U.S. DEPARTMENT OF ENERGY
OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT

NUCLEAR WASTE TECHNICAL REVIEW BOARD
PANEL ON STRUCTURAL GEOLOGY & GEOENGINEERING

SUBJECT: PHYSICAL PROCESSES OF MAGMATISM AND EFFECTS ON THE REPOSITORY

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ALEXIS PARK HOTEL
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Outline

- Introduction
- Study Plan
- Interface with performance assessment (PA)
- Technical progress and approaches
- Summary

Introduction

Purpose of study

- To assess possible effects of magmatic activity in or near the repository block
  - Volcanic eruption
  - Subsurface intrusion
- To assess physical processes of magmatism to support observational data and probabilistic studies of magmatic activity
- To provide a conceptual framework for magmatism in the Yucca Mountain region

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Study Plan, 8.3.1.8.1.2, Physical Processes of Magmatism and Effects on the Potential Repository

- Activity 1 - Eruptive effects
- Activity 2 - Subsurface effects
- Activity 3 - Magma system dynamics

Activity 1 - Eruptive Effects

- **Goal: to estimate the probability that regulatory release limits could be exceeded by eruption of waste onto the surface, given an eruption through the repository**
- **Approach - Combine analog and modeling studies**
  - **Analogs - Study centers in the Western U.S. that are of similar size, composition, and eruptive style to Crater Flat centers**
    * **Measure quantities of erupted lithic material ejected; identify depths of origin. Use to estimate fraction of material that could conceivably be carried from repository**
    * **Study geometry of deeply eroded centers for further constraints**
  - **Modeling - Estimate vesiculation and fragmentation depths**

Activity 2 - Subsurface Effects

- **Goal: to estimate the probability that regulatory release limits could be exceeded as a result of subsurface processes related to magmatism**
- **Approach - Combine analog and modeling studies**
  - **Analogs - Focus on basaltic intrusions in silicic tuffs. Quantify range of geometries, sizes, including effects on host rocks. Study thermal and mechanical effects on host rocks, including welding and fracturing. Look for perching of groundwater by intrusions**
  - **Modeling - Hydrothermal processes in vadose zone. Parameter studies of "zones of influence" for subsurface E2. Sensitivity to material properties. Transport calculations**

Activity 3 - Magma System Dynamics

- **Goal: to provide theoretical framework for magmatism in Yucca Mountain region, incorporating all observational data. Support probabilistic studies**
  - **Issues include - Melt generation and segregation, magma chamber dynamics, magma transport, eruption dynamics**
- **Approach - Apply theoretical modeling to data obtained from other characterization studies, with some new observational studies, where necessary**

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Interface with Performance Assessment (PA)

- Scenario development (event trees)
- Parameter values and expert opinion for specific PA calculations
- Interaction with other repository components (e.g., waste package)
- Feedback into whole system CCDF
- Provide physical effects at repository horizon, which PA uses to estimate radiological releases

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Technical Progress and Approaches

- **Volcanic release probability (R)**

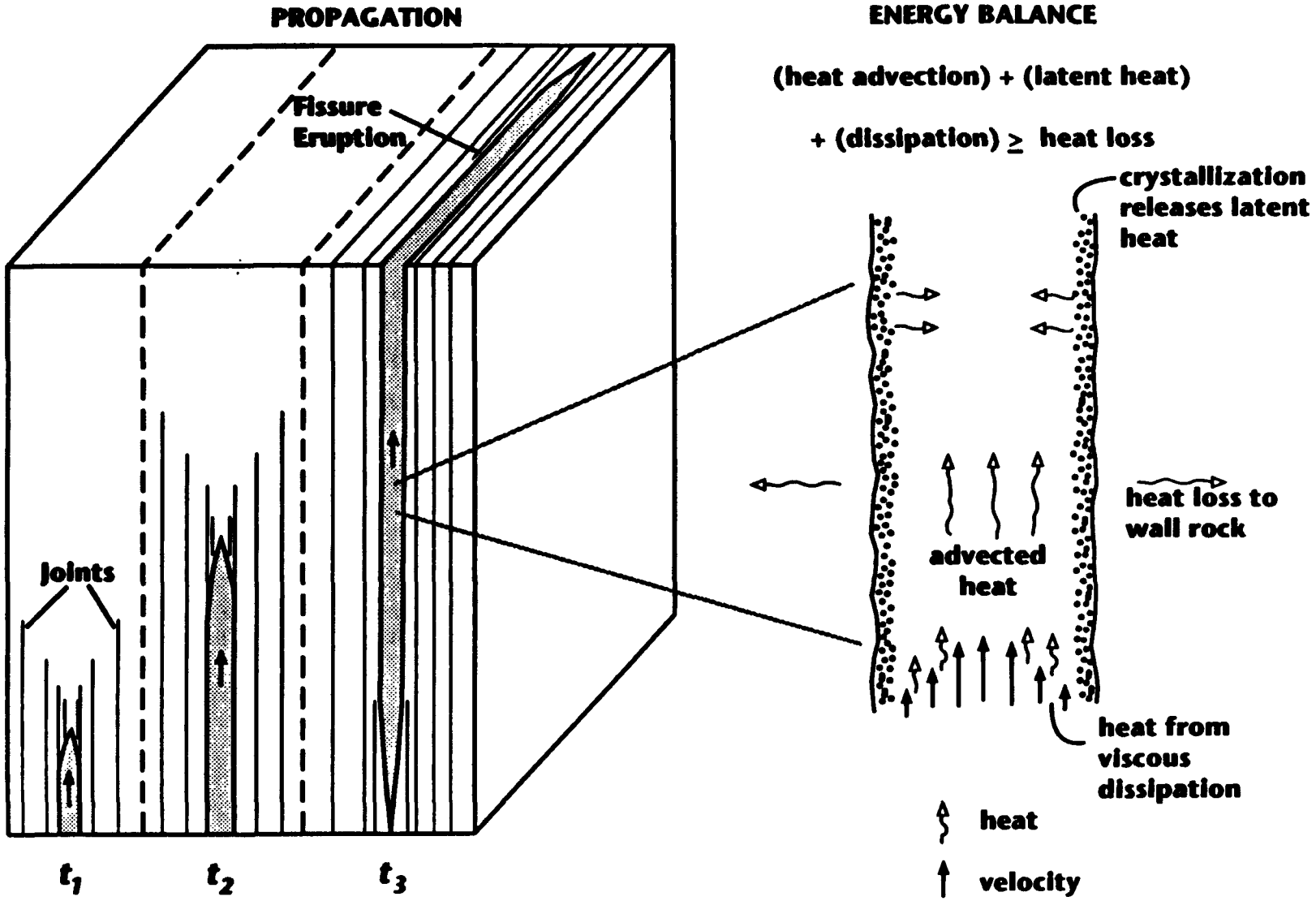
  R = Pr (E3 given E2, E1) Pr (E2 given E1) Pr (E1)

  E1 = annual igneous event probability in Yucca Mountain region

  E2 = probability that such an event affects the waste isolation system

  E3 = probability that an igneous event in the waste isolation system has consequences (releases) that exceed regulatory limits

Simple Linear Dike



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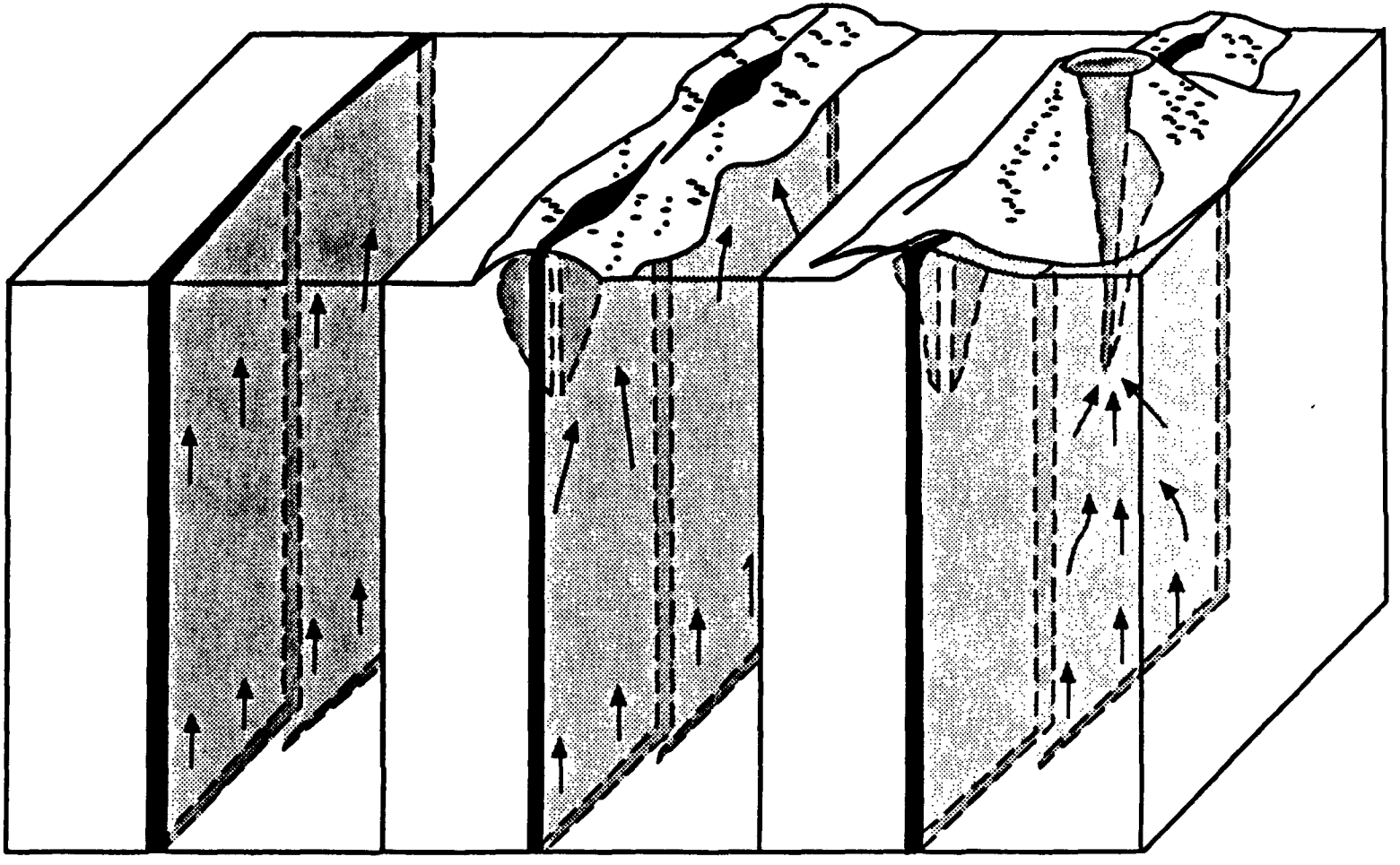
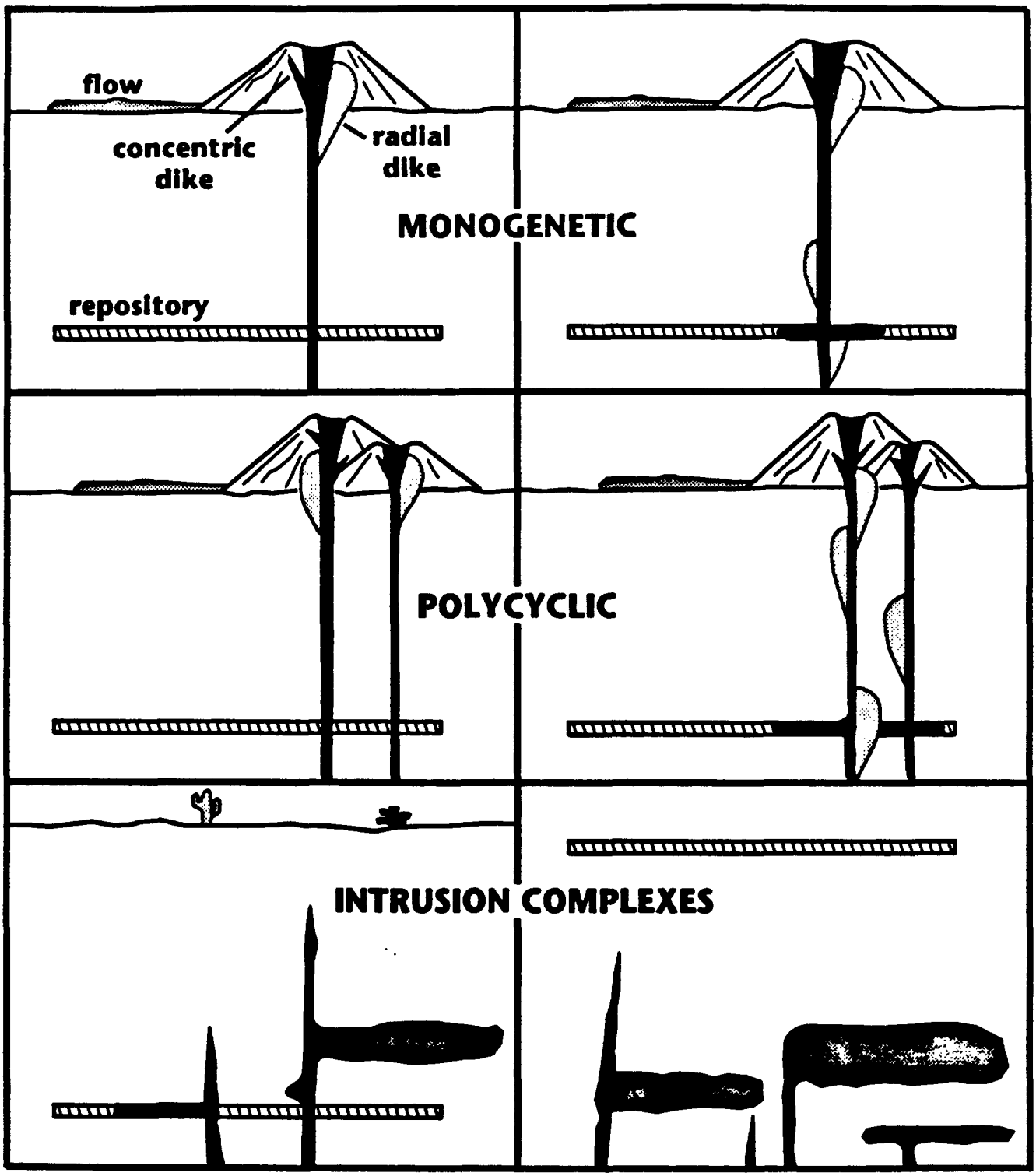
Simple Eruption Evolution and Geometry



Fissure eruption ⟶ Focusing to a few vents ⟶ Central vent

Scenario Examples



Eruptive Effects (E3)

- Analog volcanoes
- Assumption - waste entrained and erupted like wall rock fragments
  - Strength — conservative because waste is denser than wall rock
  - Weakness — need to quantify entrainment of unconsolidated layers. Looking for analogs, where dikes intersect weak layers or lava tubes
- Volume of erupted wall rock proportional to total erupted volume

Eruptive Effects

(Continued)

- Consequence estimate from early data
  - Conservative total eruptive volume 10^8 m^3
  - Conservative lithic content (Strombolian/Hawaiian) 0.06%
  - Average depth to repository 300 m
  - Repository horizon 5 m thick (1.7% of total depth)
  - Release between 1 and 2 waste package equivalents
- E3 ~ 1.0 for this case
- Refinement of calculation
  - Critical assumption: constant wall-rock erosion with depth to repository
  - Field studies: variation in wall-rock erosion with depth

Photo of Conduit Plug/Dike Complex at Paiute Ridge

Photo of Basaltic Center at Vulcan's Throne Area, Grand Canyon

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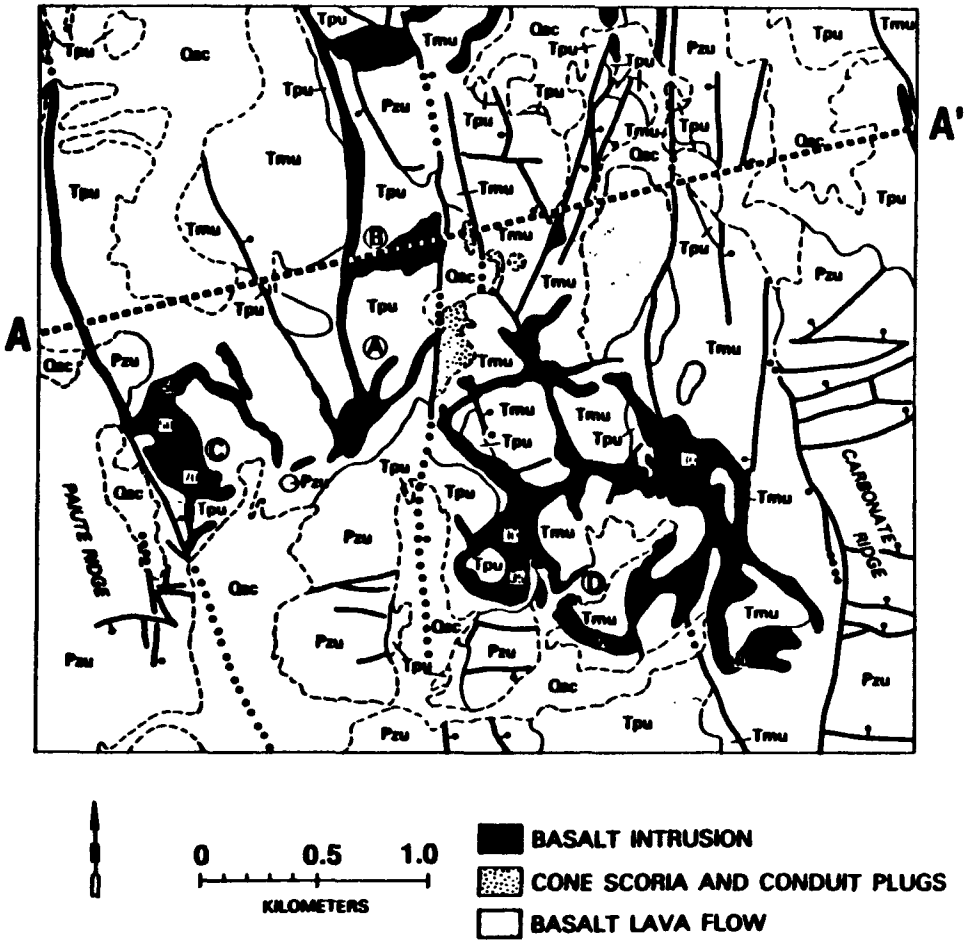
Subsurface Effects (E2, E3)

- **Short - term effects**
  - **Factors affecting intrusion geometry and location**
  - **Mechanical effects of intrusions on wall rocks**
  - **Hydrothermal flow in UZ**
  - **Flow of vapor (air) in response to intrusion**
  - **Volatile releases from magma**

Paiute Ridge Basalt Centers/Intrusions



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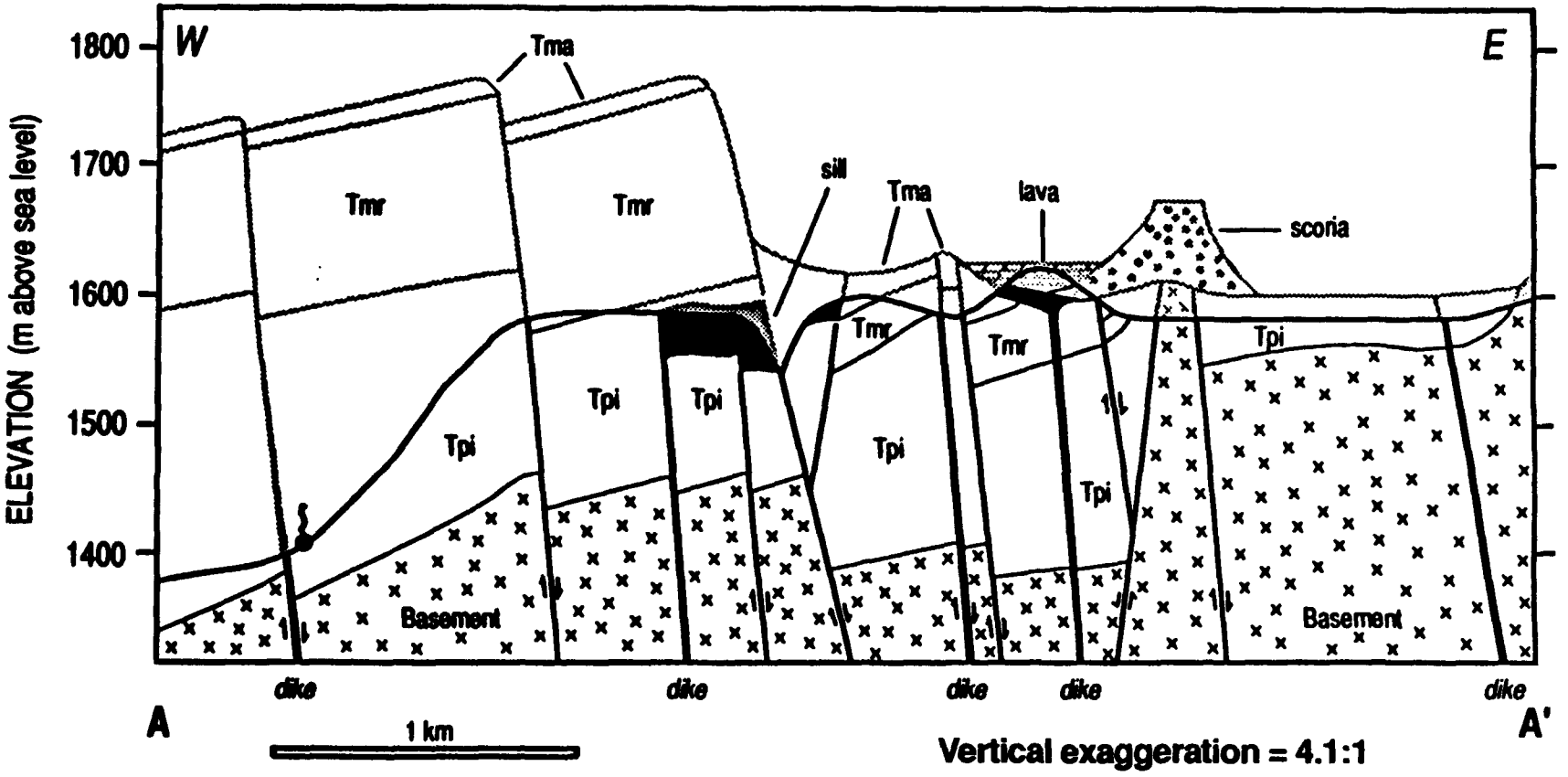

ELEVATION (m above sea level)
1800
1700
1600
1500
1400
W
E
Tma
Tmr
Tmr
sill
Tma
lava
scoria
Tmr
Tmr
Tpi
Tpi
Tpi
Tpi
Tpi
Tpi
Basement
Basement
dike
dike
dike
dike
dike
A
A'
1 km
Vertical exaggeration = 4.1:1

Photo of Basaltic Dike Intruding Tuffs, Paiute Ridge Area

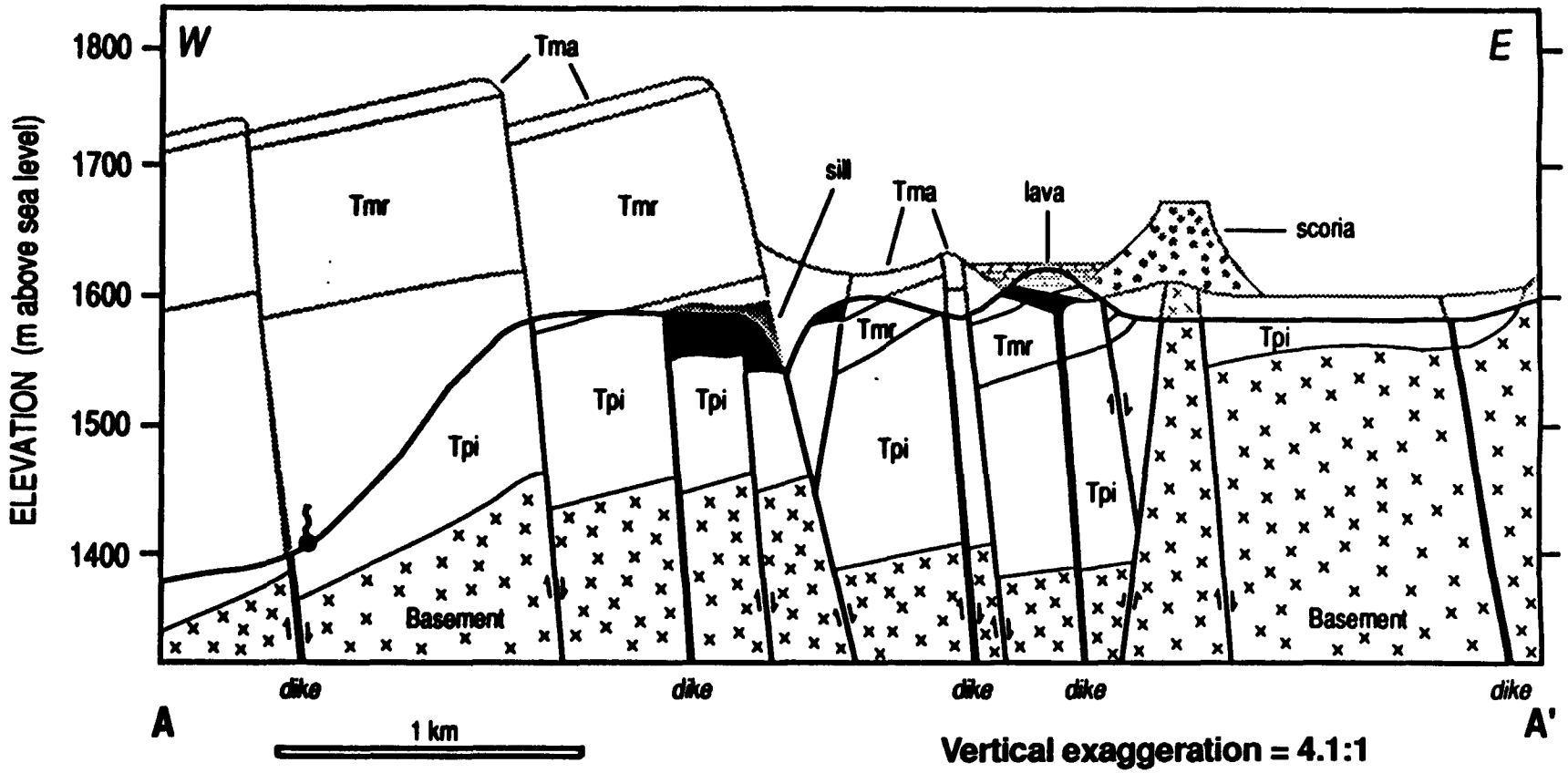
Close-up Photo of Dike at Paiute Ridge

Subsurface Effects

(Continued)

- Long - term effects
  - Effects of intrusion properties, size, and location on post-cooling hydrologic flow field

Photo of Spring Near Basaltic Dike at Paiute Ridge


W
E
1800
1700
1600
1500
1400
ELEVATION (m above sea level)
Tma
Tmr
Tmr
sill
Tma
lava
scoria
Tmr
Tmr
Tpi
Tpi
Tpi
Tpi
Tpi
Tpi
Basement
Basement
dike
dike
dike
dike
dike
A
A'
1 km
Vertical exaggeration = 4.1:1

Magma System Dynamics (E1, E2)

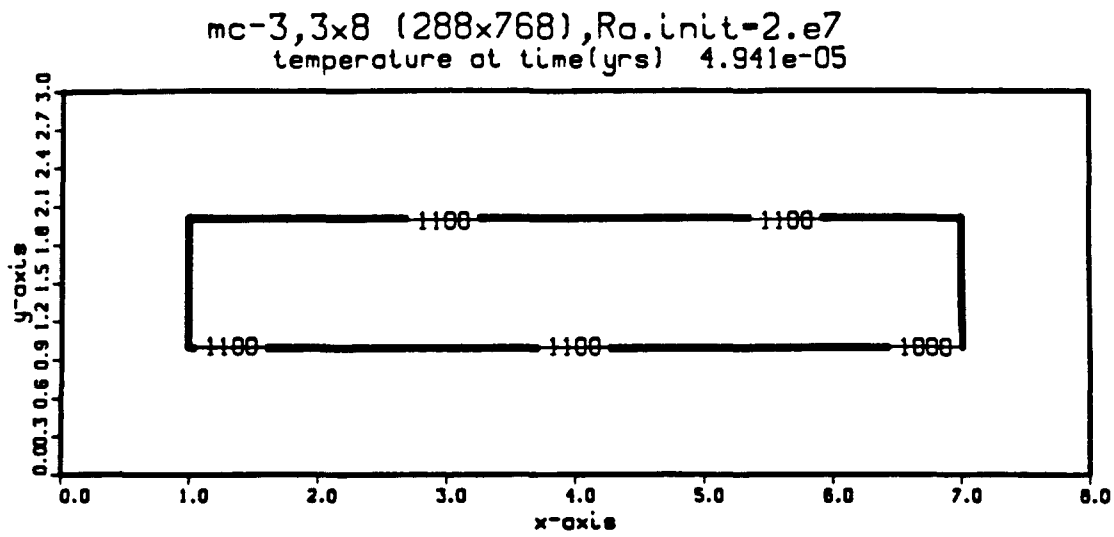
- Goal is to maximize understanding of volcanic systems in Yucca Mountain region
  - Data: petrology, geochemistry, geochronology, volumes, geophysics, eruptive styles, general field relations
  - Theory: melt segregation, magma chamber dynamics, magma ascent in dikes, eruption dynamics
- To provide physical basis for prediction of future hazards
- Examples of work to date

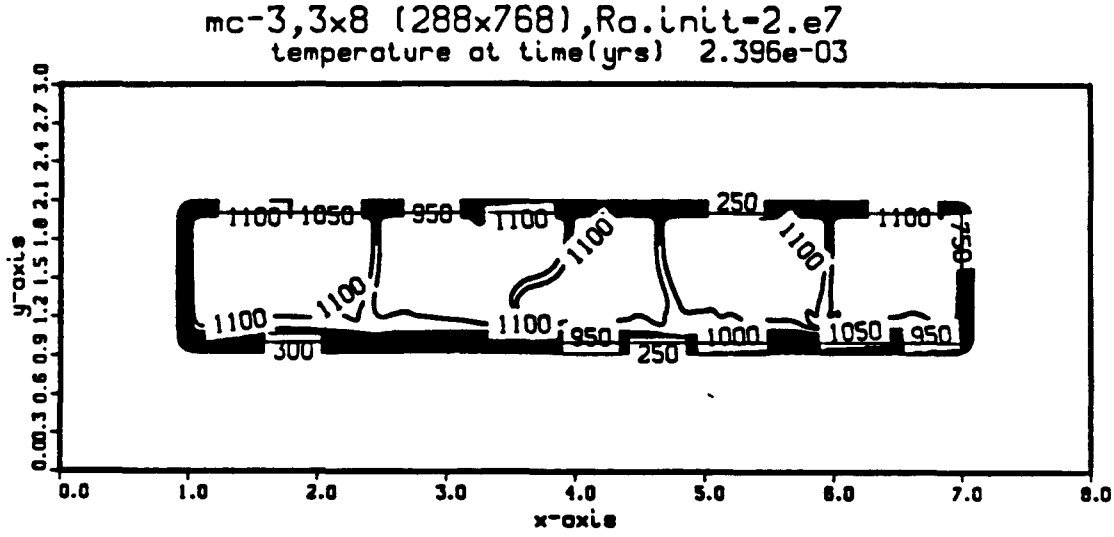
Magma System Dynamics

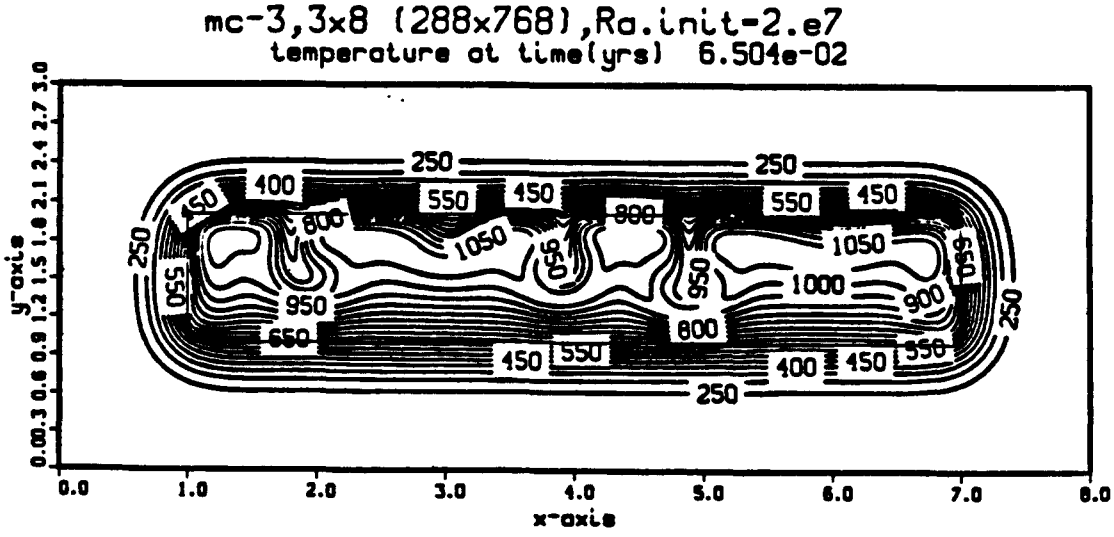
(Continued)

- **Magma Chamber Dynamics**
  - Thermal and chemical processes in small (?), deep basaltic chambers
  - Protracted fractionation, low crystal content
  - Separate small magma batches
  - Possible eruption triggers
  - Open vs. closed system behavior for each batch

Example of Fluid Dynamics of Small Sill







Magma System Dynamics

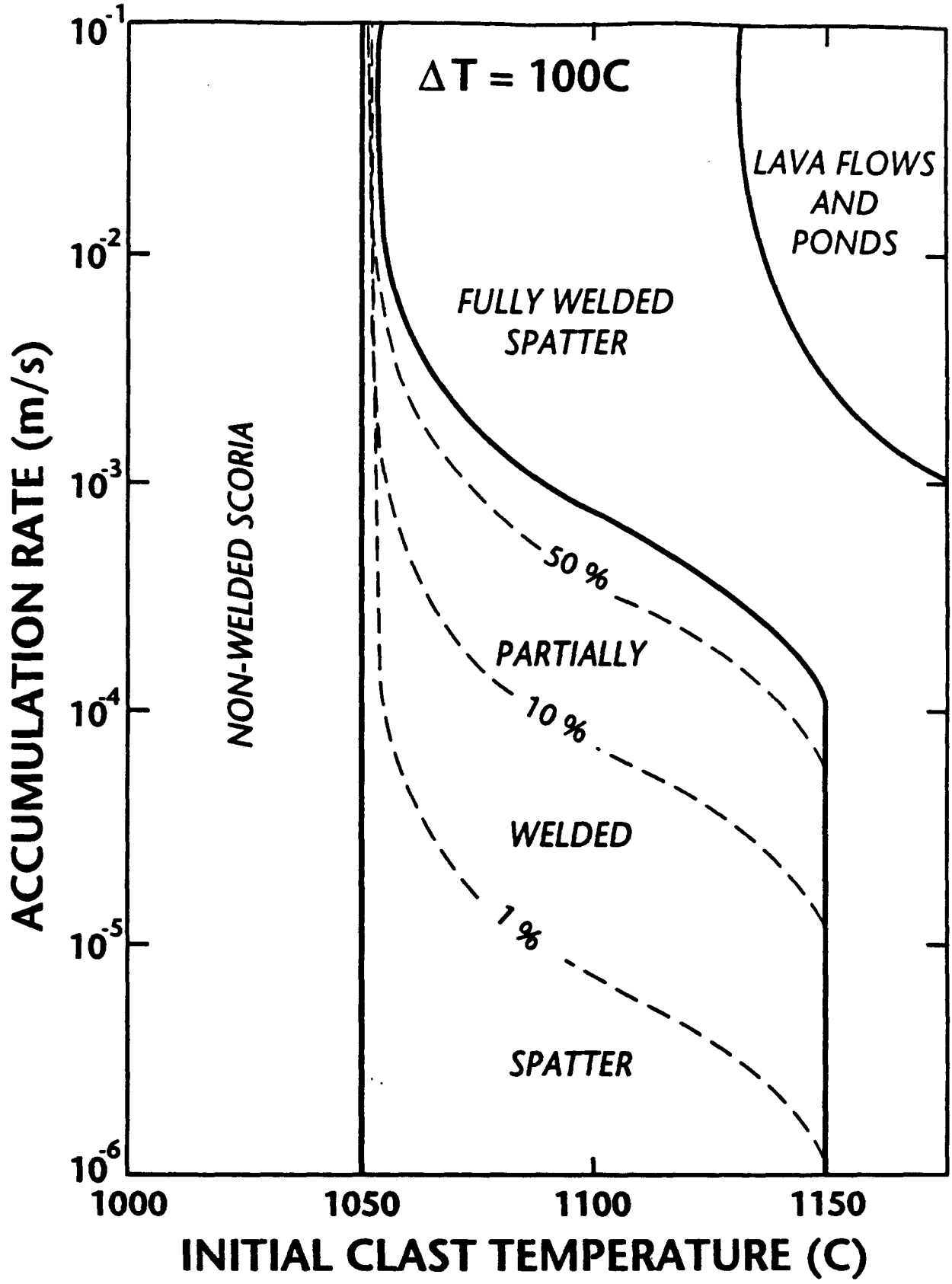
(Continued)

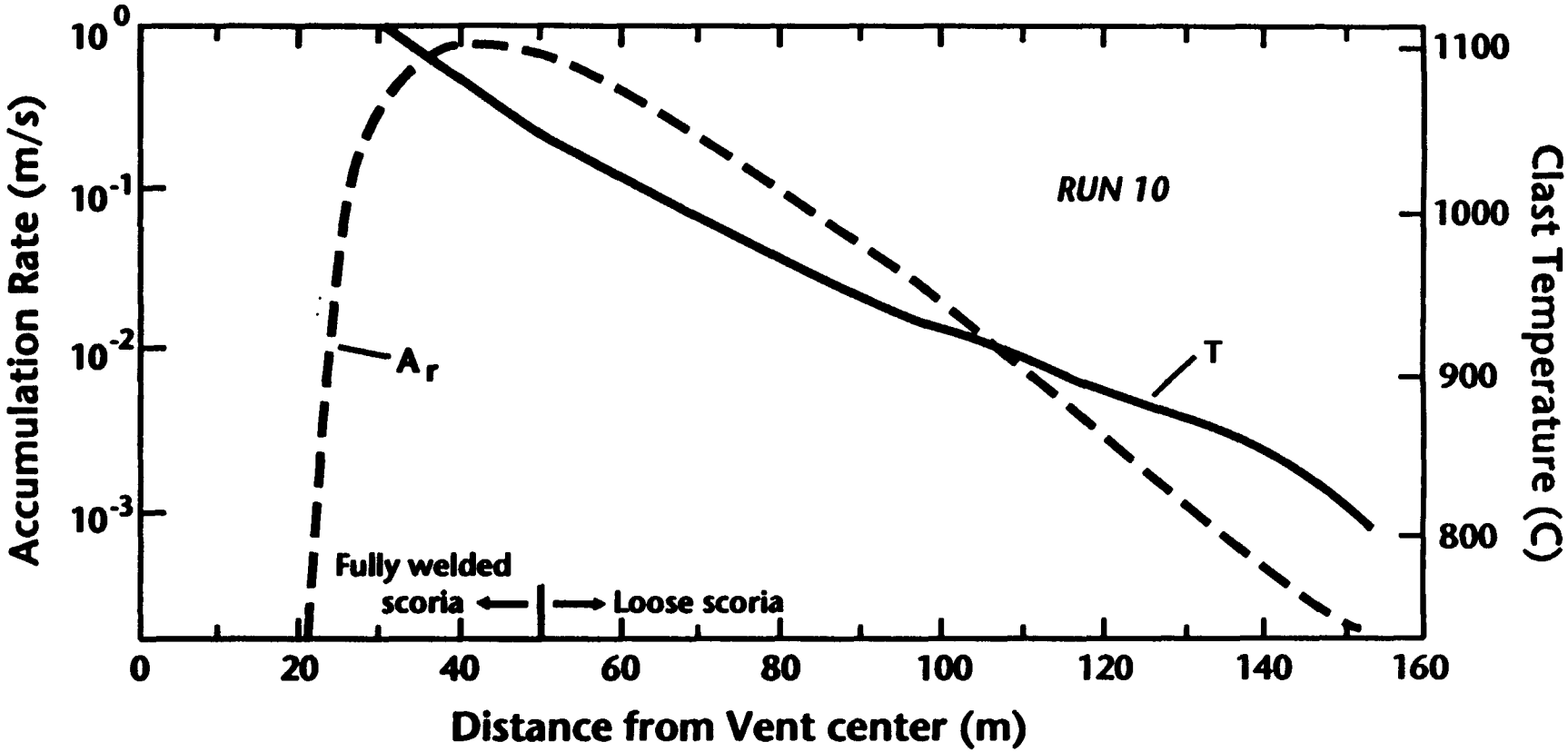
- **Eruption Dynamics**
  - Constrain volatile contents and ascent dynamics
  - Magma discharge rates
  - Eruption durations
  - Basaltic explosive eruptions
    * Hawaiian (steady fountains)
    * Strombolian (bursts and short-lived fountains)

Photo of A-cone at Cima Volcanic Field

Photo of Inner Wall of A-come

Photo of Inner Wall of Lathrop Wells Cone


ΔT = 100C
LAVA FLOWS AND PONDS
FULLY WELDED SPATTER
NON-WELDED SCORIA
50 %
PARTIALLY
10 %
WELDED
1 %
SPATTER
ACCUMULATION RATE (m/s)
10-1
10-2
10-3
10-4
10-5
10-6
1000
1050
1100
1150
INITIAL CLAST TEMPERATURE (C)


Accumulation Rate (m/s)
10^0
10^{-1}
10^{-2}
10^{-3}
RUN 10
A_r
T
Fully welded
scoria
Loose scoria
1100
1000
900
800
Clast Temperature (C)
0
20
40
60
80
100
120
140
160
Distance from Vent center (m)

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Conclusions and Directions

- **Most problems have been identified along with strategies for addressing them**
- **Initial scoping studies (field and theoretical) have helped define strategies and have laid groundwork for detailed work**
- **Study plan written and in review**
  - ***Priority*–complete acceptance process as soon as possible**

Conclusions and Directions

(Continued)

Technical goals for next two years

- **Priority 1 - Complete lithic distribution study and final analysis of eruptive effects**
- **Priority 2 - Perform sensitivity analyses of subsurface "zone of influence" (E2)**
- **Priority 3 - Complete eruption dynamics study**
- **Priority 4 - Continue analog studies of subsurface effects**
- **Priority 5 - Continue melt segregation and magma chamber modeling**