic volcanism at the repository is considered a low-probability, potentially high-consequence event. If radioactive waste was entrained in the conduit of a future volcanic event, tephra and waste could be transported in the resulting eruption plume. During an eruption, basaltic tephra would be dispersed primarily according to the height of the eruption column, particle-size distribution, and structure of the winds aloft. Following an eruption, contaminated tephra-fall deposits would be affected by surface redistribution processes. In collaboration with the University of South Florida (C. Connor, Department of Geology), the computer code TEPHRA was developed to calculate atmospheric dispersion and subsequent deposition of tephra and spent nuclear fuel from a potential eruption at Yucca Mountain and to help prepare the U.S. Nuclear Regulatory Commission to review a potential U.S. Department of Energy license application.



Landsat Thematic Mapper image showing the Yucca Mountain region, southern Nevada. The potential repository is shown in red. The Fortymile Wash drainage system is outlined in yellow with the catchment basin to the north and the depositional basin to the south. Fortymile Wash drainage system outlines are determined from U.S. Geological Survey 7.5 minute topographic maps. Map projection is Universal Transverse Mercator (Zone 11).

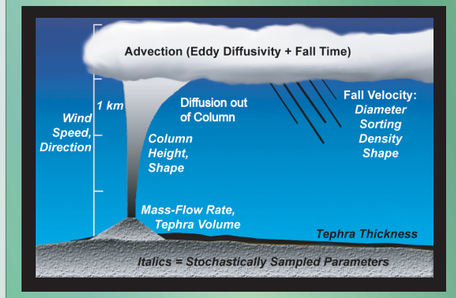
2. APPROACH

Violent strombolian activity is the most likely potentially disruptive magmatism at the potential high-level waste repository at Yucca Mountain. The TEPHRA transport code uses the Suzuki (1983) model to simulate the thermo-fluid dynamics of atmospheric tephra dispersion. TEPHRA models the transport of airborne pyroclasts based on particle diffusion from an eruption column, horizontal diffusion of particles by atmospheric and plume turbulence, horizontal advection by atmospheric circulation, and particle settling by gravity. More recently, TEPHRA was modified to calculate potential tephra deposit distributions using stratified wind fields based on upper atmosphere data from the Desert Rock airstrip near Mercury, Nevada. Wind data are binned into 1-km [0.62-mi]-high intervals with coupled distributions of wind speed and direction produced for each interval. Using this stratified wind field and discretization with respect to height, TEPHRA calculates particle fall and lateral displacement for each interval. This implementation permits modeling of split wind fields.

The primary equation for calculating the areal density of ash deposition following a volcanic eruption was modified by Jarzemba, et al. (1997)

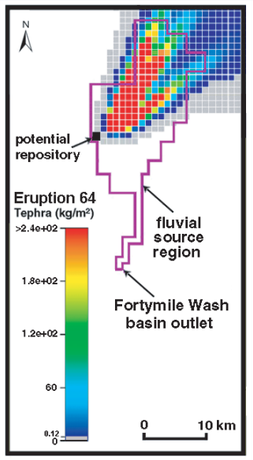
$$X(x,y) = \int_{\phi_{min}}^{\phi_{max}} \int_0^H \frac{5 f_z(z) f_\phi(\phi) Q}{8\pi C(t+t_s)^{5/2}} \exp\left\{ -\frac{5\left[(x-ut)^2 + y^2\right]}{8C(t+t_s)^{5/2}} \right\} dz\, d\phi$$

where X is the mass of ash and radionuclides accumulated at geographic location x, y relative to the position of the volcanic vent; $f_z(z)$ is a probability density function for the diffusion of particles out of the eruption column treated as a line source extending vertically from the vent to the total column height, H; $f_\phi(\phi)$ is a probability density function for grain size (particle diameter), ϕ; Q is the total mass of material erupted; u is wind speed in the x-direction; t is the particle fall-time through the atmosphere; t_s is the diffusion time of tephra and high-level-waste-laden tephra; and C is eddy diffusivity.



MODELING AERIAL TRANSPORT OF VOLCANIC ASH WITH THE TEPHRA CODE

We use a parallel version of the TEPHRA code to calculate expected tephra and high-level waste accumulation at specified points on a two-dimensional spatial grid, thereby simulating a three-dimensional initial deposit. To assess subsequent tephra and high-level waste (spent nuclear fuel) redistribution and resuspension, modeling grids were devised to measure deposition in fluvial and eolian source regions. The fluvial source region (see adjoining figure) covers 318 km² [123 mi²] of the southernmost portion of the Fortymile Wash catchment basin. The eolian grid occupies 2,600 km² [1,000 mi²], or approximately the remainder of the area in the figures displaying model results. The Fortymile Wash basin outlet is near the location of the receptor for dose calculations.



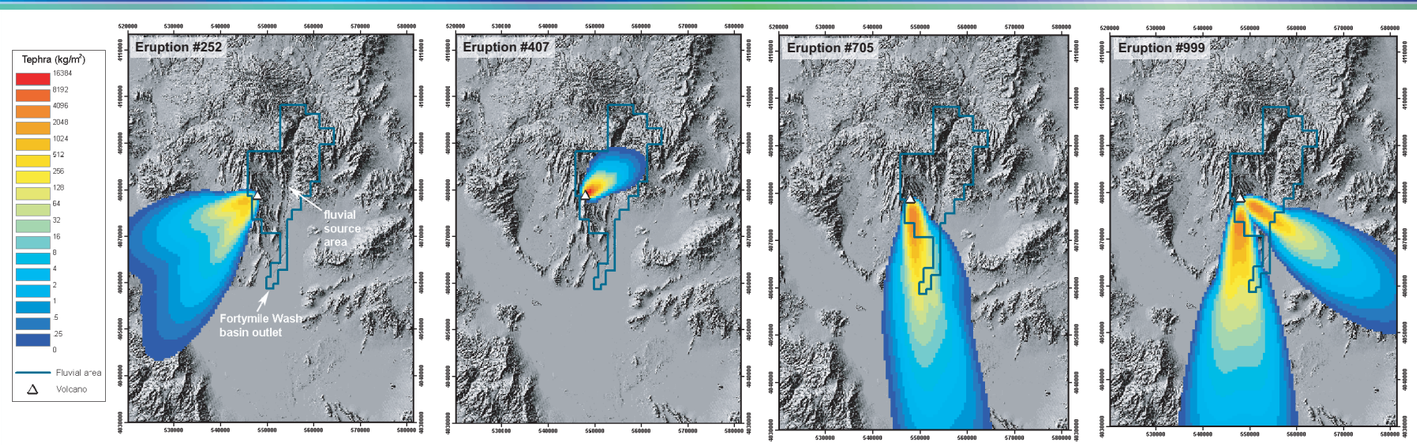
3. MODELING RESULTS

TEPHRA was used to calculate the distribution of tephra and spent nuclear fuel for 1,024 different eruptions. For this set of examples (see parameter table), 1,000 kg [2,204.5 lbs] of fuel is expelled during each eruption. The distribution of fuel (not shown) follows that of tephra deposition, but with reduced concentration values. Actual daily wind measurements are used in each realization. The mass per unit area of tephra (and fuel) was calculated on a regular grid of points spaced 500 m [0.31 mi] apart. Eruption duration is a log-uniform distribution ranging from 1 to 30 days.

ERUPTION PARAMETERS

Eruption Number	Mass of Tephra Erupted (kg)	Mass of Fuel Erupted (kg)	Mean Tephra Particle Diameter* (cm)	Mean Fuel Particle Diameter† (cm)	Eruption Column Height (m)
64	7.94×10^{10}	1,000	0.07	0.001	2,888
252	1.12×10^{10}	1,000	0.07	0.001	4,142
407	2.58×10^{10}	1,000	0.07	0.001	2,029
705	5.24×10^{10}	1,000	0.07	0.001	3,799
999	9.83×10^{10}	1,000	0.07	0.001	3,794

*Tephra particle diameter range: 0.01 to 1 cm
†Fuel particle diameter range: 0.0001 to 0.01 cm



Eruption #252 displays a potential eruption with a slightly split wind field and with little tephra deposition in the fluvial source region, but tephra and fuel could become remobilized by eolian processes after initial deposition.

Eruption #407 was selected to demonstrate a scenario in which tephra deposition occurred only within the fluvial area. The wind direction for this realization was uniform, depositing tephra in a northeasterly direction from the potential vent. Fluvial redistribution and eolian remobilization over time could transport contaminated tephra to the south toward the outlet of the Fortymile Wash catchment basin and near the receptor for dose calculations.

Eruption #705 illustrates a potential eruption in which a wind to the south may deposit contaminated tephra directly at the location of the receptor (or reasonably maximally exposed individual) near the outlet of the Fortymile Wash catchment basin.

Eruption #999 shows an eruption scenario with a split wind field. Of the chosen examples, this realization had the largest amount of erupted tephra. Each realization is independent, and differences in distributions of tephra and high-level waste (fuel) among the realizations reflect uncertainty in source-term and transport characteristics.

4. CONCLUSIONS

- Following a possible volcanic eruption in the potential repository at Yucca Mountain, tephra and spent nuclear fuel may be ejected and dispersed to the accessible environment according to such factors as the height of the eruption column, particle-size distribution, and structure of the winds aloft.

- The computer code TEPHRA has been developed to calculate potential atmospheric transport and subsequent depostion of tephra and high-level waste. Transport code follows the Suzuki (1983) model.

- TEPHRA allows the user to calculate expected tephra and waste accumulation as areal mass density (variable thickness over a two-dimensional grid) by sedimentation out of the eruption plume.

- TEPHRA is an improvement over previous volcanic transport codes because it uses real wind data to simulate complex transport processes. Actual daily measurements are used for realizations, and a stratified wind field uses ten 1-km height bins.

5. REFERENCES

Jarzemba, M.S., P.A. LaPlante, and K.J.Poor "ASHPLUME Version 1.0 – Code for Contaminated Ash Dispersal and Deposition." CNWRA 97-004. San Antonio, Texas: Center for Nuclear Waste Regulatory Analyses. 1997.

Suzuki, T. "A Theoretical Model for the Dispersion of Tephra." Arc Volcanism: Physics and Tectonics. D. Shimozuru and I. Yokiyama, eds. Tokyo, Japan: Terra Scientific Publishing Company. p. 95-113. 1983.

6. ACKNOWLEDGMENTS

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