YUCCA
MOUNTAIN
PROJECT

Studies

Performance-Assessment Analyses for Igneous Activity

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Disturbed Events
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Office of Civilian Radioactive
Waste Management

Supporting Contributors

- Greg Valentine, Frank Perry (LANL) – *Volcanic processes*
- Kathryn Hansen, Bob Youngs, Kevin Coppersmith (Geomatrix) – *PVHA interpretations*
- Peter Burck (DE&S) – *ASHPLUME calculations*
- Steve Miller (KTECH) – *RIP calculations*
- George Barr, Sharon Shannon (SNL) – *SZ flow calculations*

Outline

- Scenarios Considered
- Model Development
- Parameter Development
- Calculations
- Results
- Discussion

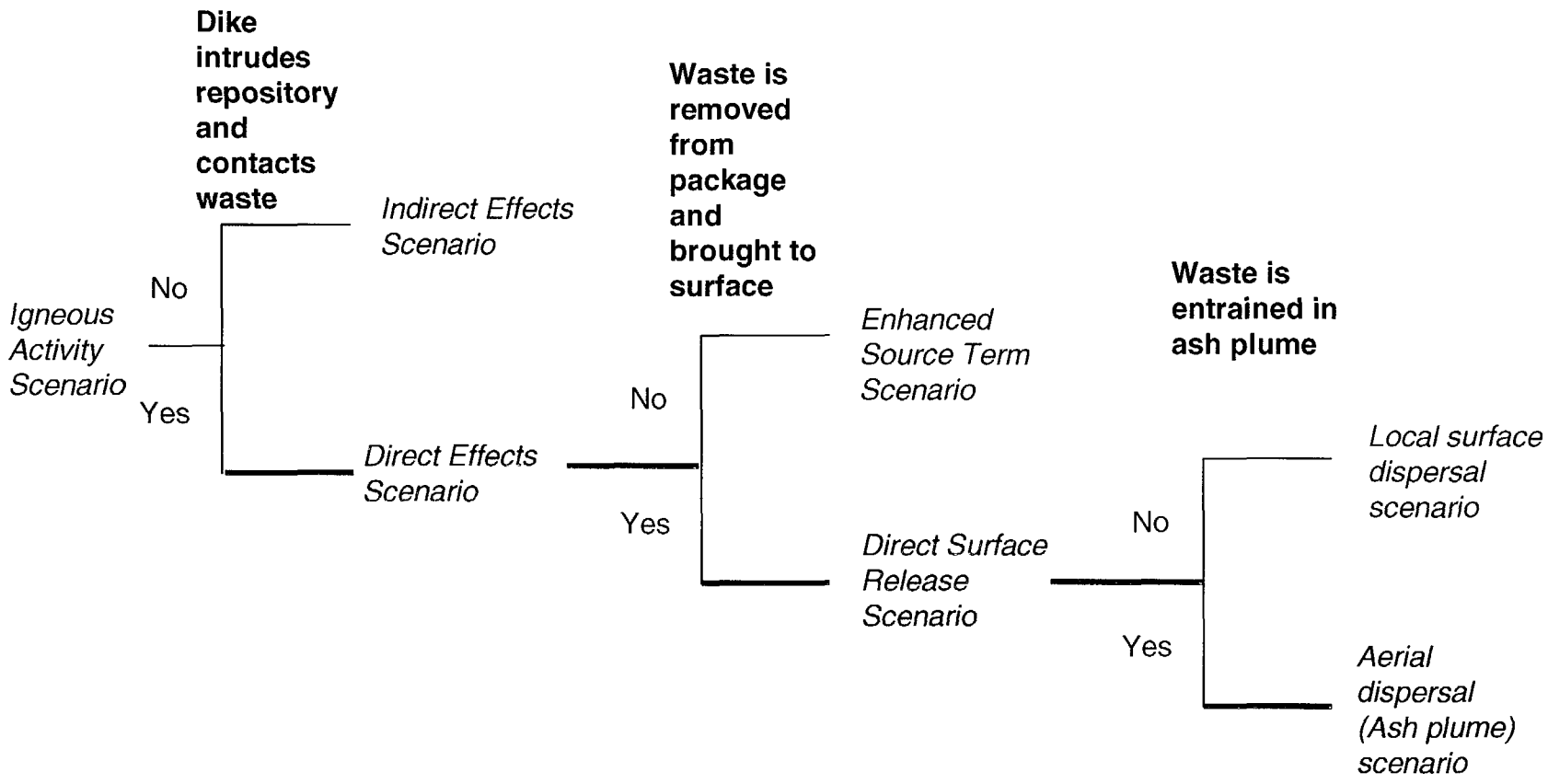
Scenario Screening Steps

- Initial igneous-activity FEP list from generalized event trees (Barr et al. 1993)
- Mean probability of occurrence of volcanic activity in the YM region ~1.5×10^{-8}/year probability of intersection
  - Therefore, igneous-activity scenario classes cannot be excluded on probability arguments
- Consequences modeled for 3 sub-scenarios
  - Direct surface, direct subsurface, indirect
- Because probabilities <1, will be treated as DFEPs

Scenario Screening

- Scenarios Considered
  - Direct surface releases with dispersal by ash plume
  - Groundwater transport of magmatically enhanced radionuclide source term
  - Indirect effects on groundwater flow and transport of a dike intrusion outside the repository
- Scenarios not Considered
  - Variants of direct-interaction
    - Polycyclic events (unlikely, per PVHA experts)
    - Dispersal by lava flows (less consequence than aerial)

Logic Diagram for Igneous-Activity Sub-scenarios



Models for Direct Interactions

- Source Term
  - Plumbing of intrusion
  - Waste-package breach
  - Removal of contents (surface release)
  - Entrainment (surface release)
  - Dissolution/alteration of waste (enhanced source term)
- Dispersal/Transport/Doses
  - Eruption characteristics (surface release)
  - Waste-form degradation rate (enhanced source term)
  - Groundwater transport (enhanced source term)

Interaction of Dike with Repository

- Intersection of dike with repository footprint
  - (length, azimuth)
- Fragmentation depth - change from liquid to solids/ash
- Dike width/ conduit diameter
- Number of vents along dike occurring inside repository

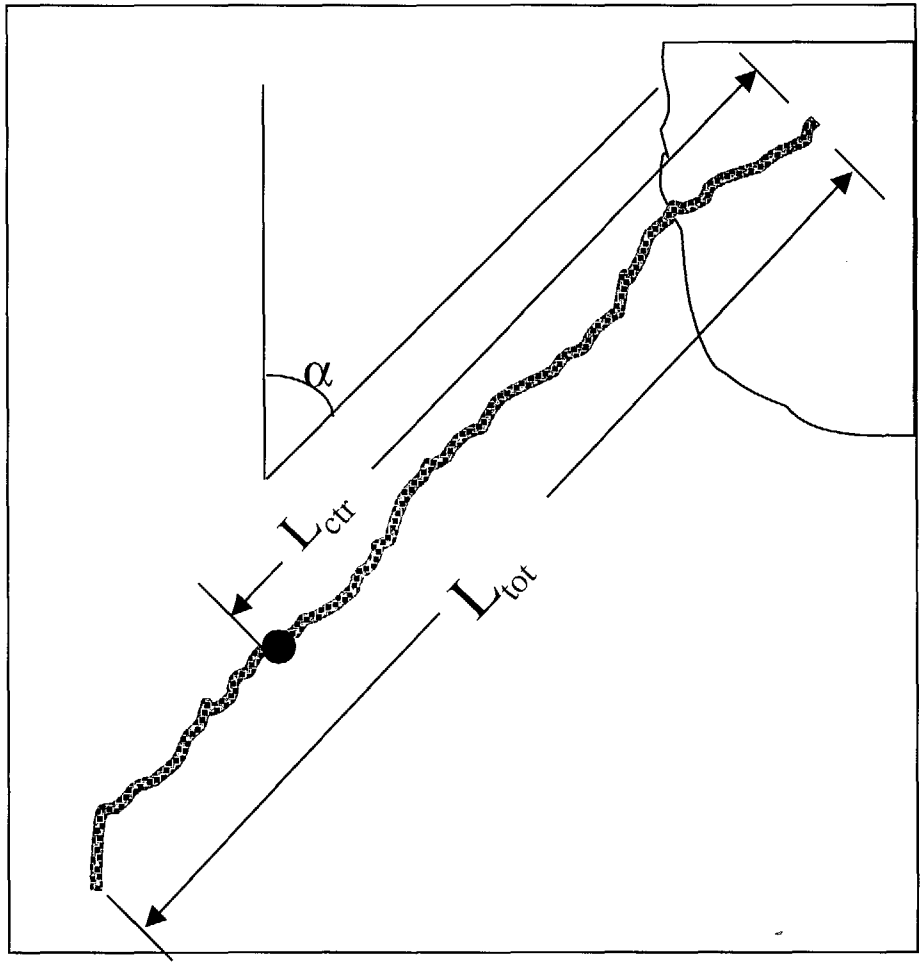
Conditional Probability of Intersection

based on source zone model

- PVHA provides a model for length of dike into repository relative to point-event location

over what area does DOE use for its probability

- Parameters are dike length, dike azimuth, and relative location of point event (the eruption center)

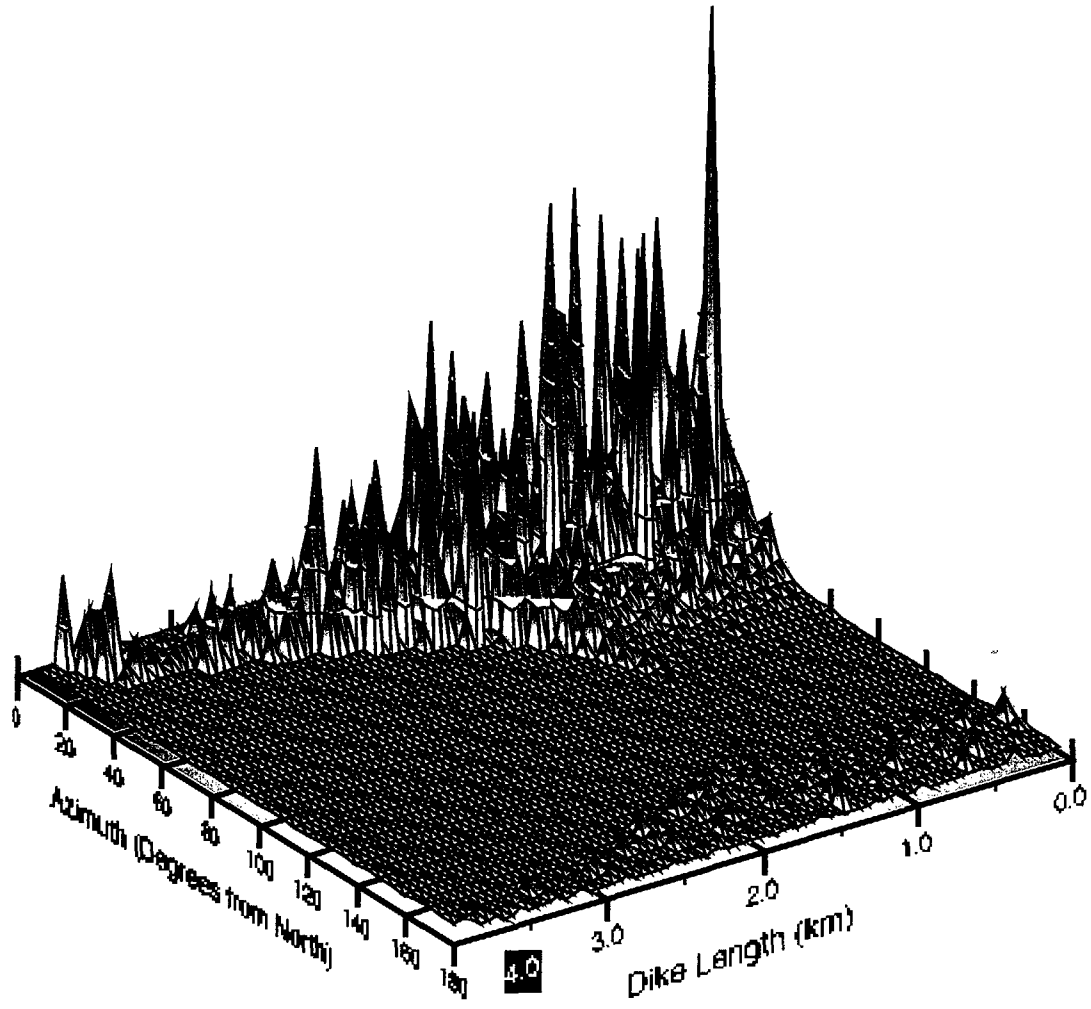


Simulations of Dikes Intersecting the Repository

- Annual frequency of intersection is function of rate of volcanic events at point (x,y) and conditional probability that event centered at (x,y) intersects repository (per PVHA)
- Conditional probability is function of two probability densities
  - Length of dike at (x,y) extends into repository
  - Azimuth of dike at (x,y) points to repository
    - Influences number of drifts intersected
- Summed over all locations

Dike Orientation PDF

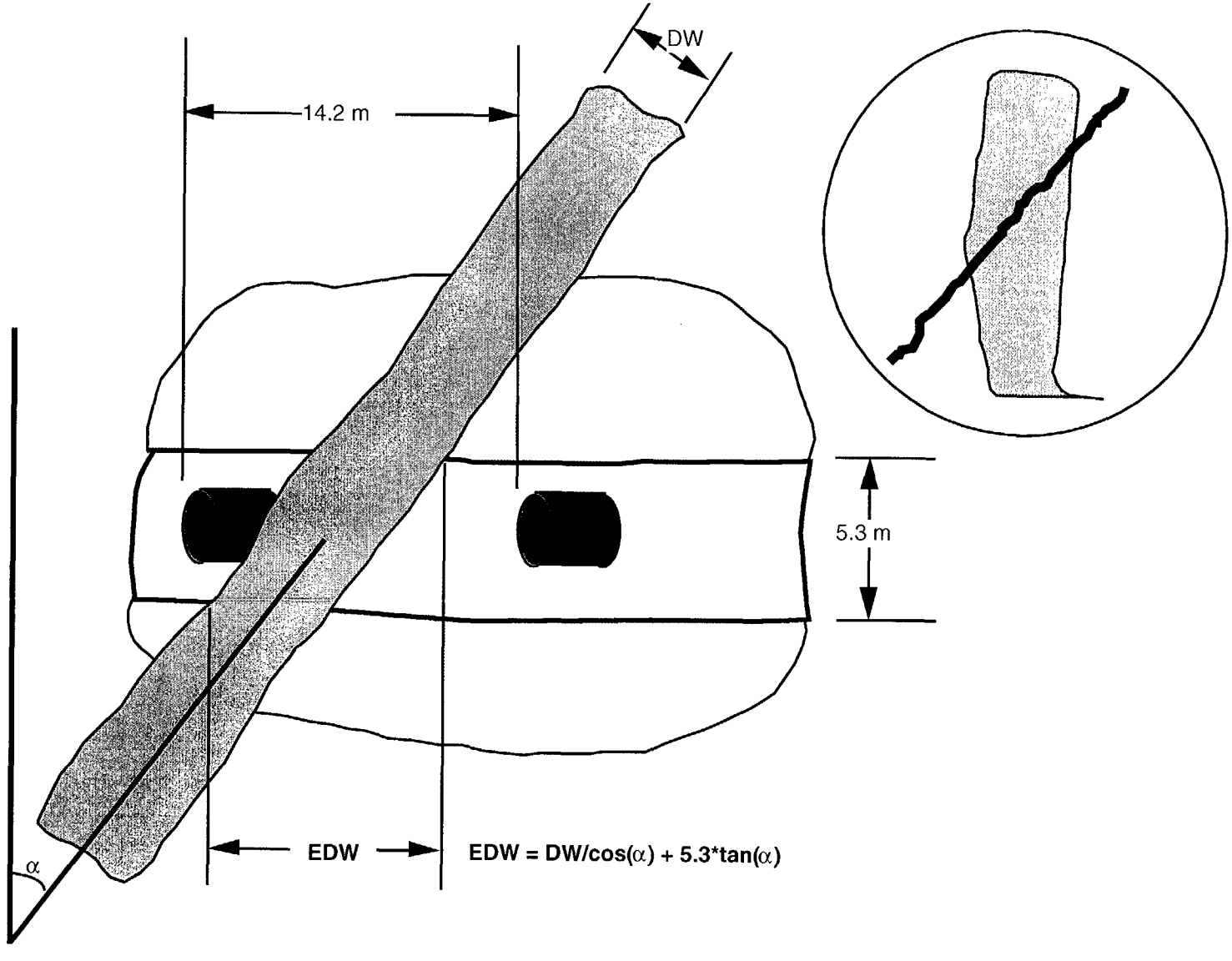
- Joint probability function for length and azimuth of dike inside repository block
- Dikes are strongly oriented N–S



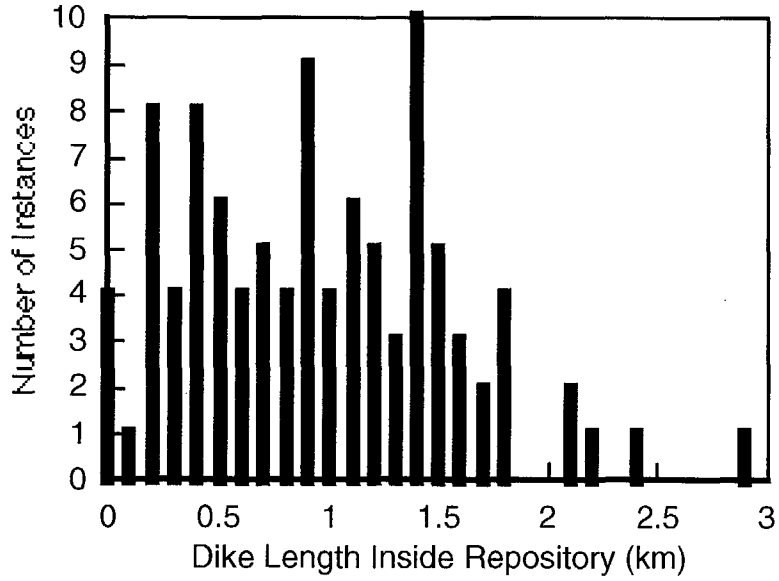
Number of Eruptive Vents in Repository

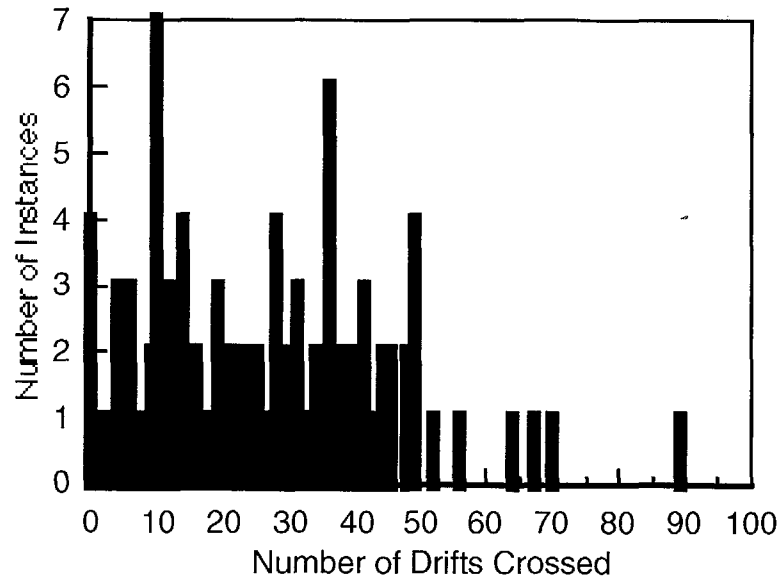
- PVHA experts provided assessments of number of events represented by observed cones
  - Gives a distribution of number of separate cones per event
- Assume cones are uniformly distributed along dike length
- P(cone|intersection) = P(intersection|x,y)*P(cone)
- Vents inside repository required for waste release

Dike Intersection with Drifts



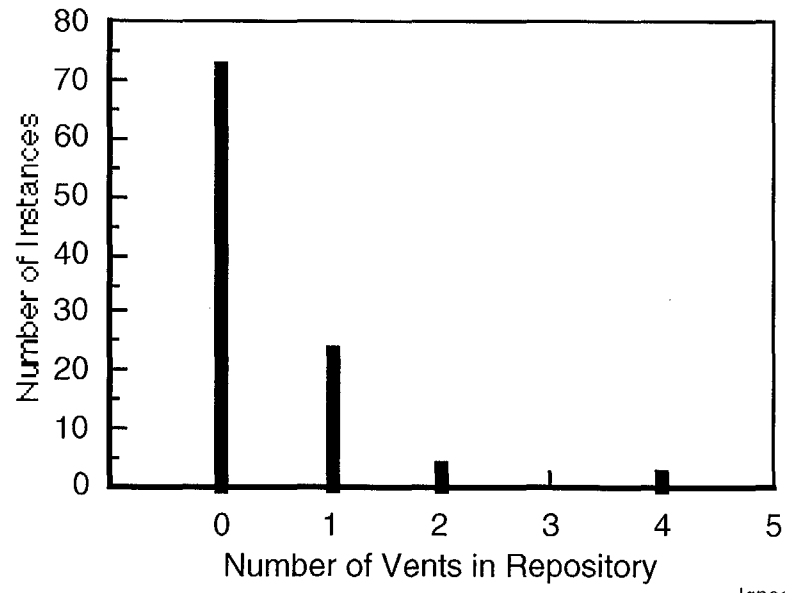
Example Dike-Intersection Parameters





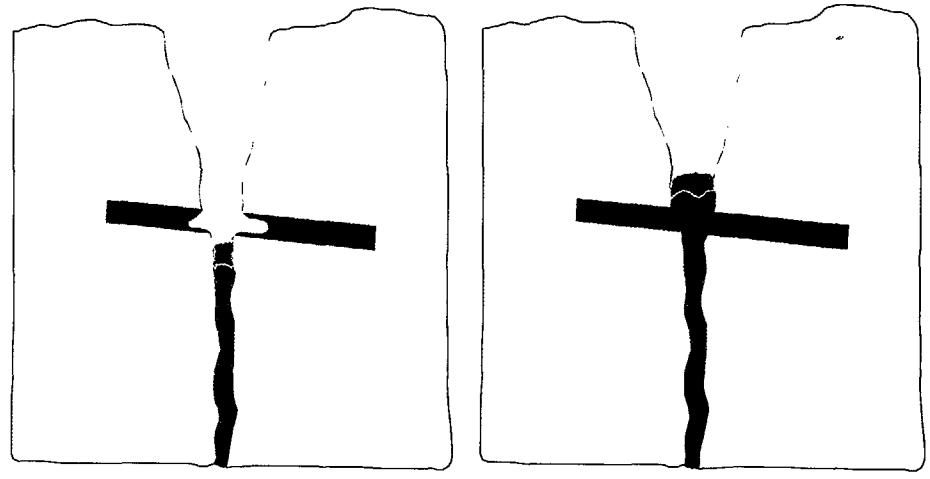
Histograms based on 100 realizations

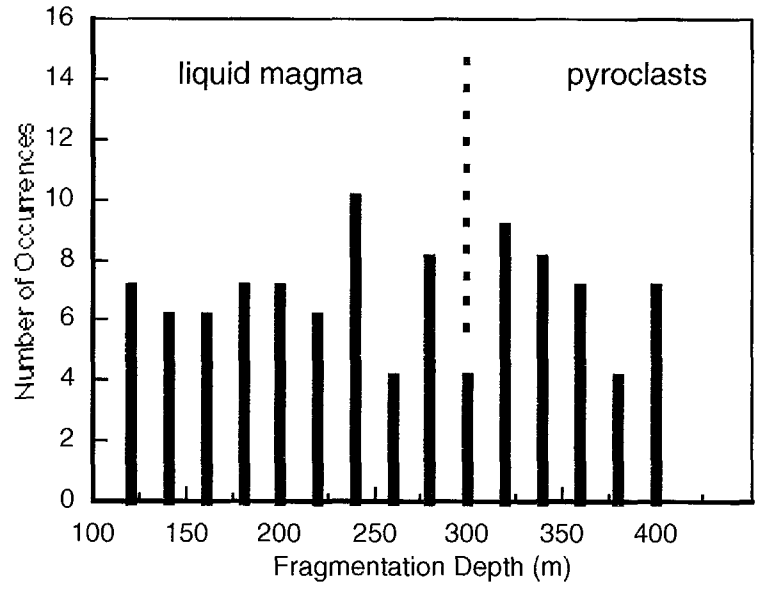
more than 100 realizations were done



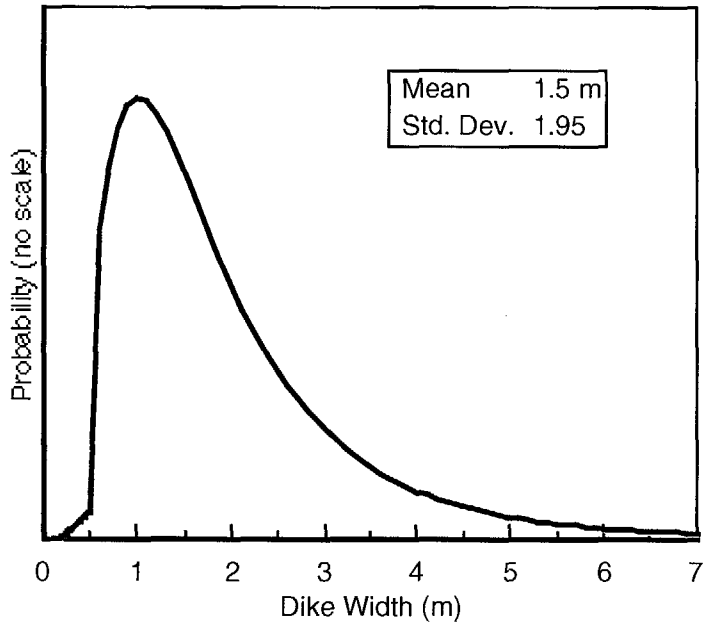
Intrusion Characteristics

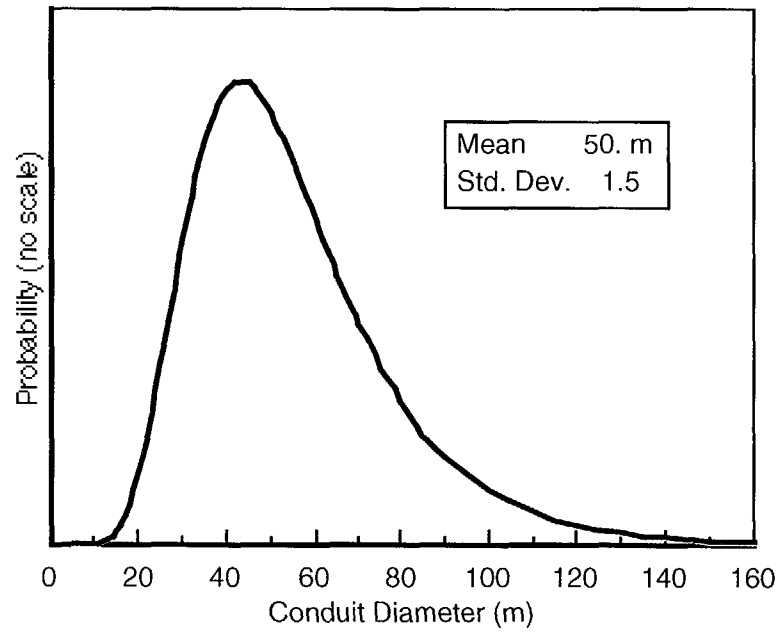
- Fragmentation depth
  - Depth at which gasses exsolve from liquid magma and form bubbles
  - Determines whether liquid magma or ash/pryoclasts intersect repository
  - Uncertainty/variability in depth expressed as uniform pdf from 100 - 400 m

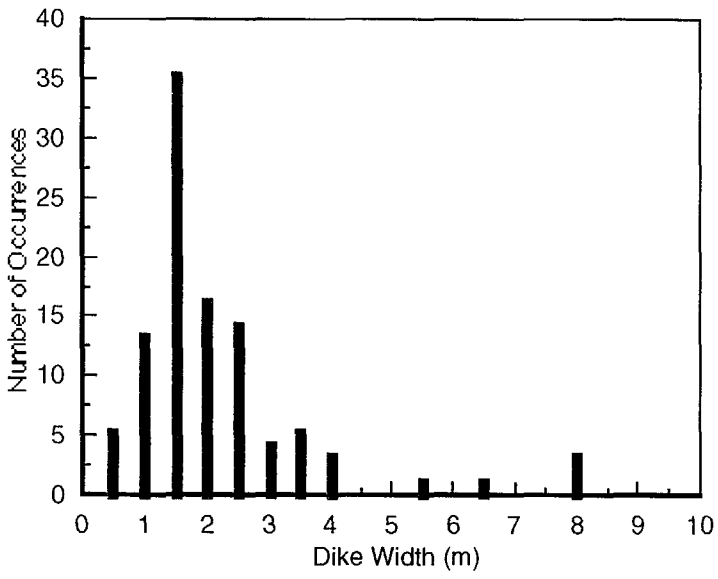


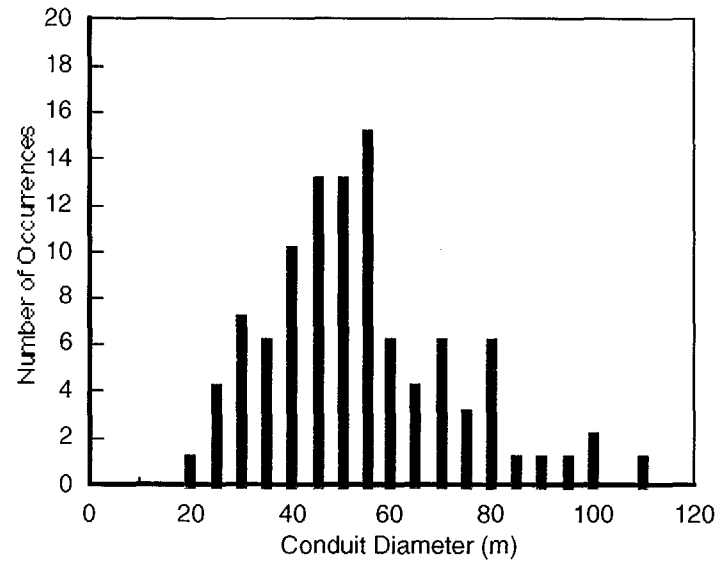


Intrusion Dimensions





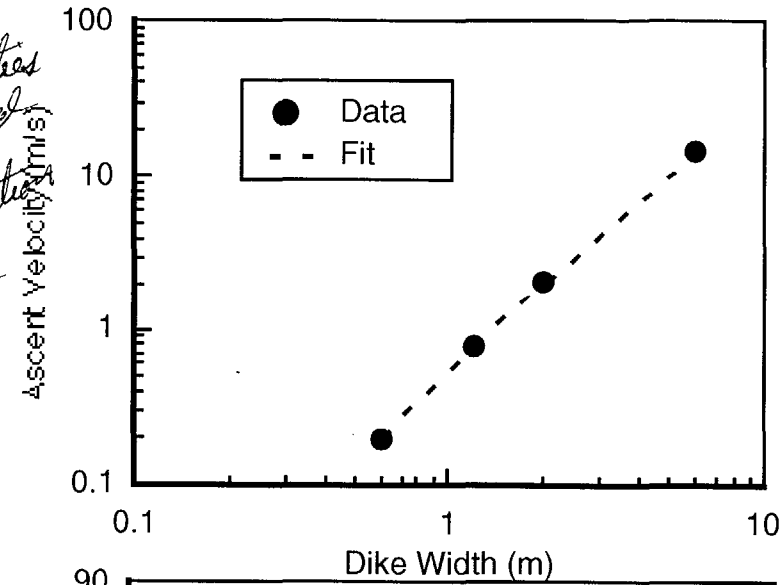




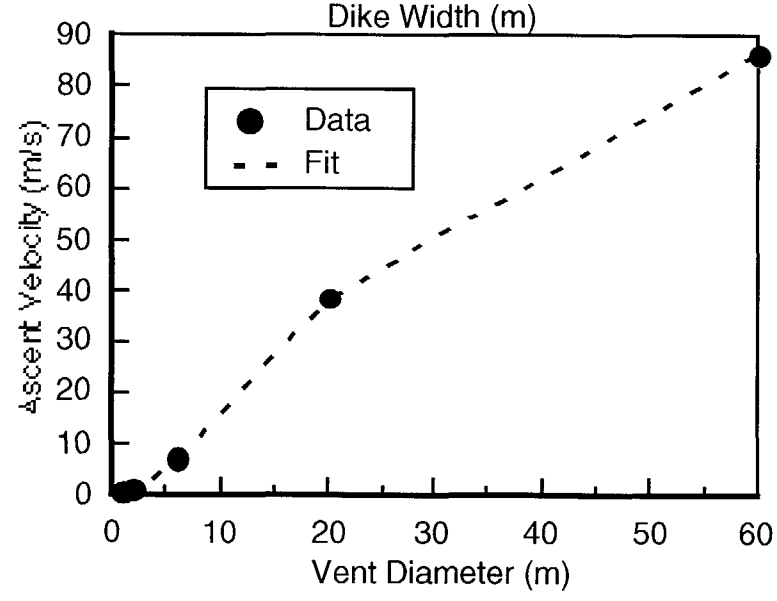
Magma Ascent Velocity

- Liquid-magma ascent velocity
  - A function of dike width
  - Range (0.2 — 20 m/s)

ascent velocities could change with fragmentation depths



- Ash/pyroclast ascent velocity
  - A function of conduit diameter
  - Range (1 — 85 m/s)



Source Term Components

- Source term for surface releases
  - Plumbing of intrusion
  - Waste-package breach
  - Removal of contents
  - Entrainment

Models for Waste-Package Breach

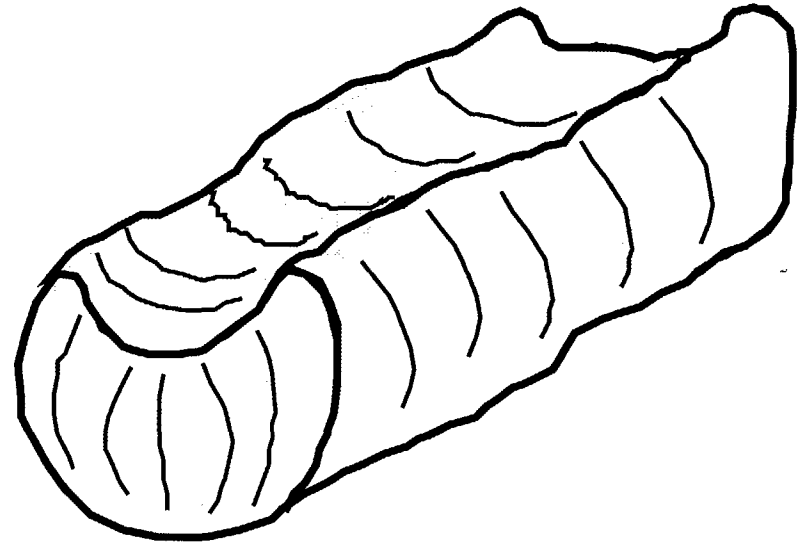
- Mechanical Degradation
  - Internal pressurization
  - Plastic deformation
- Chemical Degradation
  - Corrosion
- Environment is outside of specifications for most materials
  - Temperature
  - Corrosive gasses

Magmatic Environment in Drifts

- Magma temperature: 1000° – 1200° C
  - Contact cooling could reduce temperature to ~ 800°C
- Magmatic gases contain 2% – 10% sulfur compounds
  - Up to 20% CO_2
    - HCl and HF may be present

Plastic Deformation of Waste Packages

- At high temperatures, reduction of strength of waste-package materials could result in collapse (like a toothpaste tube)

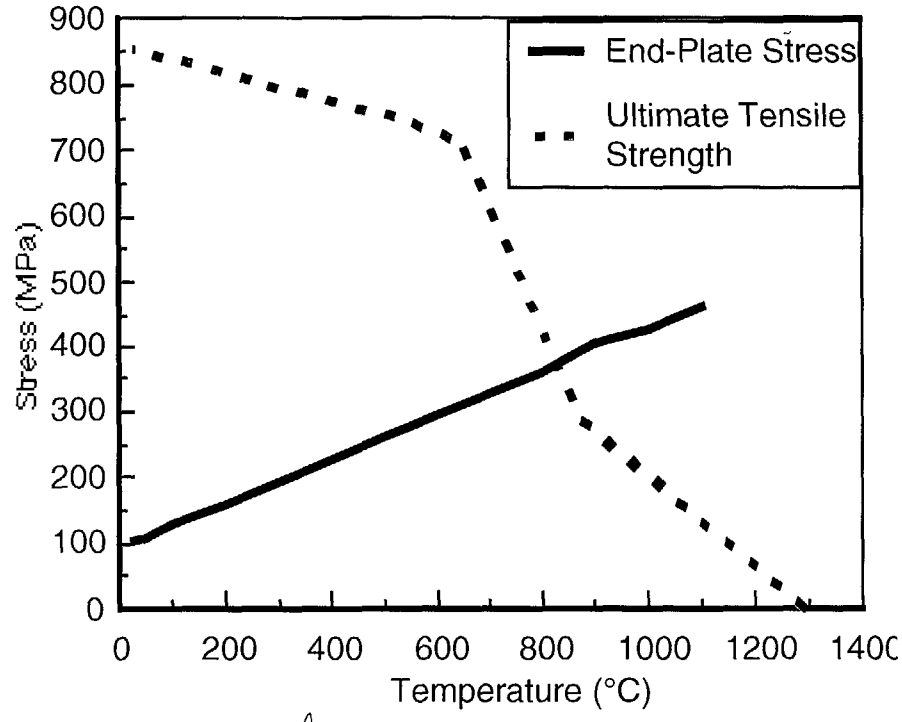


Internal Pressurization of Waste Packages

- Waste packages are initially filled with helium at atmospheric pressure at room temperature
  - CSNF rods are pressurized by inert gas and fission product gasses
  - Above ~900°C the rods can burst, releasing gas into waste package
- At magmatic temperatures, gas pressure inside waste package can range from ~1 MPa to ~1.8 MPa

Waste-Package Overpressure

- Circumferential stress is fairly low (~35 – 65 MPa)
  - For WP wall thinned by 50%, stress is doubled
  - Approaches ultimate tensile strength of Alloy-22 at higher temperatures
- End-cap stress is ~400 MPa at 1000°C



data based on alloy 625 above 775°C, based on extrapolation

Waste-Package Breach Model

- Temperature rise from magma contact is slow enough that overpressure gas explosion does not occur
  - Temperature is above annealing temperature for Alloy 22, but below solidus temperature Kelly's conclusion – crack may or may not propogate
- Gas vents from waste package, but walls are largely intact
- Depending on degree of prior corrosion, walls and end-plates collapse to cause breach
  - For extensive corrosion, breach can occur within time of active magma flow eruption duration 1 hour – 50 days

Source Term Components

- Source term for surface releases
  - Plumbing of intrusion
  - Waste-package breach
  - Removal of contents
  - Entrainment

Ejection of Waste from Package

- Consider kinematic ejection, dissolution, advection
- Kinematic effects occur when the ascending magma is in ash/pyroclastic form
  - Elastic and inelastic interactions are considered
    - Effect of scattering angle not considered - assumed to be vertical exit direction
- Dissolution and advection can occur with liquid magma
  - Approximately 20 – 40 wt.% UO_2 can dissolve in basalt

Kinematic Ejection

- Density difference between UO_2 (~11 g/cm^3) and ash (0.8 – 2.6 g/cm^3) limit relative sizes of ash and waste particles
  - For elastic collisions, waste particle can be no bigger than about 1/2 the size of the impinging ash particle
  - For inelastic collisions, waste particle can be no bigger than the same size as the impinging ash particle
  - Calculations use average of ash-density range

size – diameter

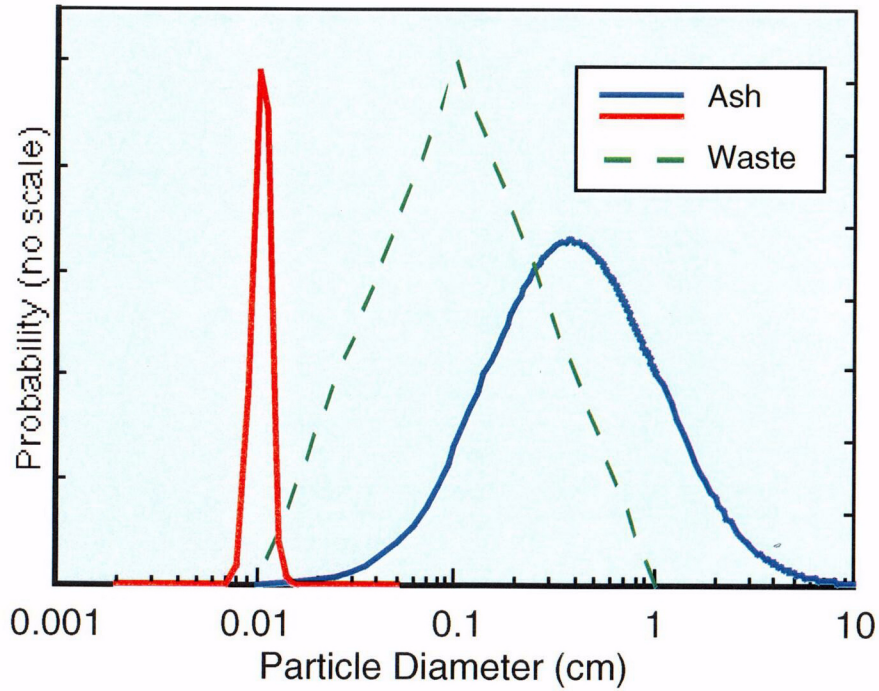
Source Term Components

- Source term for surface releases
  - Plumbing of intrusion
  - Waste-package breach
  - Removal of contents
  - Entrainment

Entrainment of Waste

two distributions of ash particles represent end points

- Model compares settling velocity of heavy waste with ascent velocity of ash or magma
- 10-cm waste particles settle at ~0.75 – 1.5 m/s (depending on magma density)
- Therefore, most ascent velocities will entrain waste

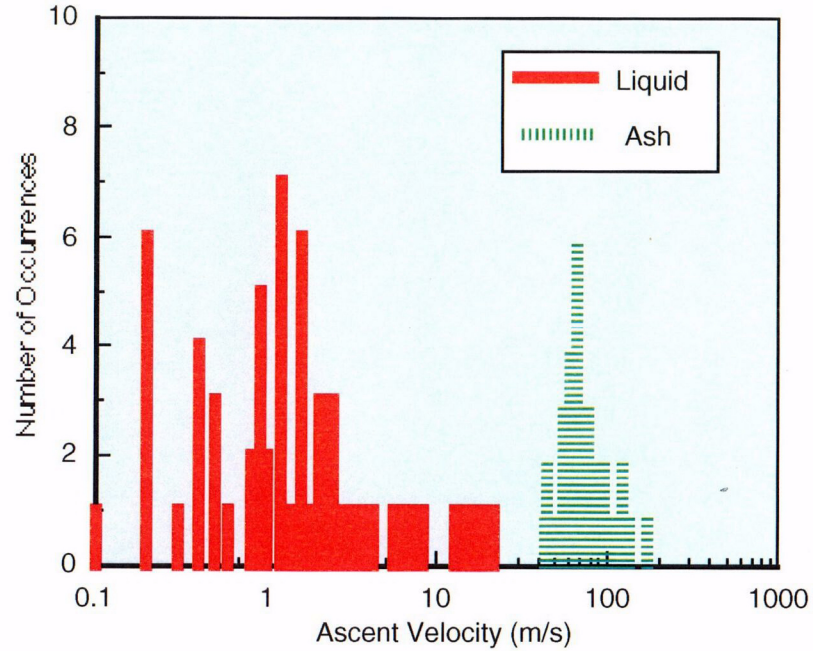


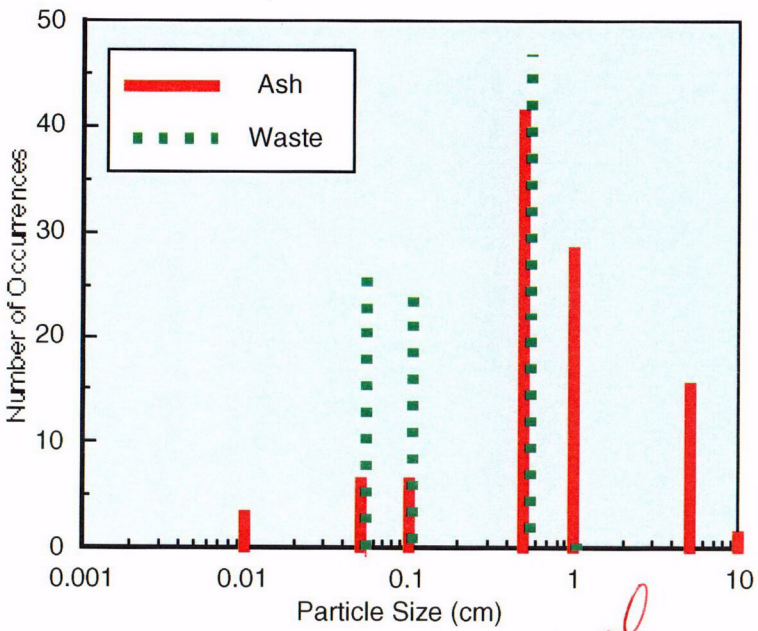
Ash and waste-particle sizes consistent with CNWRA 1996 work

C-01

Example Particle Parameters

Ascent velocities cover wide range





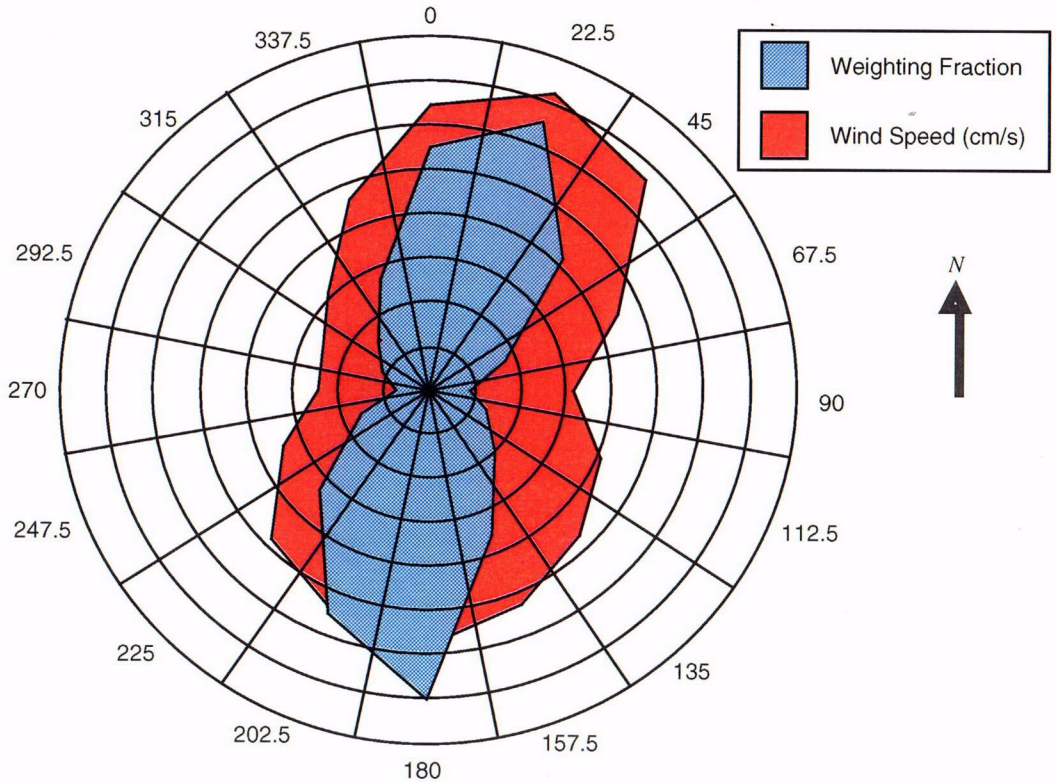
Waste-particle sizes are bracketed by ash-particle sizes

C-02

Dispersion Model

- Eruptions characterized by volume, rather than time
- ASHPLUME code was slightly modified
  - Eruption volume is input
  - Ash density is fixed
- Wind data are same as CNRWA 1996 work

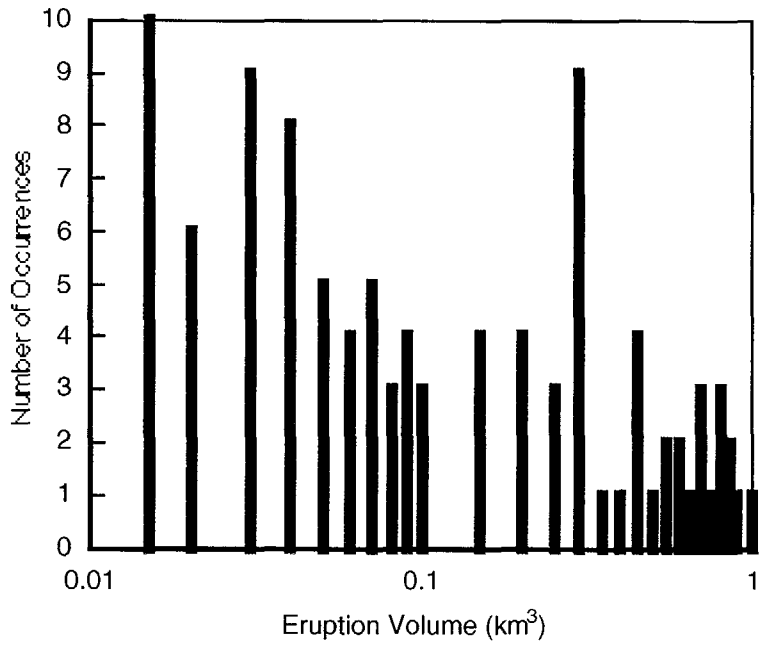
(Wind blowing to north)

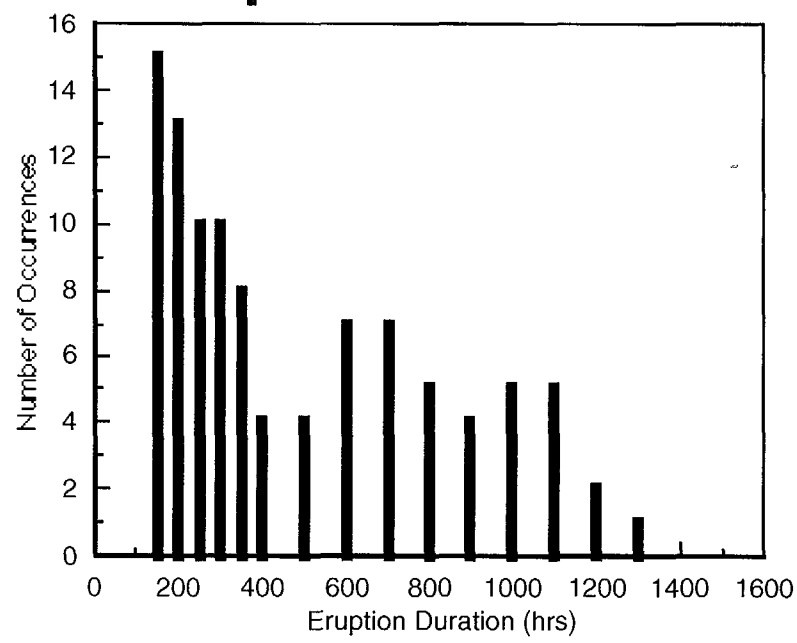
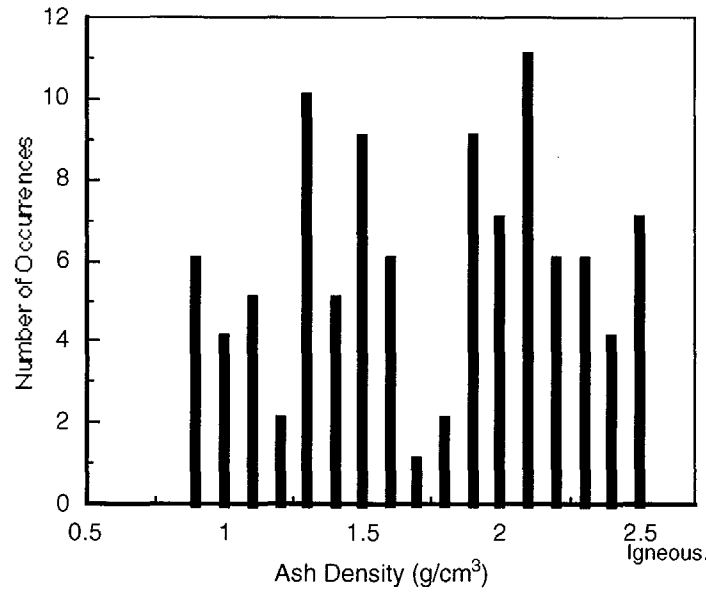


(Wind blowing to south)

C-03

ASHPLUME Inputs





All parameter ranges derived from CNWRA (1996) work