U.S. Department of Energy
Office of Civilian Radioactive Waste Management

Total System Performance Assessment Supplemental Sensitivity Analyses: Igneous Activity

Presented at:
DOE/NRC Technical Exchange on Key Technical Issues Topics Related to Igneous Activity

Presented by:
Peter Swift
Total System Performance Assessment

June 21-22, 2001
Las Vegas, Nevada

YUCCA MOUNTAIN PROJECT

Outline

- **Presentation objective**
- **Total System Performance Assessment (TSPA) supplemental sensitivity analysis methodology**
- **TSPA supplemental sensitivity analysis results**
  - **Sensitivity to alternative wind speed data**
  - **Sensitivity to uncertainty in waste particle diameter**
  - **Relative dose contributions from Zone 1 and Zone 2, igneous intrusion**
    - Modifications to the cumulative distribution functions characterizing uncertainty in the number of waste packages damaged by intrusion
- **Bounded approach to ash redistribution**

Presentation Objective

- **Describe the basis for resolving open agreement items associated with the Igneous Activity Key Technical Issue that are addressed by TSPA supplemental sensitivity analyses**

TSPA Supplemental Sensitivity Analyses Methodology

- **New information developed since the TSPA-SR REV 00 ICN 01 is being evaluated in the FY 2001 Supplemental Science and Performance Analyses (draft, in preparation)**
  - Volume 1: *Scientific Bases and Analyses* (TDR-MGR-MD-000007)
  - Volume 2: *Performance Analyses* (TDR-MGR-PA-000001)
- **Sensitivity analyses conducted as one-off comparisons to TSPA-SR REV 00 ICN 01 (TDR-WIS-PA-000001)**
  - All models and parameters identical to those used in TSPA-SR REV 00 ICN 01 except the ones being examined
  - Results shown as probability-weighted mean annual dose histories, compared to TSPA-SR REV 00 ICN 01 results

Sensitivity to Alternative Wind Speed Data

- **Issue: Discuss incorporation of new wind velocity data into the DOE TSPA model. Discuss method used to average wind velocity in TSPA models (i.e., account for time laterally advecting in plume)**
- **Basis for Resolution**
  - **TSPA-SR REV 00 ICN 01 used wind data from Quiring (1968)**
    - Data from approximately 1500 m to 5000 m above mean sea level

Sensitivity to Alternative Wind Speed Data

(continued)

- **Basis for Resolution (continued)**
  - **Data from Desert Rock airstrip (NOAA n.d.) includes higher altitudes**
    - Wind speed distribution used in supplemental analyses based on 300 millibar data, (average elevation 9400 m above mean sea level)
    - Maximum speed 5683 cm/s, ~2.4X TSPA-SR REV 00 ICN 01
    - Median value 1033 cm/s, ~1.6X TSPA-SR REV 00 ICN 01
- **Conclusion: Calculated probability-weighted mean annual doses are moderately sensitive to wind speed uncertainty**
  - **New data increase probability-weighted dose ~2×**

Sensitivity to Alternative Wind Speed Data

(continued)

- **Reference**
  - NOAA (National Oceanic and Atmospheric Administration) n.d. Upper Air Data: Desert Rock, Nevada, 1978-1995
  - Quiring, R.F. 1968, *Climatological Data Nevada Test Site and Nuclear Rocket Development Station*
  - Supplemental Science and Performance Assessment Volume 2 (work in progress)

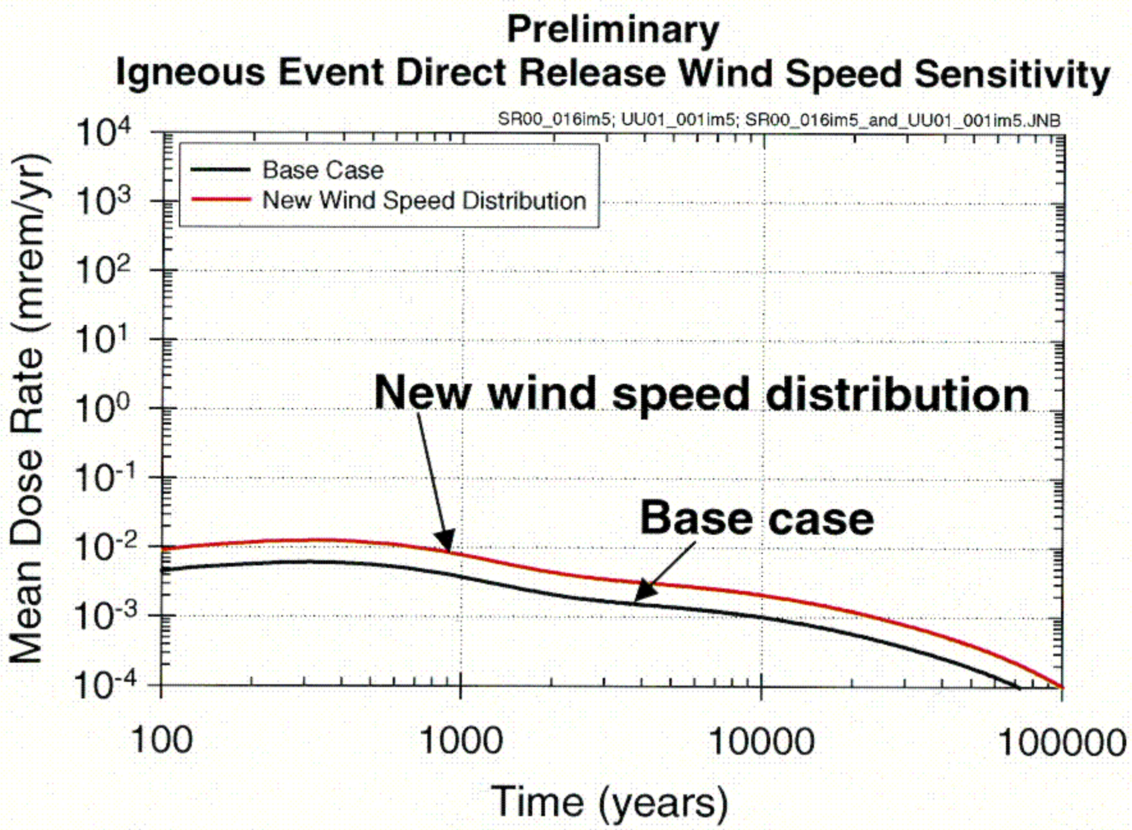
Sensitivity to Alternative Wind Speed Data

(continued)

Probability-weighted mean annual dose from volcanic eruption in any year

All models and parameters from TSPA-SR REV 00 ICN 01 base case, except for new wind speed distribution, based on 300 millibar data from Desert Rock airstrip

All results are preliminary



Source: *Supplemental Science and Performance Assessment* Volume 2, (work in progress)

Sensitivity to Uncertainty in Waste Particle Diameter

- **Issue: Document the results of sensitivity studies for particle size**
- **Basis for Resolution**
  - **TSPA-SR REV 00 ICN 01**
    - Log triangular distribution
    - Min = 0.0001 cm, mode = 0.002 cm, and max = 0.05 cm
  - **Supplemental sensitivity analyses (work in progress)**
    - Minimum decreased by factor of 2, maximum increased by a factor of 2, mode varied over a range from 1/10 to 10x the base case
- **Total of 7 cases**
- **Conclusion: Calculated probability-weighted mean annual doses are insensitive to uncertainty in waste particle diameter within this range (0.00005 to 0.1 cm, modes between 0.0002 and 0.02 cm)**

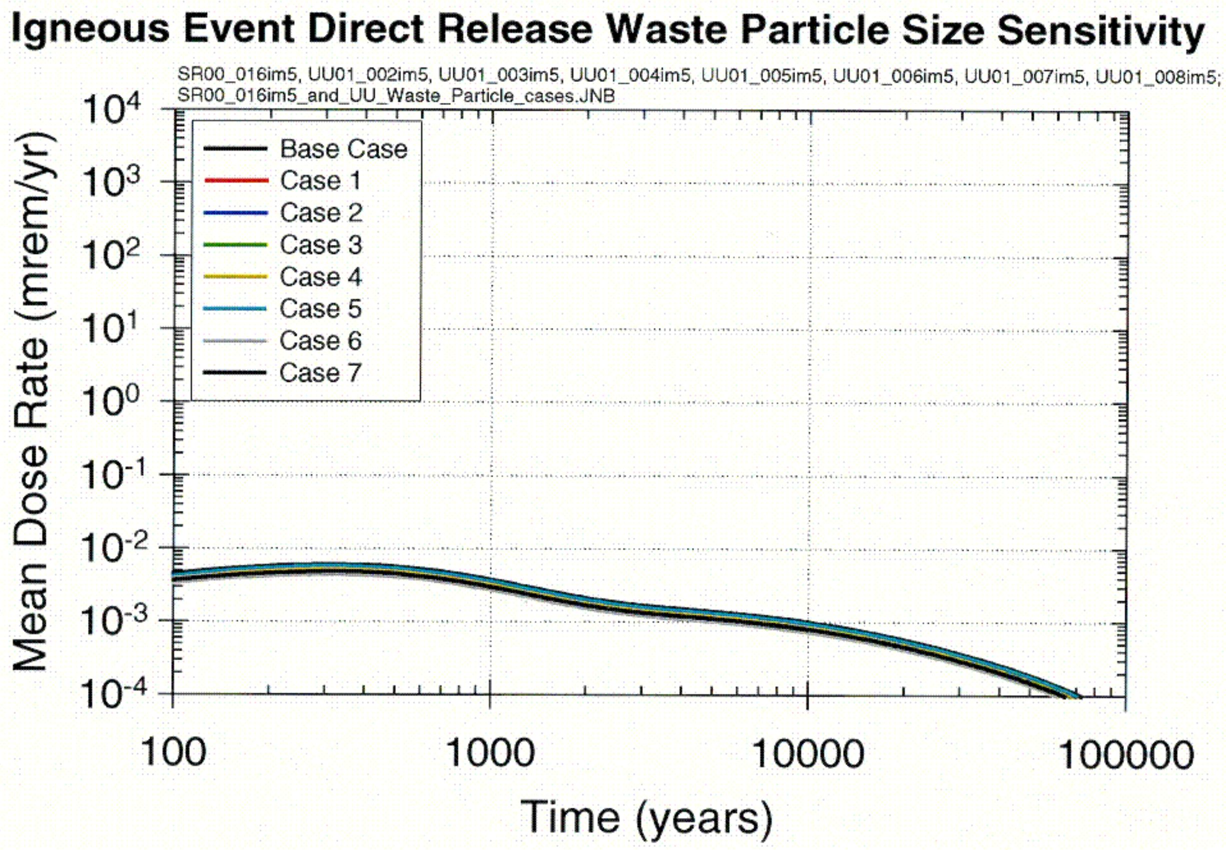
Sensitivity to Uncertainty in Waste Particle Diameter

(continued)

Probability-weighted mean annual dose from volcanic eruption in any year

All models and parameters from TSPA-SR REV 00 ICN 01 base case, except for 7 different distributions for waste particle diameter

All results are preliminary



Source: *Supplemental Science and Performance Assessment* Volume 2, (work in progress)

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Relative Contributions to Calculated Annual Dose from Zone 1 and Zone 2

- **Issue: Provide results showing the relative contributions of releases from Zones 1 and 2**
- **Basis for Resolution**
  - Zone 1 and Zone 2 are used to characterize damage to waste packages from igneous intrusion; doses occur by the groundwater pathway
  - Zone 1 packages are close to point of intrusion and assumed sufficiently damaged that they provide no further protection for the waste
  - Zone 2 packages are the remainder of packages in all intruded drifts and are assumed to be breached with an aperture of uncertain area (truncated log-normal distribution, 1 cm^2 to 1.9×10^4 cm^2, mean = 10 cm^2)
- **Conclusion: Zone 1 is the major contributor to igneous groundwater dose**

Relative Contributions to Calculated Annual Dose from Zone 1 and Zone 2

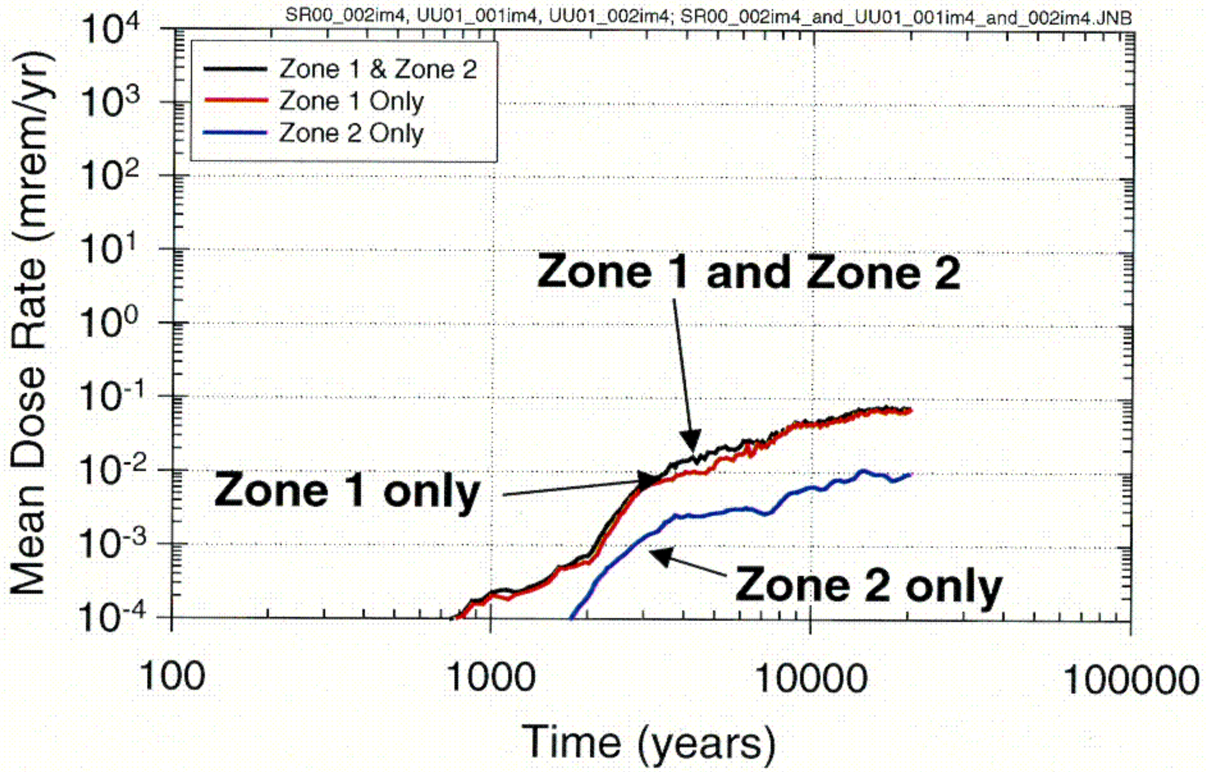
(continued)

Probability-weighted mean annual dose from igneous intrusion in any year

All models and parameters from TSPA-SR REV 00 ICN 01 base case

All results are preliminary

Preliminary
Igneous Event Zone 1 and Zone 2 Sensitivity



Source: *Supplemental Science and Performance Assessment* Volume 2, (work in progress)

Modifications to the Cumulative Distribution Functions for the Number of Packages Damaged by Intrusion

- New information since TSPA-SR REV 00 ICN 01 has led to recalculation of the CDFs describing uncertainty in the number of packages damaged by intrusion

SOURCE DOCUMENT	CUMULATIVE DISTRIBUTION FUNCTION	
	Zone 1	Zone 1 + 2 Combined
TSPA-SR Rev 00 ICN 01, Section 3.10.2.3 (December 23, 2000)	Range: 105-227 Median = 192	Range: 0-11,180 Median = 1,720
Igneous Consequences Modeling AMR Rev 00 ICN 01, Section 6.2 (November 21, 2000)	Range: 98–1,785 Median = 197	Range: 0-11,184 Median = 1,838

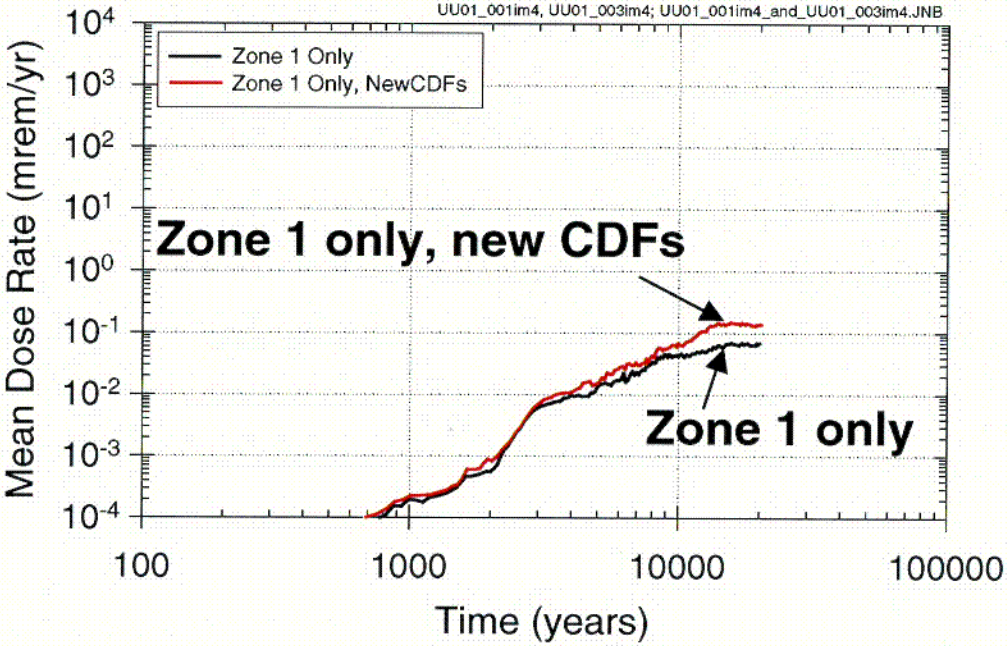
Effect of Recalculating Distributions for the Number of Waste Packages Damaged by Igneous Intrusion: Zone 1

Probability-weighted mean annual dose from igneous intrusion in any year, Zone 1 packages only

All models and parameters from TSPA-SR REV 00 ICN 01 base case except for number of packages damaged

All results are preliminary

Preliminary
Igneous Event Zone 1 and Zone 1 w/new CDFs Sensitivity



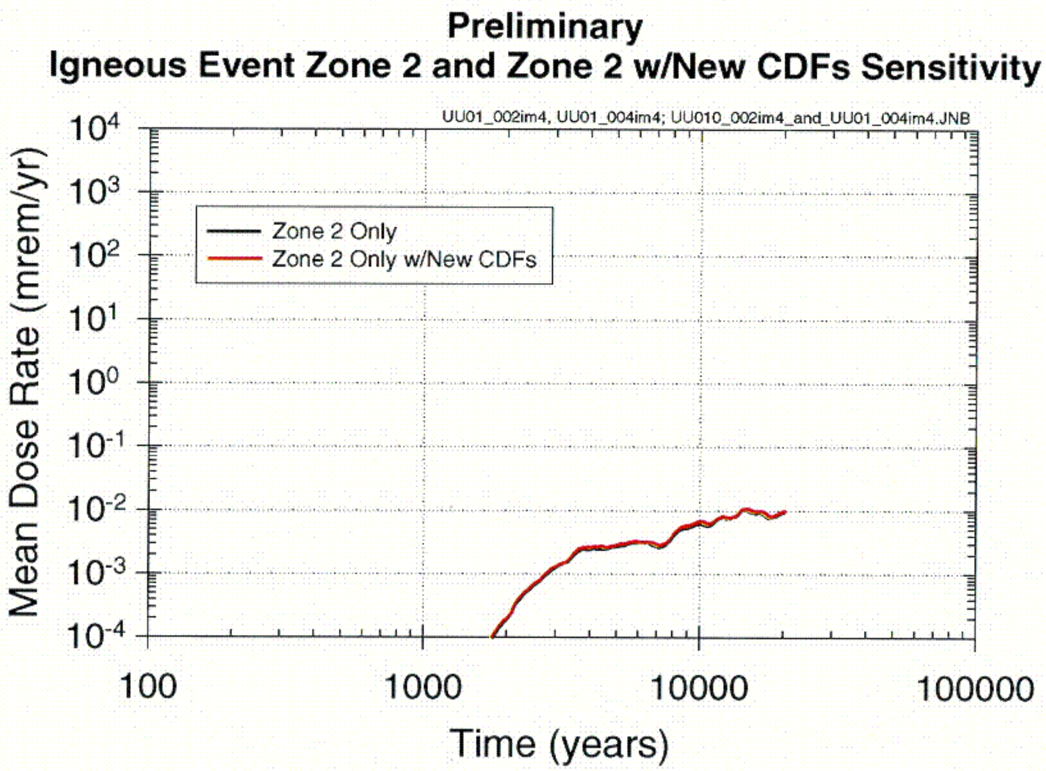
Source: *Supplemental Science and Performance Assessment* Volume 2, (work in progress)

Effect of Recalculating Distributions for the Number of Waste Packages Damaged by Igneous Intrusion: Zone 2

Probability-weighted mean annual dose from igneous intrusion in any year, Zone 2 packages only

All models and parameters from TSPA-SR REV 00 ICN 01 base case except for number of packages damaged

All results are preliminary



Source: *Supplemental Science and Performance Assessment* Volume 2, (work in progress)

TSPA-SR REV 00 ICN 01 Approach to the Effects of Ash Redistribution

- Issue: Develop a technical basis to support conclusions that the effects of eolian and fluvial remobilization are bounded by conservative modeling assumptions in the TSPA-SR REV 00 ICN 01. Demonstrate how more realistic models account for:
  - i) rate of mobilization off slopes
  - ii) rate of transport in Fortymile Wash drainages
  - iii) rate of transport from eolian processes
  - iv) deposition rate at proposed critical group location
  - v) changes in particle-size distributions during fluvial transport

would not lead to higher calculations of risk

TSPA-SR REV 00 ICN 01 Approach to the Effects of Ash Redistribution

- **Basis for Resolution**
  - **Evaluated probability-weighted annual dose from eruptions at all times**
  - **Fixed wind direction toward critical group**
    - overestimates the dose from ashfall by about a factor of 5
  - **Used "transition-phase" BDCFs for all times**
    - overestimate air mass loading for all but the first decade following eruption
    - concentrate all radionuclides in the upper 1 cm

TSPA-SR REV 00 ICN 01 Approach to the Effects of Ash Redistribution

(continued)

- **Basis for Resolution (continued)**
  - **Used a soil erosion factor consistent with agricultural land**
    - Sensitivity analysis considered much slower erosion: 1000-year soil half-life
  - **Did not account for soil buildup from possible surface redistribution**
- **Examine conditional (i.e., non-probability-weighted) doses from eruptions at selected times**

Supplemental Sensitivity Analyses Relevant to Surface Redistribution

- **Conclusion:**
  - For the same set of input parameters, conditional dose at any time following an eruption can be no greater than the dose that would result if the eruption occurred in that year (i.e., doses don't get worse than they are in the first year)
  - Given the conservative approach to the transition BDCFs (i.e., concentrating radionuclides in the upper 1 cm and assuming high air mass loading), conditional eruptive doses with no soil removal bound surface redistribution effects
  - Assumes concentrations do not increase during redistribution
  - DOE considers that this approach provides a technical basis to demonstrate that the modeling assumptions in TSPA-SR REV 00, ICN 01 are conservative

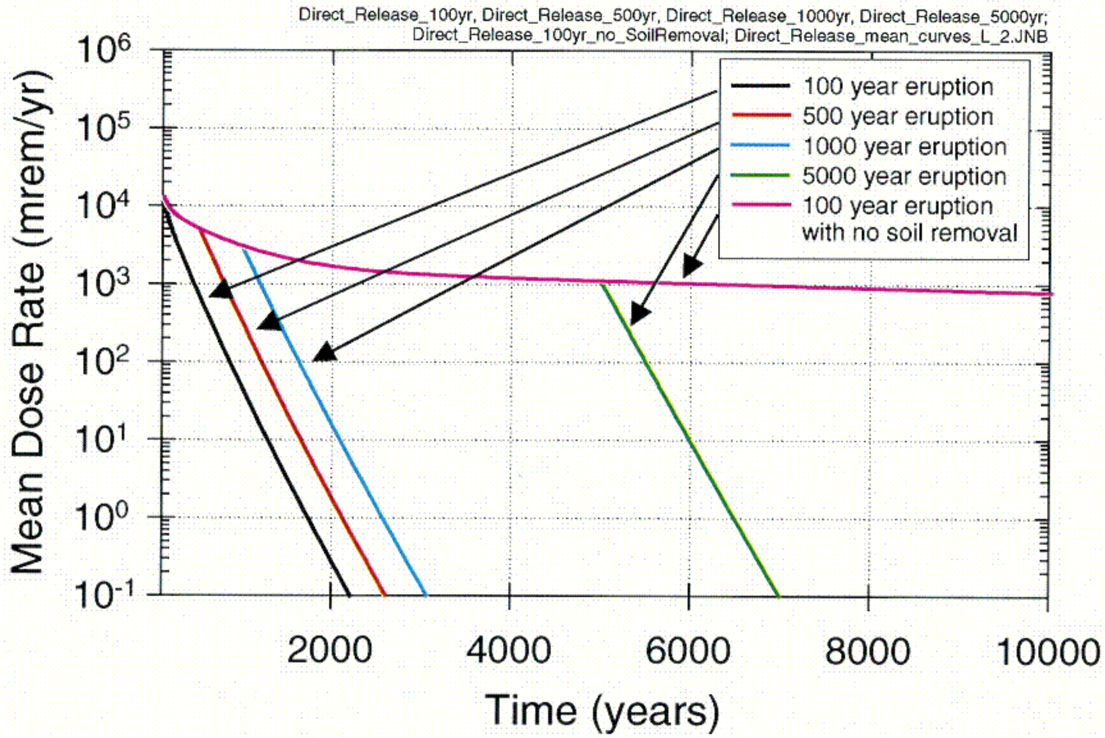
Supplemental Sensitivity Analyses Relevant to Surface Redistribution
(continued)

Conditional mean annual dose from volcanic eruption at selected times

All models and parameters from TSPA-SR REV 00 ICN 01 base case except event probability

All results are preliminary

Igneous Case
Non-Probability Weighted Direct Release Mean Dose Time Histories



Source: *Supplemental Science and Performance Assessment* Volume 2, (work in progress)

Conclusions

- Sensitivity to alternative wind speed data: Calculated doses are moderately sensitive to wind speed uncertainty, and new wind speed data have been included in the supplemental sensitivity analyses
- Sensitivity to waste particle diameter: Calculated doses are insensitive to uncertainty in waste particle diameter within the range of diameters examined
- Relative releases from Zones 1 and 2: Zone 1 is the major contributor to igneous groundwater dose
- Ash redistribution: approach is conservative and dose does not get worse than that in the first year

U.S. Department of Energy
Office of Civilian Radioactive Waste Management

Biosphere-Igneous Activity Interactions

Presented to:
DOE-NRC Technical Exchange on Key Technical Issues
Topics Related to Igneous Activity

Presented by:
A. J. Smith
Biosphere Department Manager

June 21-22, 2001
Las Vegas, Nevada

YUCCA MOUNTAIN PROJECT

Outline

- **Presentation objectives**
- **For biosphere items discussed in the Igneous Activity Appendix 7 meeting, May 18, 2001, this presentation will:**
  - **Summarize technical basis for item resolution**
  - **Identify basis documents (references)**
  - **Summarize technical adequacy of basis**
- **Conclusions**

Presentation Objectives

- Describe the basis for resolving Biosphere-Igneous Activity items identified in the Igneous Activity Appendix 7 meeting May 18, 2001
- For the topic of airborne particle concentrations, describe how the details of the primary pathway (inhalation) improved justification for the concentration for re-suspended particles

Airborne Particle Concentrations

- **Action or information needs identified by the NRC**
  - Comparison of static vs. disturbed conditions
  - Average annual static concentrations vs. 8-hr workday disturbed conditions
  - Basis for extrapolating total suspended particulates (TSP) concentrations
  - Airborne particle concentration and fluvial and eolian flux through the critical group location
  - Assumption that the concentration of re-suspended particles returns to background values within 10 years
  - Mass loading above a tephra deposit
  - External exposure from high level waste-contaminated ash
  - Effects of climate change on disruptive events Biosphere Dose Conversion Factors (BDCFs)

Comparison of Static vs. Disturbed Conditions

- **Issue: Strengthen relationship between measurements of airborne particle concentrations for static conditions with appropriate levels of surface disturbance associated with the habits and lifestyles of critical group members**
- **Basis for Resolution**
  - **Scoping calculations used time-activity budgets based on behavior of a farmer and dust loads for post-volcanic conditions and farming activities were calculated to confirm that the static measurements were appropriate (see following slides)**
  - **This method considers the disturbed conditions specified in the issue statement**
  - **This method will be included in a future update to the AMR, *Input Parameter Values for External and Inhalation Radiation Exposure Analysis*, ANL-MGR-MD-000001, REV 01**

Example of Time-Activity Budget Calculation Done to Confirm Validity of Mass Loading Distribution - Nominal Conditions

Behavior	Hours/day[a]	Mass Load ($\mu g/m^3$, PM_{10})
Working Outdoors	8.6	120[b]
Recreating Outdoors	2.3	42[c]
Indoors	13.1	21[d]

[a] Representative of the upper bound of the critical group (i.e., a farmer) that works outdoors 60 hours/week and spends an additional 16.1 hours/week recreating outdoors

[b] Median respirable dust level for 18 typical farming activities (Nieuwenhuijsen et al. 1999. Ann. Occup. Hyg. 43:35-42)

[c] Average dust level (PM_{10}) for 5 arid farming communities

[d] 50% of farming-community average

$$\frac{(8.6\text{hours} \times 120\mu g/m^3) + (2.3\text{hours} \times 42\mu g/m^3) + (13.1\text{hours} \times 21\mu g/m^3)}{24\text{hours}} = 59\mu g/m^3$$

Conclusion: Average daily concentration based on time budget (59 $\mu g/m^3$) is slightly higher but similar to maximum PM_{10} concentrations calculated from parameters used in ANL-MGR-MD-000001 REV 01

$$\frac{(10.9\text{hours} \times 69\mu g/m^3) + (13.1\text{hours} \times 34.5\mu g/m^3)}{24\text{hours}} = 51\mu g/m^3$$

Source: Work in Progress

Example of Time-Activity Budget Calculation - Post Volcanic Eruption

Behavior	Hours/day[a]	Mass Load ($\mu g/m^3$, TSP)
Outdoors – very dusty work	4.3	10,000[b]
Outdoors – moderately dusty	4.3	5,000
Recreating Outdoors	2.3	1,000
Indoors	13.1	50

[a] Representative of the upper bound of the critical group (i.e., a farmer) that works outdoors 60 hours/week, 50% of time in very dusty work

[b] Cerro Negro data (from Igneous Activity Technical Exchange, August 2000)

$$\frac{(4.3\text{hours} \times 10000 \mu g/m^3) + (4.3\text{hours} \times 5000) + (2.3\text{hours} \times 1000) + (13.1\text{hours} \times 50)}{24\text{hours}} = 2810 \mu g/m^3$$

Conclude: Average daily concentration based on bounding time budget (2,810 $\mu g/m^3$) is slightly higher, but similar to, maximum concentration calculated from parameters used in ANL-MGR-MD-000001 REV 01 (2,180 $\mu g/m^3$):

$$\frac{(10.9\text{hours} \times 3000 \mu g/m^3) + (13.1\text{hours} \times 1500)}{24\text{hours}} = 2180 \mu g/m^3$$

Difference in TSPA estimates indicate that the original estimate was underestimated by about 30%

Source: Work in Progress

Average Annual Static Concentrations vs. 8-hr Workday Disturbed Conditions

- **Issue: Strengthen relationships between measurements of annual airborne particle concentrations under static conditions, and durations of exposure to disturbed and undisturbed conditions of critical group**
- **Basis for Resolution**
  - Duration of exposure (i.e., inhalation exposure time) was based on assumed behaviors of farmers
  - Distribution of exposure time to outdoor concentrations ranged from 8.0 to 10.8 hours per day
  - This method considers the disturbed conditions specified in the issue statement
- **References**
  - *Input Parameter Values for External and Inhalation Radiation Exposure Analysis*, ANL-MGR-MD-000001, REV 01, Sections 5.2 and 6.2.2 (November 17, 2000)

Basis for Extrapolating TSP Concentrations

- Issue: Clarify relationship used to extrapolate total suspended particulates (TSP) from PM_{10} measurements. Strengthen discussion of how TSP can be determined for disturbed conditions based on other PM_{10} measurements, as surface disturbance will likely increase the proportion of coarser particles (10-100 microns) in the breathing zone relative to static entrainment conditions (i.e., gravitationally induced settling of coarse particles may be more significant for static than disturbed conditions)

Basis for Extrapolating TSP Concentrations

(continued)

- **Basis for resolution**
  - **Ratio of TSP to PM_{10} for post-volcanic conditions was based on a ratio measured during farming activities following the Mount St. Helens eruption**
  - **TSP/PM_{10} ratio is based on analog information for a volcanic environment**
  - **DOE is re-evaluating the ratios used to determine TSPs**
  - **DOE is considering using measured values of TSPs in future calculations rather than estimates based on PM_{10} concentration**
  - **Any changes would be documented in a subsequent revision of the AMR, *Input Parameter Values for External and Inhalation Radiation Exposure Analysis* (ANL-WIS-MD-000001)**

Basis for Extrapolating TSP Concentrations

(continued)

- **References**
  - *Input Parameter Values for External and Inhalation Radiation Exposure Analysis*, ANL-MGR-MD-000001, REV 01, Section 5.1.4 (November 17, 2000)

Airborne Particle Concentrations and Fluvial and Eolian Flux Through the Critical Group Location

- Issue: Although transition-period particle concentrations are viewed by the DOE as conservative, the lower parts of that range may not be conservative for the first decades following an eruption due to prompt remobilization effects
- Basis for resolution
  - Details were provided in the Supplemental Sensitivity presentation
- References
  - *Total System Performance Assessment - Site Recommendation* (TSPA-SR), TDR-WIS-PA-00001, REV 00, ICN 01 (December 11, 2000)

Assumption that Concentration of Resuspended Particles Returns to Background Values Within 10 Years

- Issue: In particular, DOE needs to demonstrate that long-term input of fine particulates through wind and water remobilization would not significantly affect the proposed mass-load reduction factor
- Basis for resolution
  - Mount St. Helens data taken at Longview, Spokane, Yakima ($250<TSP<700\ \mu g/m^3$) indicated return to normality in few months. Ten years used as reasonable limit
  - For the purpose of developing BDCFs, no allowance has been taken for post-eruption transport that would lead to removal of material

Assumption that Concentration of Resuspended Particles Returns to Background Values Within 10 Years

(continued)

- **Basis for Resolution (continued)**
  - The combination of the 10-year period and the assumption of no removal of material are considered to be conservative
- **Reference**
  - *Input Parameter Values for External and Inhalation Radiation Exposure Analysis*, ANL-MGR-MD-000001, REV 01 (November 17, 2000)

Mass Loading Above a Tephra Deposit

- Issue: The mixing of temporal variability and parameter uncertainty in the development of the mass loading above a tephra deposit will only provide correct results if other time-dependent processes do not result in a significant change in the concentration of radionuclides in the soil over the 10 year period over which the temporal averaging is being performed. Specifically, DOE needs to demonstrate that processes that remove radionuclides from the soil (i.e., decay, erosion, and leaching) do not cause a significant change in the concentration of radionuclides in the soil over the first 10 years following the igneous eruption

Mass Loading Above a Tephra Deposit

(continued)

- **Basis for resolution**
- **DOE's method is conservative because**
  - **BDCFs that include soil removal were not used in TSPA-SR**
  - **More conservative BDCFs were used**
  - **When generating BDCFs, credit was taken for stabilization, but no credit was taken for removal**
- **References**
  - ***Input Parameter Values for External and Inhalation Radiation Exposure Analysis*, ANL-MGR-MD-000001, REV 01 (November 17, 2000)**
  - ***Total System Performance Assessment for Site Recommendation* (TDR-WIS-PA-000001) REV 00 ICN 01 (December 11, 2000)**

External Exposure from HLW-Contaminated Ash

- Issue: Dose pathways for direct release discussed in TSPA-SR (P. 3-206) list inhalation and ingestion, but do not list external exposure from HLW-contaminated ash. In addition, external exposure is not considered for indoor occupants even though the dwelling may be surrounded by HLW-contaminated ash containing high energy gamma emitters

External Exposure from HLW-Contaminated Ash

(continued)

- **Basis for resolution**
  - Transition phase BDCFs included inhalation, ingestion and external exposure
  - An appropriate shielding factor for external exposure will be incorporated in a future update of the AMR, Input Parameter Values for External and Inhalation Radiation Exposure Analyses (ANL-MGR-MD-000001)
  - The effect of external exposure is negligible (ANL-MGR-MD-000003)
  - Changing the shielding factor has little impact on dose estimates (TDR-WIS-PA-000001, REV 00 ICN 01, Figure 4.2-2)
- **Reference**
  - *Disruptive Event Biosphere Dose Conversion Factor Analysis*, ANL-MGR-MD-000003 REV 01, Section 6.3.2 (January 23, 2001)
  - *Total System Performance Assessment for the Site Recommendation* (TDR-WIS-PA-000001) REV 00 ICN 01 (December 11, 2000)

Effects of Climate change on Disruptive Events BDCFs

- **Issue: Disruptive Events BDCFs apparently are not affected by climate change, whereas BDCFs for the "nominal case" are affected [by] climate change (DE BDCF AMR)**
- **Basis for resolution**
  - The inhalation pathway is dominant for the volcanic eruption BDCFs
  - Climate change with increased precipitation would lead to more rapid stabilization and increased loss from leaching (solubility-limited) and thus leads to reduced re-suspension of radionuclides
  - Credit was not taken for these processes
- **Reference**
  - *Disruptive Event Biosphere Dose Conversion Factor Analysis*, ANL-MGR-MD-000003 REV 01 (January 23, 2001)

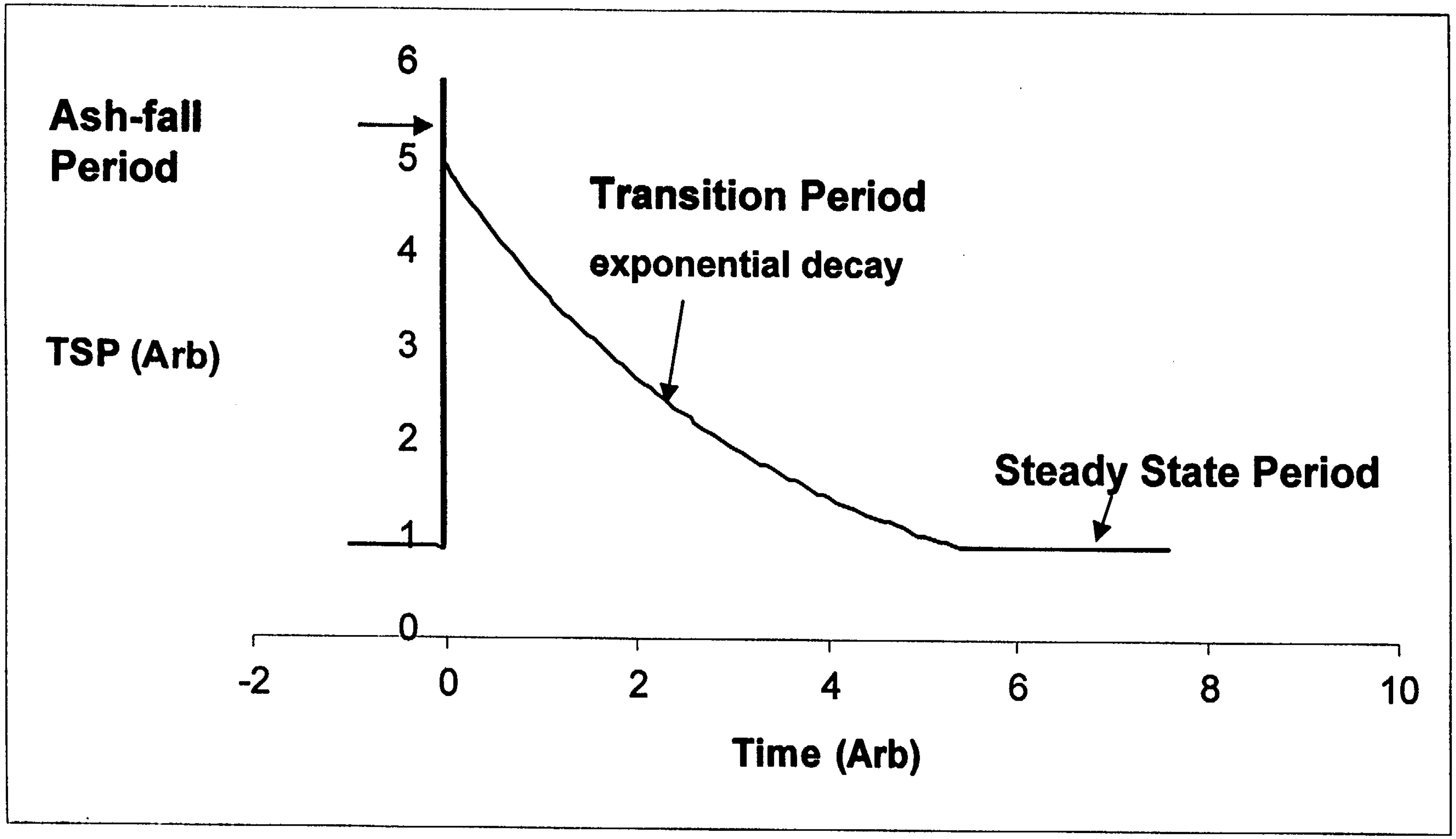
Conclusions

- **DOE believes that sufficient basis has been provided on the topic of airborne particle concentrations for Biosphere-Igneous Activity Interactions, to consider the issue closed-pending the following:**
  - **Use of measured values of total suspended particulates in future calculations**
  - **Re-evaluation of ratios used to determine TSPs**
  - **Updating the AMR, *Input Parameter Values for External and Inhalation Radiation Exposure Analyses* (ANL-WIS-MD-000001)**

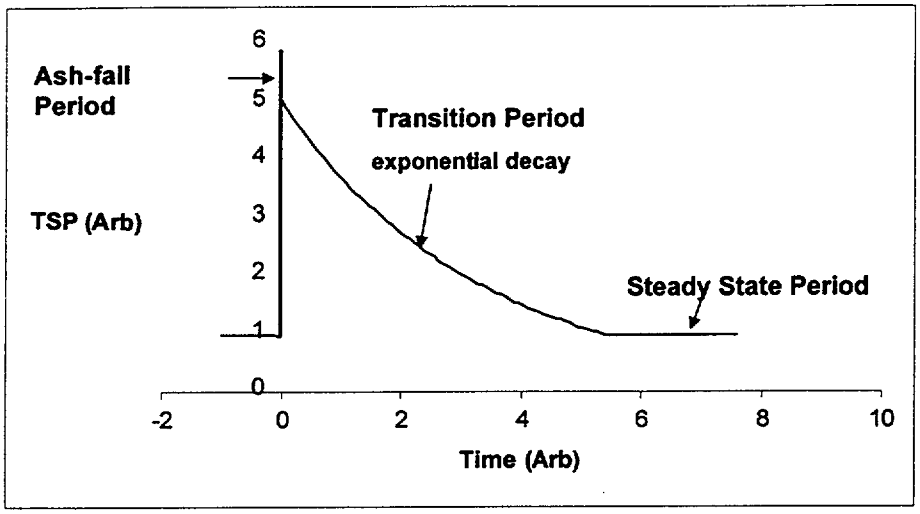
External Exposure

- External Exposure less than 0.5% for all radionuclides except ^{137}Cs where it is 75%!
- Screening factor assumed for home makes a trivial difference for all except ^{137}Cs
- Removing screening altogether for ^{137}Cs would increase BDCF by a factor of 2.13 (0.25+0.75*2.5)
- TSPA-SR Figure 4.2-2 shows ^{137}Cs contributes approximately 5% of the dose at early times (first two hundred years)
- So net effect would be an increase in expected annual dose of about 5%
- This has no impact on peak value of expected annual dose

TIME EVOLUTION OF TSP



TIME EVOLUTION OF TSP



YMP Yucca Mountain Project/Preliminary Predecisional Draft Materials BSC Graphics/Presentations/NRC/ ymSmith_082101.ppt 21

This is a stylized representation of the TSP as a function of time.

The ash fall period is few days to a few tens of days.

The Transition Period is estimated to be 10 years.

The Steady State Period then continues forever (at the same TSPA as pre-eruption.

BDCFs were generated for each period.

TSPA only used the BDCFs for the transition period and used it forever more.

Additional evidence that the initial mass loading value for disruptive events in high

- Personal exposure to respirable dust by loggers decreased by a factor of 3 (900 to 270 µg/m^3) over four months following Mount St. Helens (Buist 1986, pg. 70)

- TSP in Yakima (static monitor) was 33,400 µg/m^3 on May 18; 5,800–13,000 µg/m^3 on May 26; and 50–250 during May 27 through June 11 (Bernstein et al. 1986, pg. 27).

- "The results of NIOSH air sampling indicated that only the occupational exposures for certain categories of workers in heavy ashfall areas exceeded 800 µg/m3, ... However, even these exposures were transient" (Bernstein et al. 1986, pg. 32).

- [With regards to a 1-2 mm deposit] "Weathering can remove the fine deposits over a period of weeks, so the duration of exposure will be much less than with a thick deposit." (Baxter 1998).

- Exposure to resuspendable ash will be markedly elevated after an ashfall of over 10 cm and can last for weeks or even longer in the absence of rainfall." (Baxter 1998).

Additional evidence that the initial mass loading value for disruptive events in high

- Measurements of personal exposure to TSP in children at two camps that had 1-2 cm of ash following Mount St. Helens (Buist et al 1986, pg. 69):
  - daytime average: 1,240–1,460 µg/m^3
  - nighttime average: <10 µg/m^3

- Measurements of personal exposure to PM_{10} from loggers working in high-ash areas <1 month following Mount St. Helens (Buist et al. 1986, pg. 70):
  - cutters–900 µg/m^3 rigging–280 µg/m^3

- Measurements of personal exposure to TSP for various occupations and setting following Mount St. Helens (Buist et al. 1986, pg. 41)
  - agricultural workers: 1,420 µg/m^3
  - combines: 5,280 µg/m^3
  - home: 90 µg/m^3
  - businesses 300 µg/m^3

- Evidence that people used masks and other methods to reduce exposure to ash and removed or wetted ash to reduce resuspension near their homes and businesses (Bernstein et al. 1986, pg. 27; Baxter 1998)

New Observations about Basaltic Volcanism near Yucca Mountain: Implications for Volcanic Hazard Studies

Eugene I. Smith

Deborah L. Keenan

Department of Geoscience
University of Nevada, Las Vegas
Las Vegas, Nevada 89154-4010
gsmith@ccmail.nevada.edu

Introduction

- Present new information, most of which was not available to or not considered by the PVHA panel of experts
- Develop alternative conceptual models
- Make recommendations with implications for volcanic hazard studies

Introduction

- Patterns of volcanism
- Control of volcanism
- Implications and Recommendations

Patterns of Volcanism

- Maps show volcanism from 9.5 to 0.02 Ma
- Each red dot represents a separate volcanic center

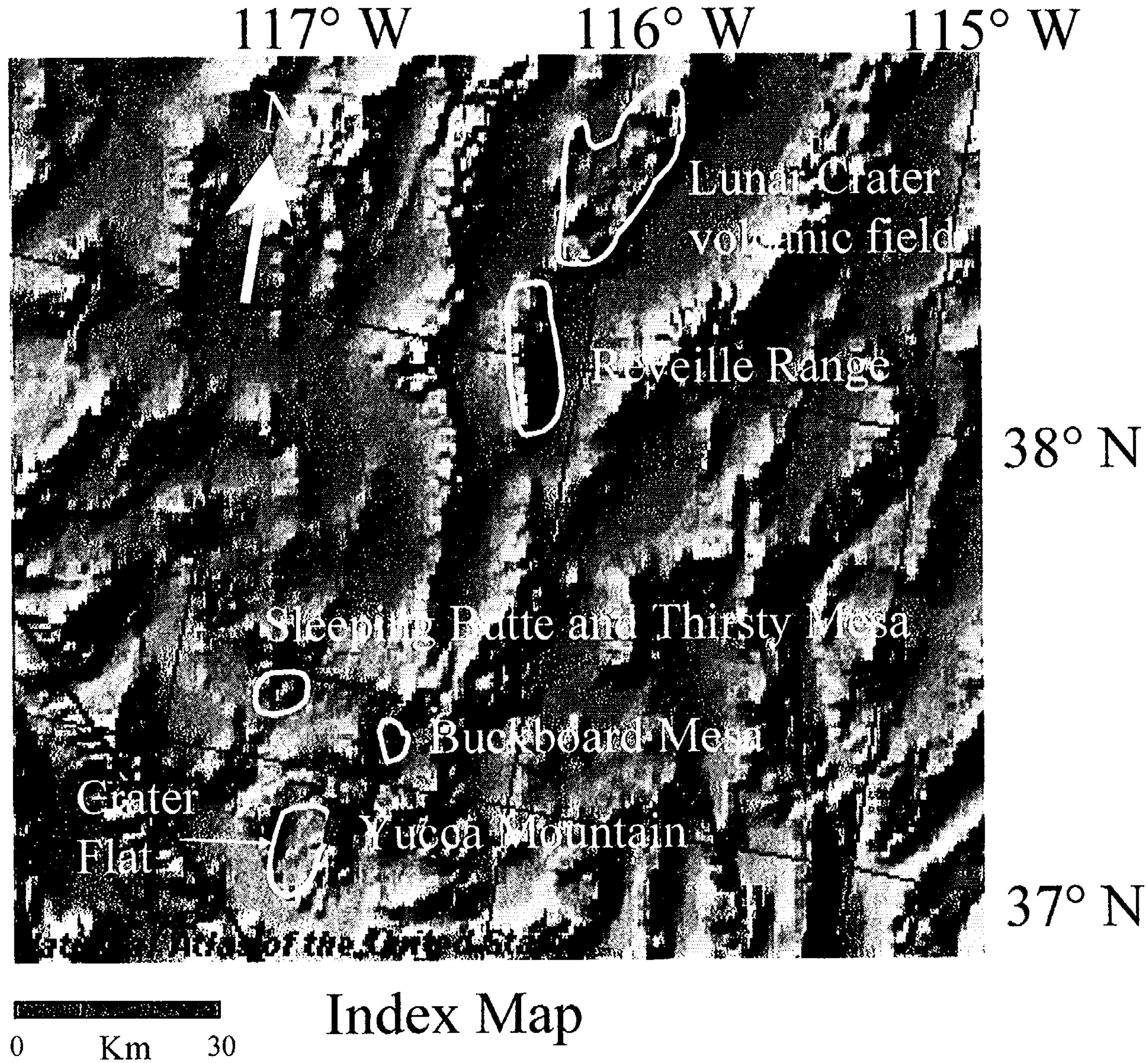


Figure 1. Index map of the Crater Flat-Lunar Crater area.

9.5-6.5 Ma

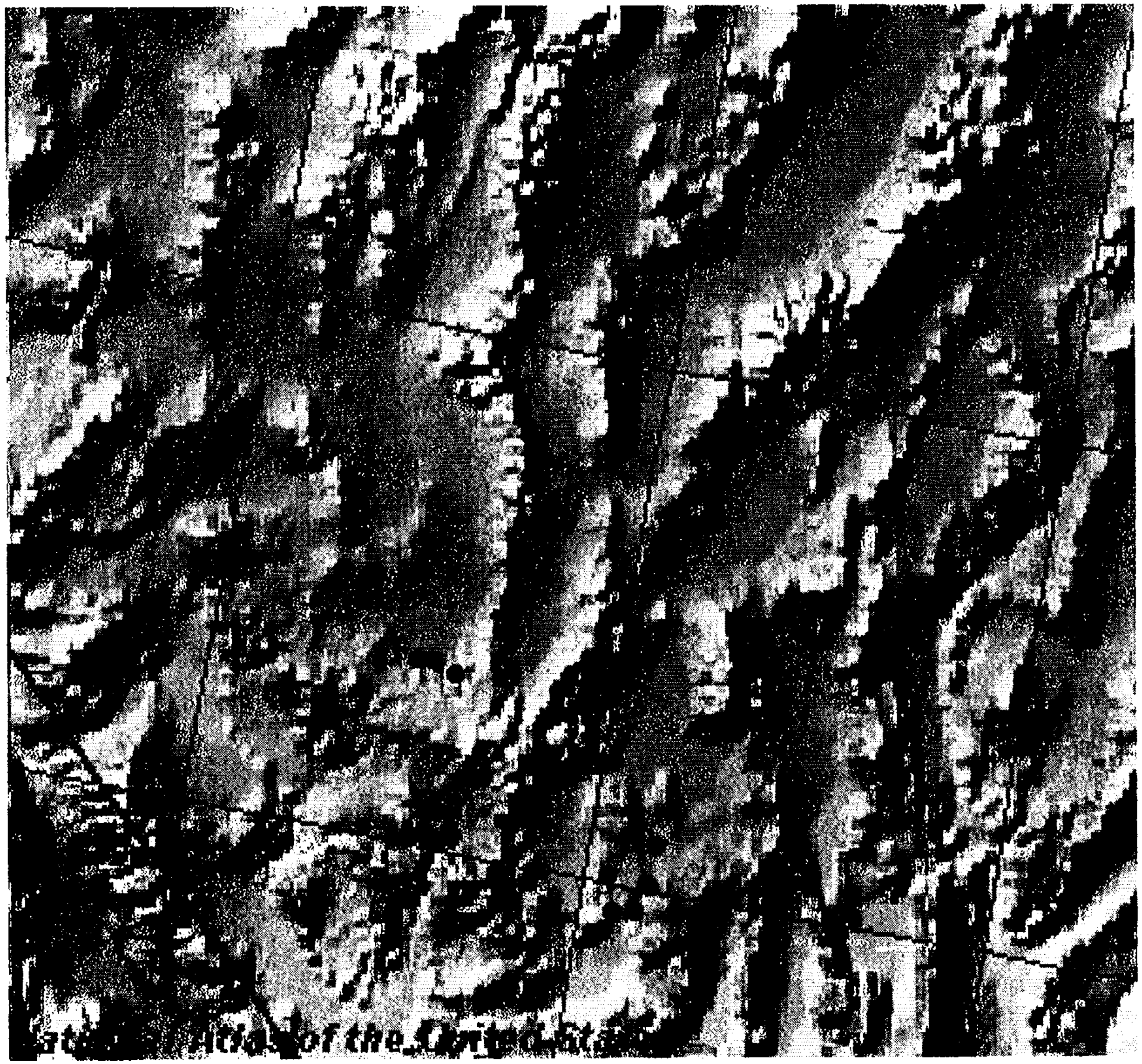


Figure 2. Basaltic volcanism in the CFLC between 9.5 and 6.5 Ma.

6.5-5.5 Ma

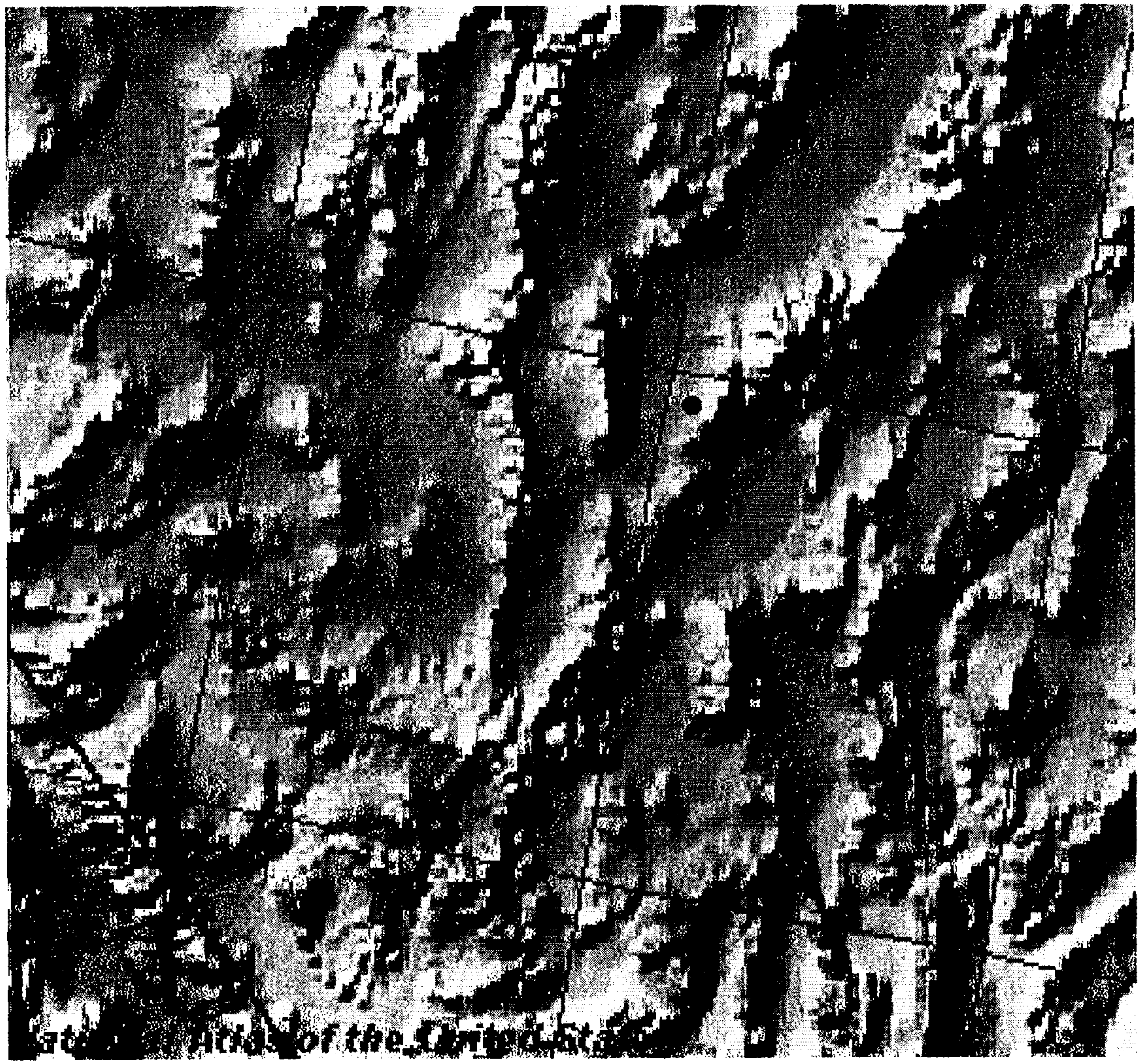


Figure 3. Basaltic volcanism in the CFLC between 6.5 and 5.5 Ma

5.5-4.5 Ma

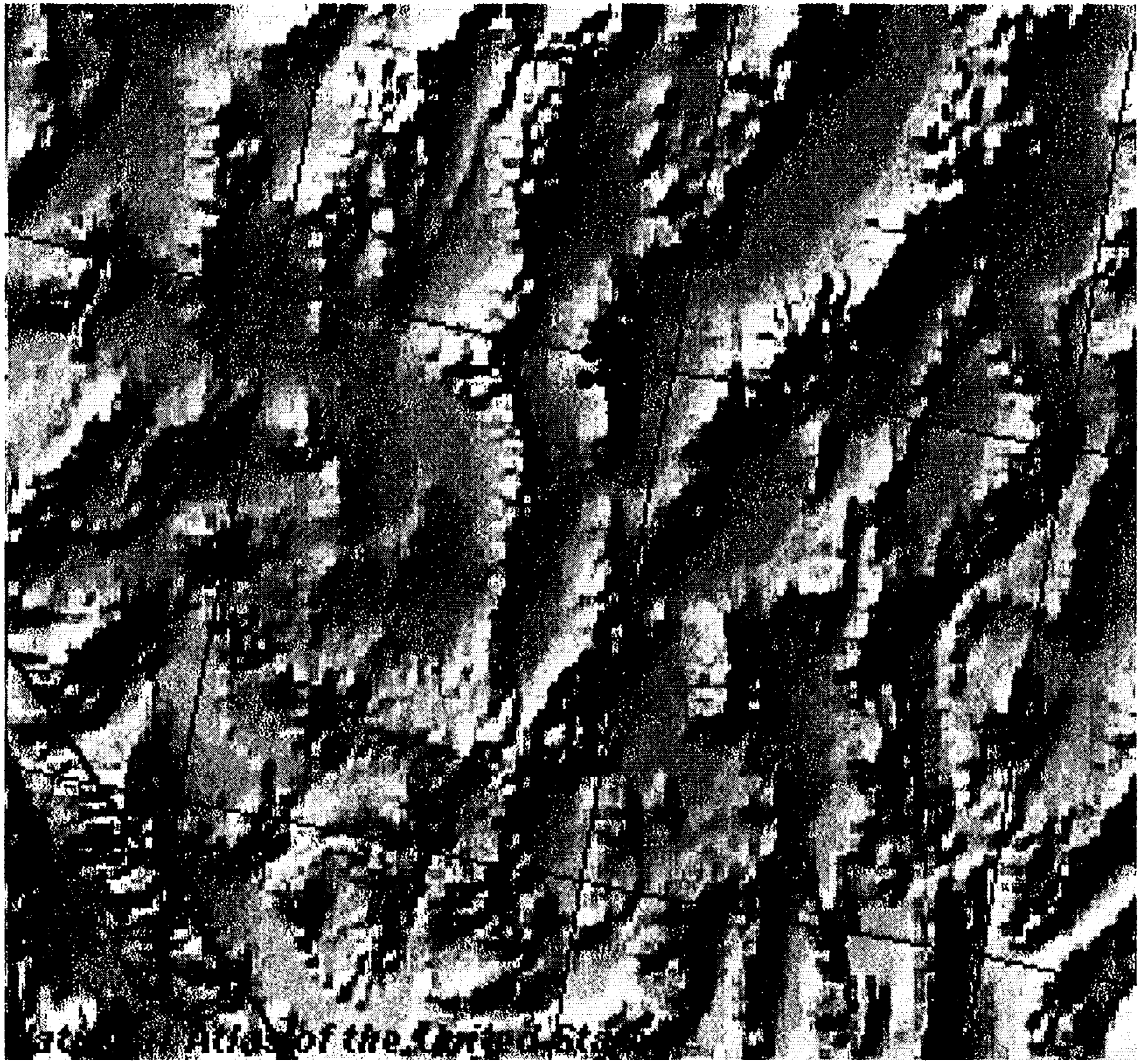


Figure 4. Basaltic volcanism in the CFLC between 5.5 and 4.5 Ma

4.5-3.5 Ma

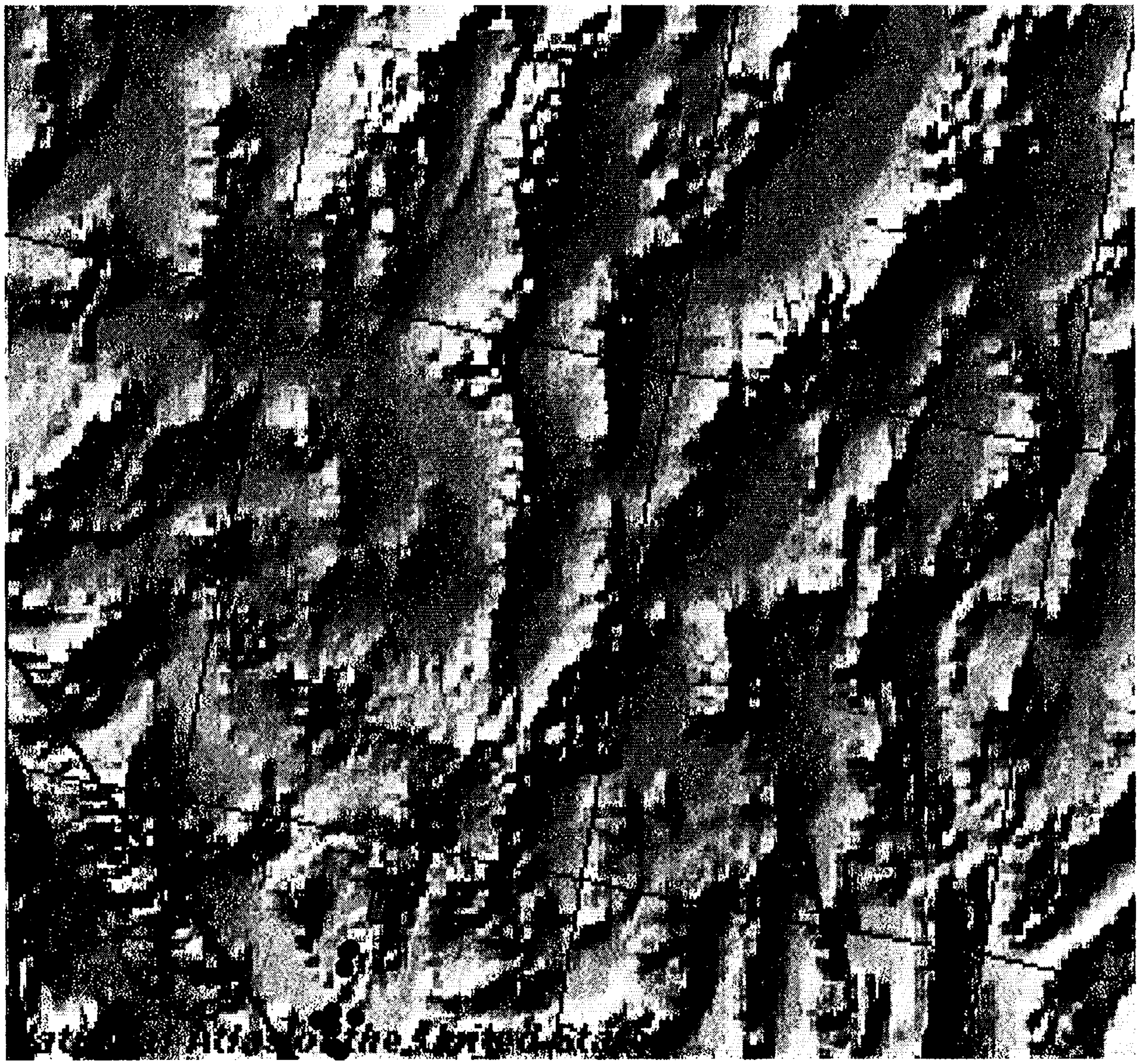


Figure 5. Basaltic volcanism in the CFLC between 4.5 and 3.5 Ma.

3.5-2.5 Ma

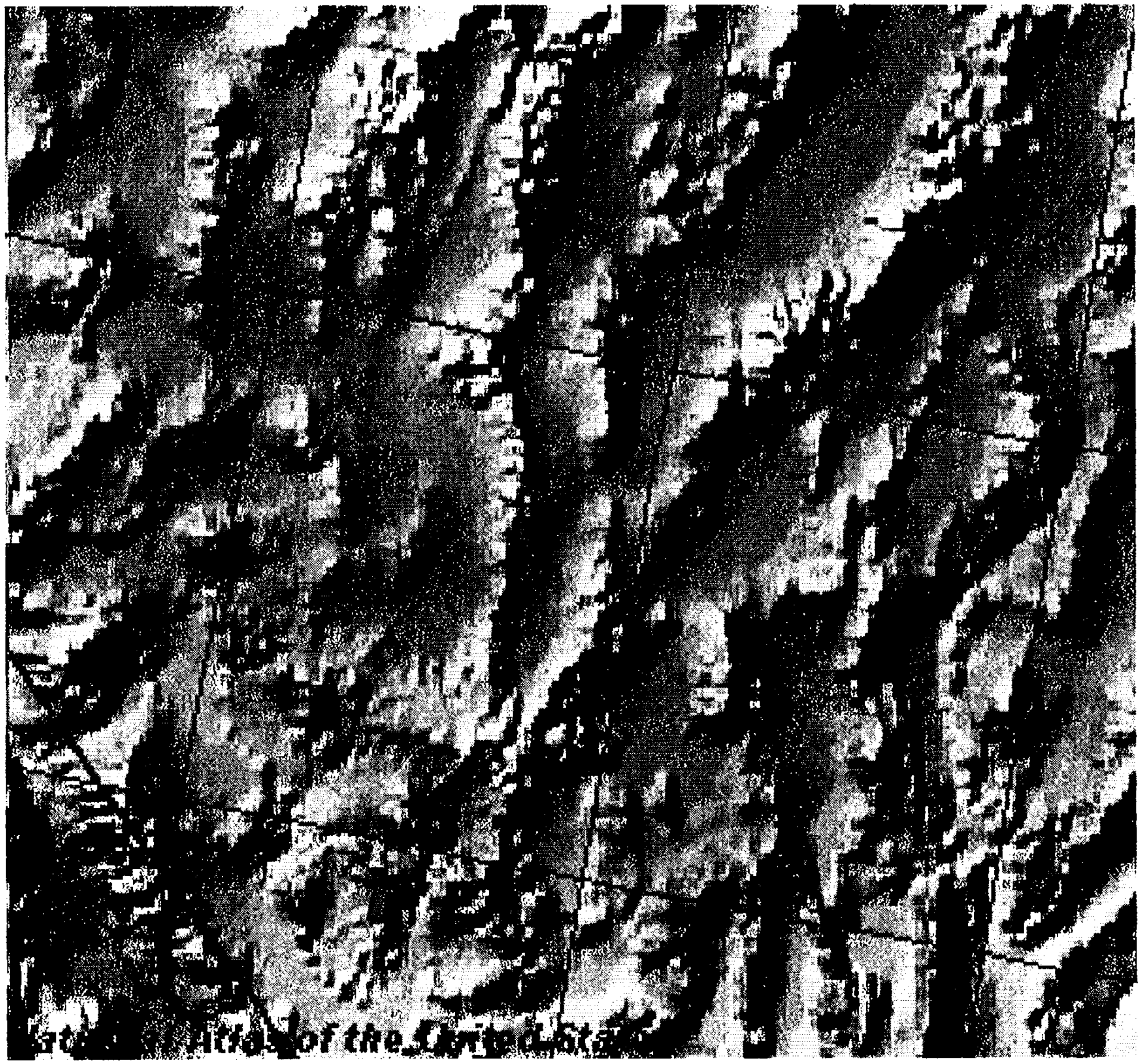


Figure 6. Basaltic volcanism in the CFLC between 3.5 and 2.5 Ma.

2.5-1.5 Ma

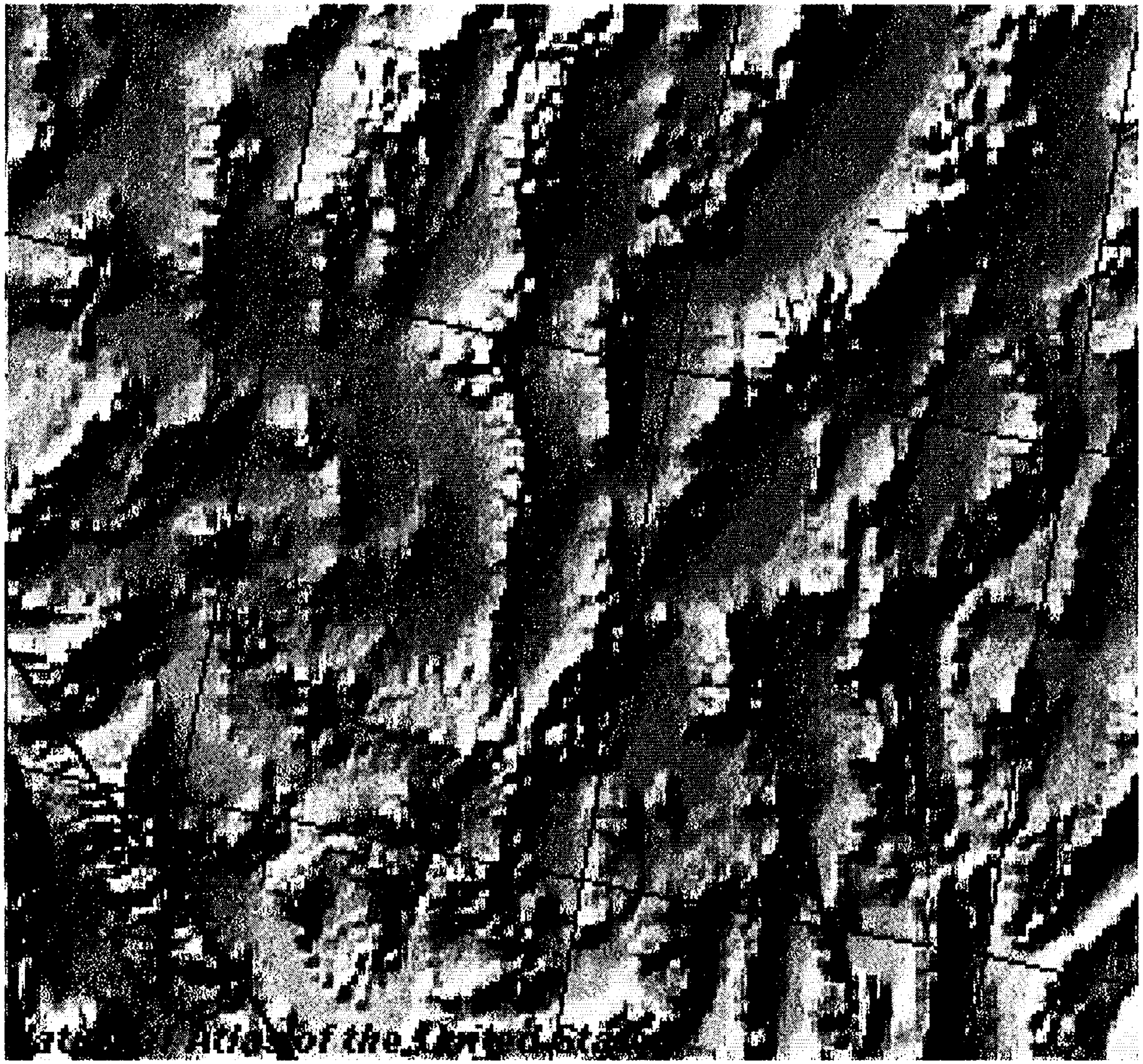


Figure 7. Basaltic volcanism in the CFLC between 2.5 and 1.5 Ma.

1.5-0.5 Ma

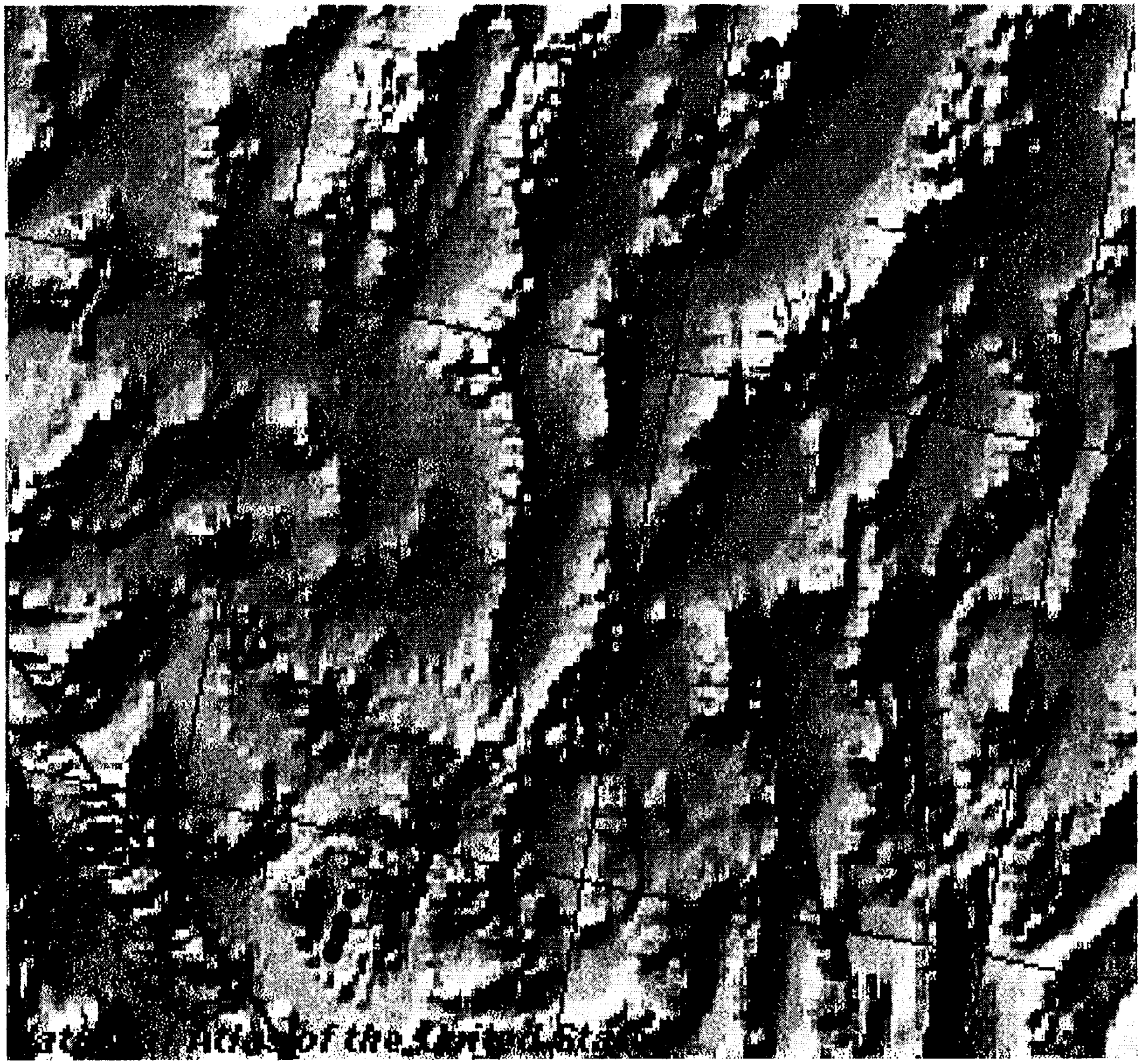


Figure 8. Basaltic volcanism in the CFLC between 1.5 and 0.5 Ma.

0.5-0.02 Ma

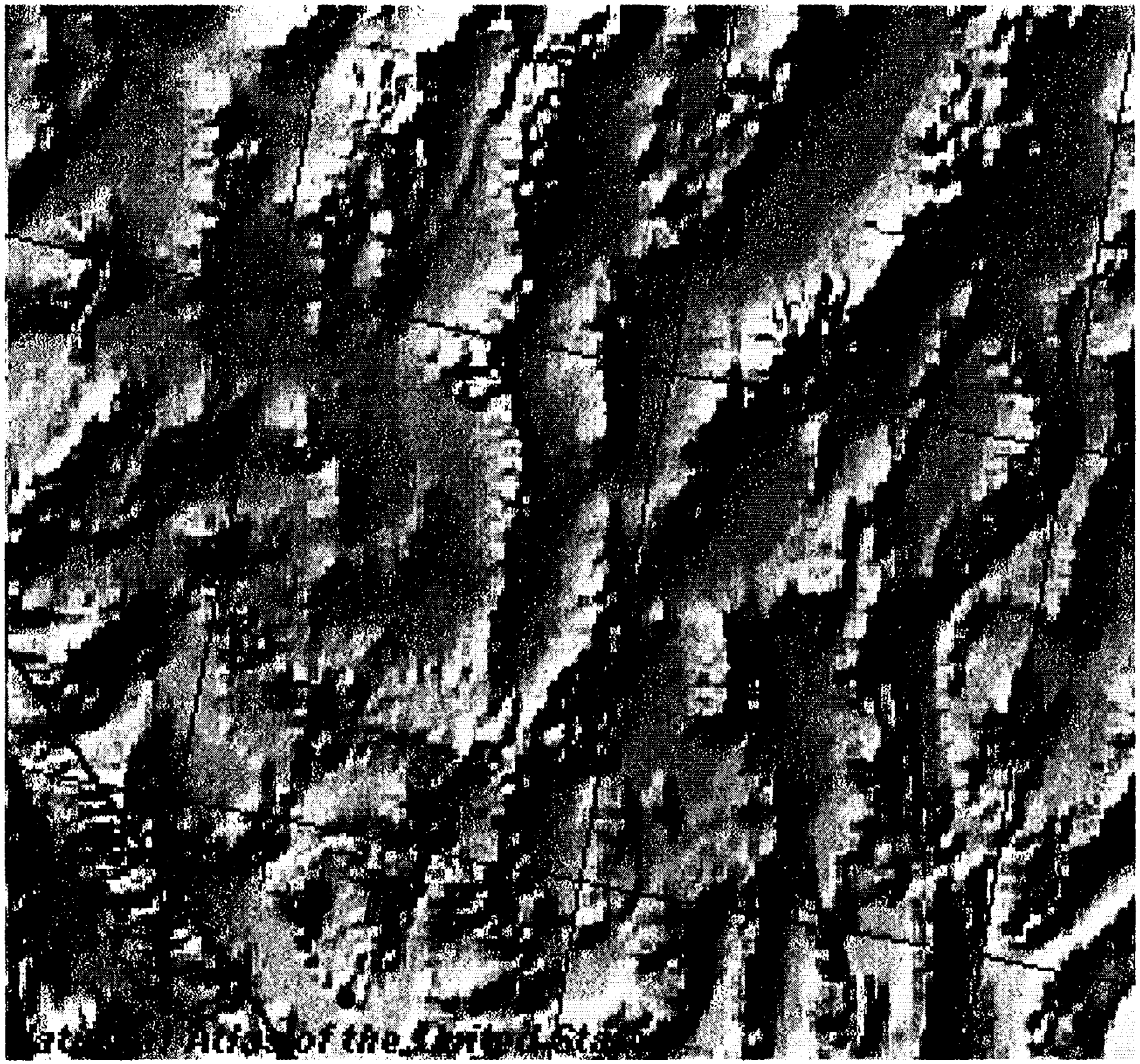


Figure 9. Basaltic volcanism in the CFLC between 0.5 and 0.02 Ma.

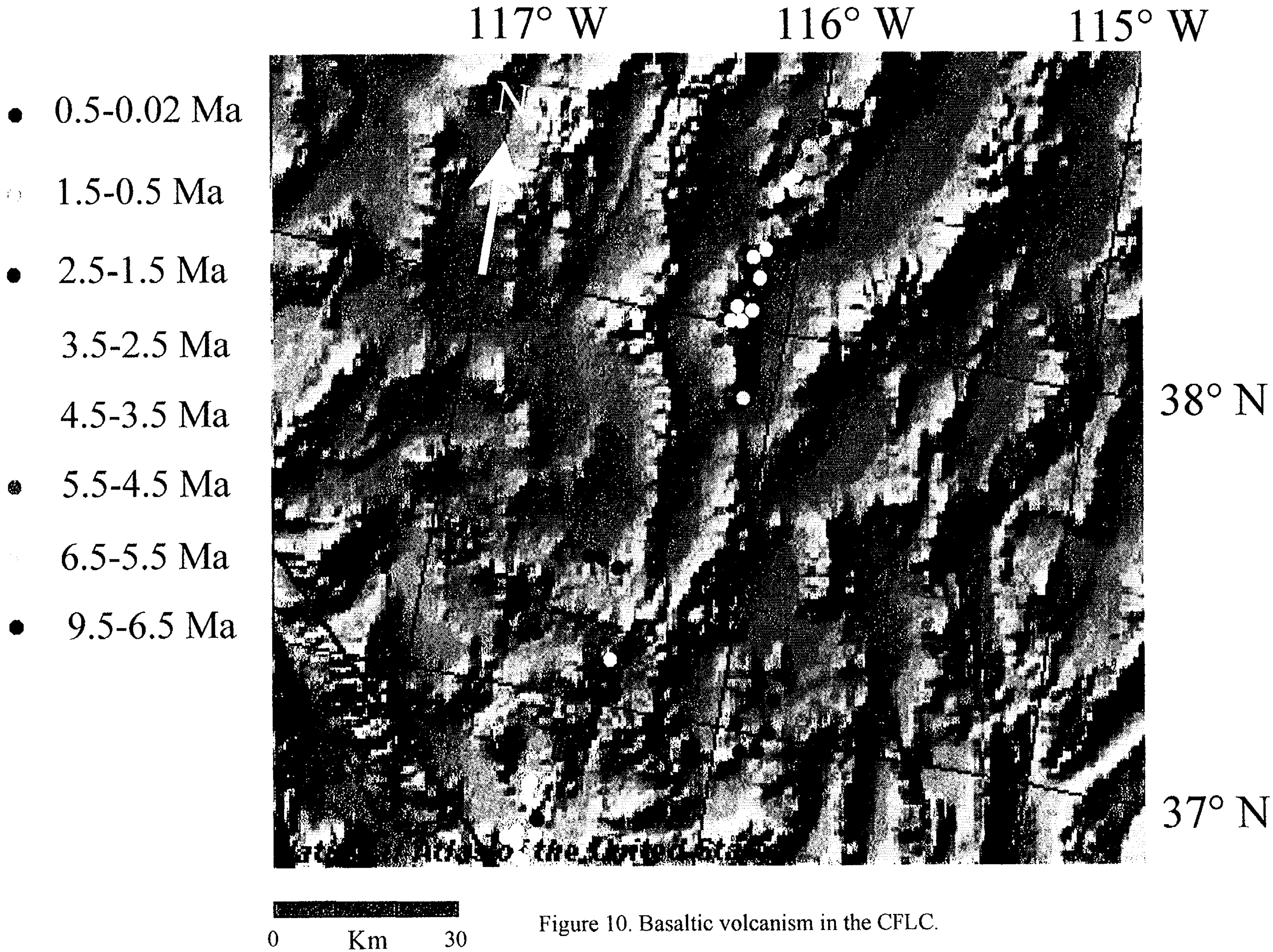
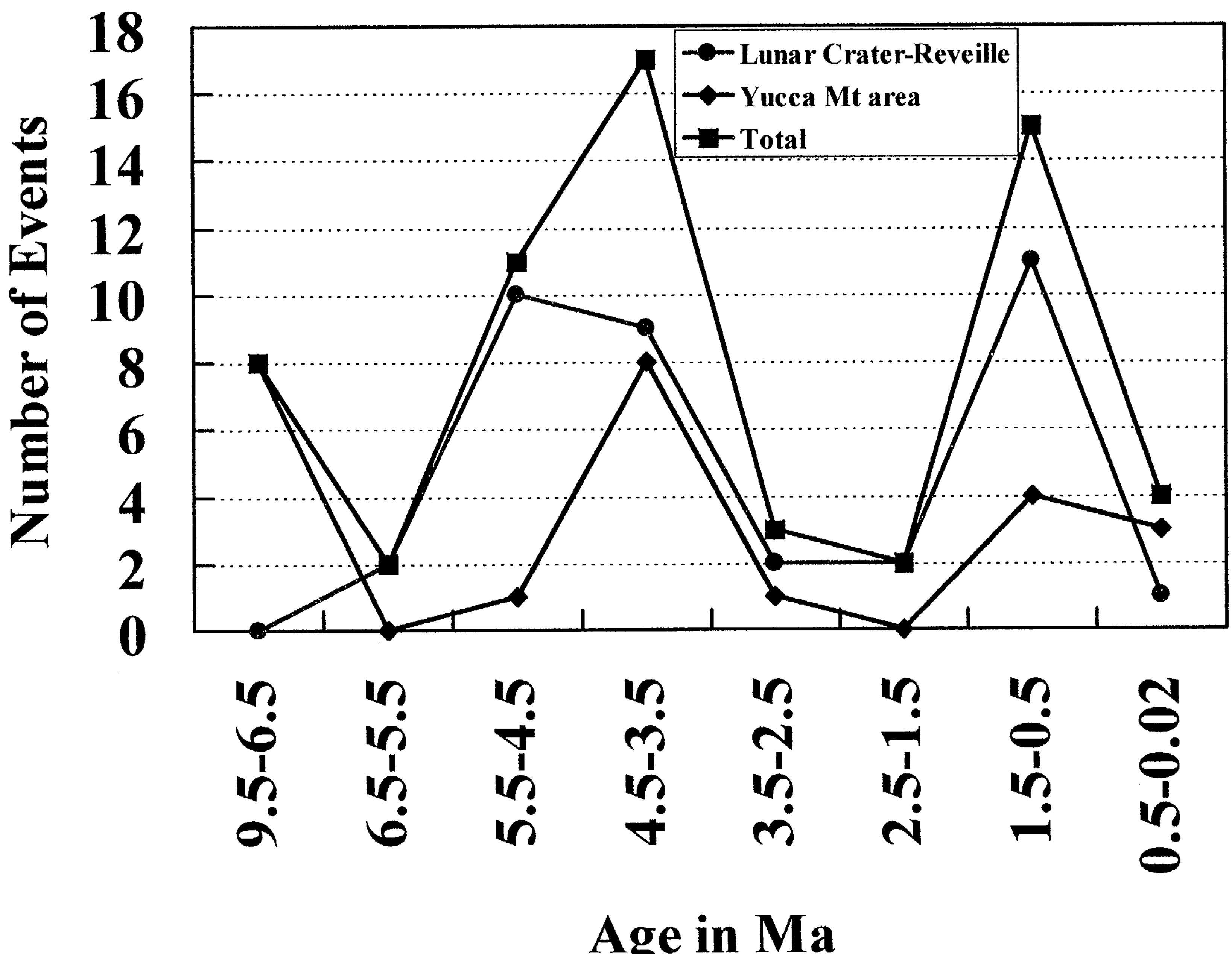


Figure 10. Basaltic volcanism in the CFLC.



Lunar Crater-Reveille
Yucca Mt area
Total
Number of Events
0
2
4
6
8
10
12
14
16
18
9.5-6.5
6.5-5.5
5.5-4.5
4.5-3.5
3.5-2.5
2.5-1.5
1.5-0.5
0.5-0.02
Age in Ma

Patterns of Volcanism

- Volcanism is episodic
- temporal link between volcanism in the Lunar Crater-Crater Flat area

Patterns of Volcanism

- Volcanic fields change shape with time.
- New cinder cones rarely occur at sites of previous events.

Introduction

- Patterns of volcanism
- Control of volcanism
- Implications and Recommendations

Control of Volcanism

- Melting Profiles
- based on a paper:
  - *"A mantle melting profile across the Basin and Range, SW USA"*
  - by Kefa Wang[1], Terry Plank[2], Doug Walker[1] and Eugene Smith[3]
  - [1]University of Kansas, [2]Boston University, [3]UNLV
- In press: Journal of Geophysical Research

Melting Profiles

- Based on 1000 samples; 400 analyzed at UNLV (major and trace elements) and the University of Kansas (Pb, Sr and Nd isotopes).
- All basalts are younger than 8.5 Ma

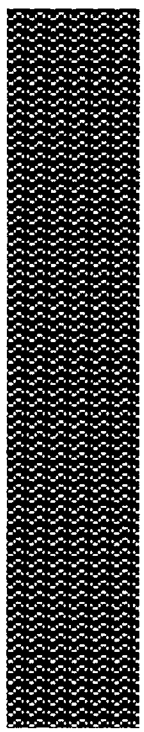
Melting Profiles

- analyses are corrected for crustal differentiation
  - project basalt data in a field to 8 wt % MgO: $Fe_{8.0}$
  - select the most primitive sample from each suite (those with highest MgO).

Melting Profile

- To correct for olivine fractionation above 8% MgO and to extrapolate to primary compositions in equilibrium with mantle olivine (Fo_{89}), an olivine addition method was used.

Melting Profile



Pf- final depth of melting determined by Na_2O is a function of the degree of melting. Na_2O behaves as an incompatible element which is diluted by further increments of melting

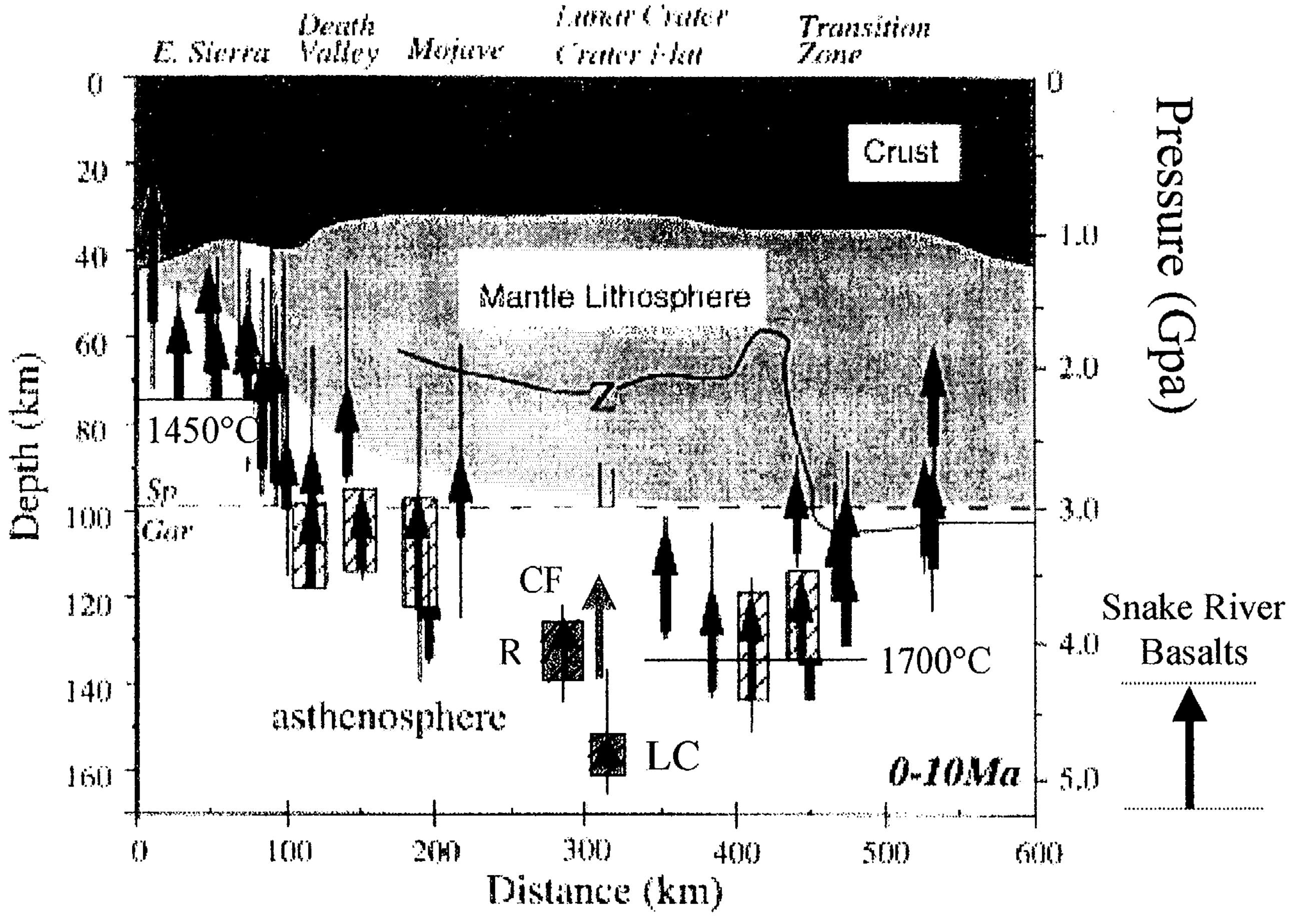
Po-initial depth of melting determined by FeO

Melting Profile

- Use model developed by Langmuir, Klein and Plank (1992) to quantify pressure and the degree of mantle melting
- The model describes compositional changes (FeO, MgO, Na_2O) in mantle melts during adiabatic decompression assuming olivine-melt equilibrium and the trace element behavior for Na

Melting Profile

- Model developed for mid-ocean ridge basalts but is a general model for dry melting of mantle.
- Assume accumulated fractional melting-melt is pooled and extracted after each 0.1 Gpa (1 kb) of pressure release.



Lithosphere thickness from Jones et al. (1996) and Zandt et al. (1995), Crustal thickness compiled from Das and Nolet (1998). Boxes indicate melting columns with average $\varepsilon_{ND} > +0.5$.

Results

- Melting depth increases from the East Sierra area reaching a maximum in the central Great Basin before decreasing gradually toward the Colorado Plateau.
- The top of the melting regime generally follows the mantle lithosphere-asthenosphere boundary.
- Deepest melting columns coincide with the highest ε_{nd}--consistent with deep melting in the asthenosphere (DePaolo and Daley, 2000).

Results

- Hot, deep melting beneath Crater Flat-Lunar Crater.
- Mantle solidus at 135 km is 1700°C, this is about 230°C hotter than the mantle temperature beneath the East Sierras consistent with range calculated between normal MORB and hot spot basalt (Klein and Langmuir, 1987; Anderson, 2000).

Results

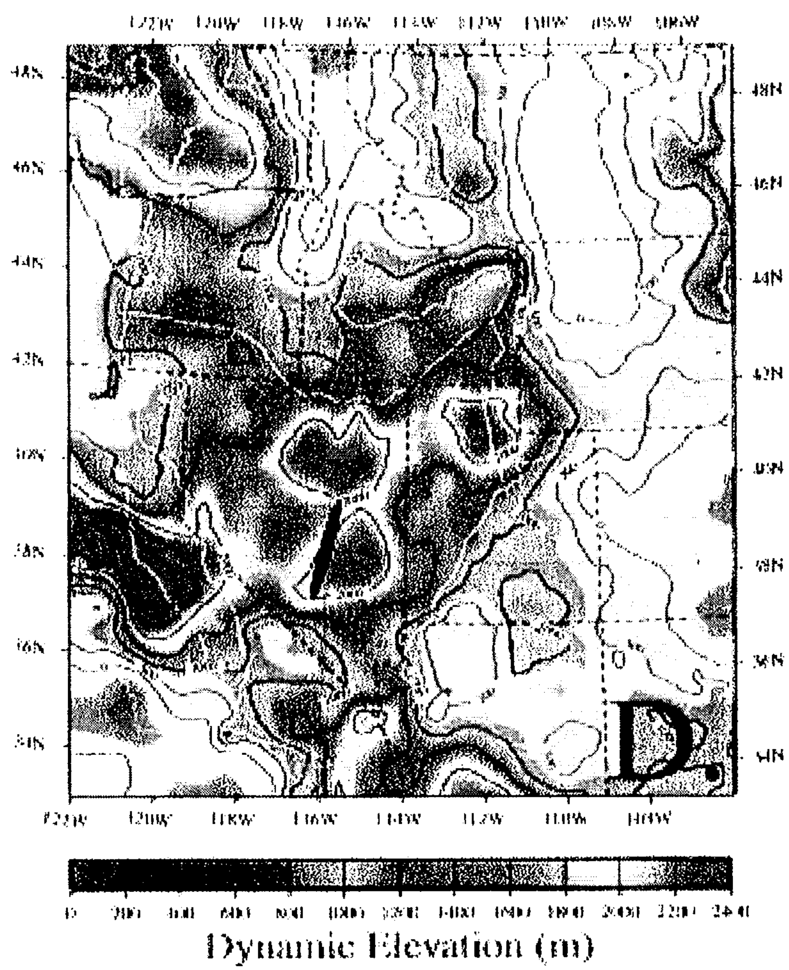
- Hot mantle may be introduced by a mantle plume.
- Independent evidence for active upwelling and/or hot mantle
  - Seismic imaging of Humphreys and Dueker (1994) indicates melting could be as deep as 200 km in the upper mantle.

Results

- The region has lower than average S-velocities at a depth of 300 km which may be expected for hot mantle (van der Lee and Nolet, 1997).
- Savage and Sheehan (2000) noted a pattern of shear wave splitting with a null region surrounded by a semicircular alignment of fast polarizations. This pattern is consistent with active mantle upwelling.

Results

- Lowry et al. (2000) showed that the LC-CR sits on an area with high dynamic elevation consistent with hotter than normal mantle.
- They suggest super-adiabatic upwelling or normal adiabatic ascent of hotter than normal mantle.



Dynamic Elevation Map of the Great Basin and adjacent areas by Lowry et al. (2000).

Results

– Pyroxene compositions in peridotite xenoliths from Lunar Crater have equilibrium temperatures 200°C higher than others from the Western US (Smith et al., 1999).

Summary

- Deep melting beneath the central Basin and Range
- most melting occurs in the asthenosphere
- mantle is about 200°C hotter than normal mantle
- Consistent with a mantle plume

Introduction

- Patterns of volcanism
- Control of volcanism
- Implications and Recommendations

Implications and Recommendations

- Probability models that depend on steady state reoccurrence rates may not adequately describe the volcanic hazard.
- Probability studies should consider the episodic nature of volcanism and the possibility that another flare-up may occur in the near future.

Implications and Recommendations

- Volcanic fields change shape with time; they expand (migrate) or contract. Few new eruptions occur at the sites of previous events. Therefore past patterns may not be an indication of future activity
- Probability models should consider the changing shape of volcanic fields and the observation that past activity may not be a key to future events.

Implications and Recommendations

- Calibrate probability models by "going back in time." Predict future activity based on distribution of volcanoes at a specific time in the past.
- For example: use distribution of volcanoes at 1.5 Ma to predict time and location of future activity.

Implications

- Volcanism at Crater Flat, Reveille and Lunar Crater may be linked (mantle plume, temporal).
- Yucca Mt lies within the Crater Flat-Lunar Crater belt in an area underlain by hot-mantle.
- If plume exists, then another volcanic flare-up is possible.

Recommendations

- Develop probability models that consider the effects of a mantle hot spot (a future flare-up).
- Include volcanoes in Reveille and Lunar Crater areas in volcanic source zone for probability studies.

Delta Analysis for the Igneous Activity Technical Exchange
June 21-22, 2001
Las Vegas, Nevada

Biosphere		
Topic	**NRC Comment**	**DOE Response**
(1) Airborne particle concentrations	Comparison of static versus disturbed conditions. Strengthen relationship between measurements of airborne particle concentrations for static conditions with appropriate levels of surface disturbance associated with the habits and lifestyles of critical group members.	Time-activity budgets based on behaviors of a farmer and dust loads for post-volcanic conditions and farming activities were computed to confirm that the static measurements were appropriate. The use of time-activity budgets will be documented in a subsequent update of the AMR, *Parameter Values for External and Inhalation Radiation Exposure Analysis* (ANL-MGR-MD-000001). Future efforts will include disturbed conditions by defining the time-activity budget of the appropriate receptor and associated particle concentrations.
(2) Airborne particle concentrations	Average annual static concentrations vs. 8-hr workday disturbed conditions. Strengthen relationships between measurements of annual airborne particle concentrations under static conditions, and durations of exposure to disturbed and undisturbed conditions of critical group.	See previous response. In addition, duration of exposure (i.e., inhalation exposure time) was based on assumed behaviors of farmers. Distribution of exposure time to outdoor concentrations ranged from 8.0 to 10.8 hours per day (ANL-MGR-MD-000001, REV 01).
(3) Airborne particle concentrations	Basis for extrapolating TSP concentrations. Clarify relationship used to extrapolate total suspended particulate concentrations (TSP) from PM10 measurements. Strengthen discussion of how TSP can be determined for disturbed conditions based on other PM10 measurements, as surface disturbance will likely increase the proportion of coarser particles (10-100 μm) in the	The ratio of TSP to PM_{10} for post-volcanic conditions was based on a ratio measured during farming activities following the Mount St. Helens eruption (ANL-MGR-MD-000001, REV 01). DOE is re-evaluating the ratios used to determine total suspended particulates and intends to use measured values of total suspended particulates in future calculations

Biosphere		
Topic	**NRC Comment**	**DOE Response**
	breathing zone relative to static entrainment conditions (i.e., gravitationally induced settling of coarse particles may be more significant for static than disturbed conditions).	rather than estimates based on PM_{10} concentration.
(4) Airborne particle concentrations	Evaluate potential changes in airborne particle concentration in response to fluvial and eolian flux through the critical group location. Although transition-period particle concentrations are viewed by the DOE as conservative, the lower parts of that range may not be conservative for the first decades following an eruption due to prompt remobilization effects. This also affects the following item.	The *FY01 Supplemental Science and Performance Analyses: Vol. 2, Performance Analyses.* (TDR-MGR-PA-000001 REV 00, under development) uses a conservative approach to analyze the effects of ash redistribution (See supplemental sensitivity presentation). Analysis conservatisms include (1) Fixing the wind direction toward the critical group, which overestimates the dose due to ashfall by about a factor of 5 versus estimates based on current wind direction data. (2) Using transition-phase BDCFs for all times, which overestimates air mass loading for all but the first decade following eruption and concentrates all radionuclides in the upper 1 cm of soil. (3) Using a soil erosion factor consistent with agricultural land (4) Not accounting for soil buildup due to possible surface redistribution These conservatisms were used to estimate a conditional dose which shows that the dose does not get worse than that in the first year.
(5) Airborne particle concentrations	Additional data are needed to support the assumption that the concentration of resuspended particles returns to background values within 10 years of the cessation of an igneous event. In particular, DOE needs to demonstrate	See previous response.

Biosphere		
Topic	**NRC Comment**	**DOE Response**
	that long-term input of fine particulates through wind and water remobilization would not significantly affect the proposed mass-load reduction factor.	
(5a) TSPAI NRC Comment - DOSE 2.2.2	Additional data are needed to support the assumption that the concentration of resuspended particles returns to background values within 10 years of the cessation of an igneous event. This concern is focused on the sustainability of elevated mass loadings over thicker tephra deposits. Reference: *Input Parameter Values for External and Inhalation Radiation Exposure Analysis* (CRWMS M&O, 2000)	Mt. St. Helens data showed that for this event, the dust settled well before one year had elapsed (ANL-MGR-MD-000001 REV 01). Assuming an increase in settling time of greater than a factor of 10 (to 10 years), 10 years was taken as a reasonable estimate. Data collected under NRC sponsorship at Cerro Negro may help re-evaluate this issue; these data should be available before the end of the fiscal year.
(6) Airborne particle concentrations	DOE needs to demonstrate that processes removing radionuclides from the soil (i.e., decay, erosion, and leaching) do not cause a significant change in the concentration of radionuclides in the soil over the first 10 years following the eruption. The mixing of temporal variability and parameter uncertainty in the development of the mass loading above a tephra deposit will only provide correct results if other time-dependent processes do not result in a significant change in the concentration of radionuclides in the soil during the 10 year period that is averaged.	Credit can only be taken for radionuclide removal mechanisms from the soil if the balance between accretion and depletion has been assessed using assumptions that are conservative from the perspective of annual dose consequences.
(6a) TSPAI NRC Comment - DOSE 2.3.1	The mixing of temporal variability and parameter uncertainty in the development of the mass loading above a tephra deposit is confusing and will only provide correct results if other time-dependent processes do not	Conservative assumptions are included in the DE process model. The BDCFs that were generated eliminated the need for analysis of time dependency. DOE is considering evaluating the relationship

Biosphere		
Topic	**NRC Comment**	**DOE Response**
	result in a significant change in the concentration of radionuclides in the soil over the 10 year period over which the temporal averaging is being performed. Reference: *Input Parameter Values for External and Inhalation Radiation Exposure Analysis* (CRWMS M&O, 2000)	between resuspension and mass loading.
(7) Airborne particle concentrations: thin deposits	DOE needs to support the assumption that the average mass load over the first 10 years following an eruption is directly proportional to the thickness of the deposit. Models currently sample from a log-uniform distribution between the nominal mass load representing a thin deposit and the average mass load for a thick deposit. Although the effects of airborne remobilization have not been evaluated, deposits less than several mm may be removed relatively quickly and thus not influence significantly the average mass load over the 10 years following the eruption. However, once a critical thickness of deposit is reached, a fines-depleted surface layer forms that protects lower levels of the deposit. Subsequent surface disturbance exposes the protected, lower levels of the deposit, which would increase mass load significantly in the form of a step function. Also, redistribution effects may cause initially thin deposits to have an effect on the 10-year average mass load.	The BDCFs generated using the approach discussed in the comment were not used in TSPA-SR to calculate the expected annual dose from an igneous release. Instead, the BDCFs for the transition phase were used. The BDCF distributions for the transition phase represent an exponential time decay of mass loading from a peak in the first year (based on Mt St. Helens) to a level at the natural (pre-eruption) mass loading value. This distribution is higher than that used for the nominal scenario. To address the processes discussed in items 4 and 6a (fluvial and eolian ash/contamination transport), the modeling approach for assessing resuspension to be adopted for LA is under review.
(7a) TSPAI NRC Comment - DOSE 2.3.2	Sampling from a loguniform distribution between the nominal mass load representing a thin deposit and the average mass load for a thick deposit assumes that the	See response to item 7, above.

Biosphere		
Topic	**NRC Comment**	**DOE Response**
	average mass load over the first 10 years following an event is directly proportional to the thickness of the deposit. Reference: *Input Parameter Values for External and Inhalation Radiation Exposure Analysis* (CRWMS M&O, 2000)	
8) External Exposures	Dose pathways for direct release discussed in TSPA-SR (P. 3-206) list inhalation and ingestion, but do not list external exposure from HLW-contaminated ash. In addition, external exposure is not considered for indoor occupants even though the dwelling may be surrounded by HLW-contaminated ash containing high energy gamma emitters.	External exposure was not considered in the eruption phase dose factors, which are described on page 3-206. These dose factors were not used to calculate doses in the TSPA-SR. They were only used in sensitivity studies. BDCFs for the transition phase used in the TSPA-SR analysis for a volcanic eruption included inhalation, ingestion and external exposure. During the volcanic eruption, only the inhalation pathway was considered because for all radionuclides, except ^{137}Cs, external exposure from the ground is insignificant when compared with the inhalation pathway, as can be verified by examining the results of pathway analysis (ANL-MGR-MD-000003 REV 01, Tables 16-20). For the overall external exposure from volcanic eruption, the exposure during the eruption phase (which, on the average, lasts only 8 days) is negligible compared with the exposure during the transition phase (BDCFs for the transition phase were calculated for one-year exposure) because of the relative duration of these phases. In addition, during the transition phase, 100% of the available activity is

Biosphere		
Topic	**NRC Comment**	**DOE Response**
		already deposited on the ground resulting in the highest external exposure, as opposed to the eruption phase when the deposition is in progress. The reason that ingestion was included was based on the assumption that the intake of two thirds of the activity (large particles) is through the ingestion pathway. The recent model considers that the intake of all airborne particles occurs through the inhalation.
(8a) TSPAI NRC Comment DOSE 2.TT.3 TSPAI NRC Comment DIRECT2.TT.1	The dose pathways for direct release scenario are discussed on p. 3-206 in TSPA-SR. Inhalation and ingestion have been considered, but external exposure from contaminated ash on the ground surface was not listed. TSPA-SR should clearly state whether ground surface exposure was considered. TSPA-SR *Total System Performance Assessment for the Site Recommendation* (TDR-WIS-PA-000001, REV. 00, ICN 01)	See response to item 8.
(8b) TSPAI NRC Comment DOSE 3.TT.12	The selected value for soil exposure time is based on the assumption the individual is not exposed when indoors. This is true for many radionuclides due to shielding provided by the house. However, this is not true for high energy gamma emitters (the only radionuclides where direct exposure is significant pathway). This is particularly true for the direct release scenario where the house would be surrounded by deposited ash. Staff were unable to locate the argument for exclusion of this exposure pathway.	The NRC comment is correct. An appropriate shielding factor for external exposure will be included in future analyses. Because external exposure contributes very little to the predicted dose, this change will have little effect on the results of future dose calculations.

Biosphere		
Topic	**NRC Comment**	**DOE Response**
	Reference: CRWMS M&O. 1999. *Input Parameter Values for External and Inhalation Radiation Exposure Analysis*. ACC: MOL19991110.0266.	
(8c) TSPAI NRC Comment DOSE 2.TT.4	No reference was provided on p. 3-210 in TSPA-SR to the basis for the assumption that the total suspended particle is 3 times higher than the mass load. References: TSPA-SR "Total System Performance Assessment for the Site Recommendation" (TDR-WIS-PA-000001, REV. 00, ICN 01) CRWMS M&O. *Input Parameter Values for External and Inhalation Radiation Exposure Analysis* AMR (ANL-MGR-MD-000001, REV 01, ICN 00) Las Vegas, NV. 2000	The assumption is documented in CAL-MGR-MD-000003 REV 00. However, this assumption was not used in the recent version, as explained in Item 8.
9) Effects of climate change on BDCFs	Disruptive Events BDCFs apparently are not affected by climate change, whereas BDCFs for the "nominal case" are affected [by] climate change (DE BDCR AMR)	*Disruptive Event Biosphere Dose Conversion Factor Analysis*. ANL-MGR-MD-000003 REV 01 indicates that inhalation pathway is dominant for the volcanic eruption BDCFs. Climate change was considered for only groundwater release BDCFs in REV.1. Increased precipitation would lead to more rapid stabilization and increased loss from leaching (solubility limited) and thus lead to reduced resuspension of radionuclides. Therefore, in the absence of surface

Biosphere		
Topic	**NRC Comment**	**DOE Response**
		redistribution, climate change will have a negligible effect on the BDCFs for the volcanic eruption exposure scenario. DOE is considering evaluating the potential effects of climate change on redistribution.
(9a) TSPAI NRC Comment DOSE 3.1.1	The AMR does not discuss how the analysis of disruptive event BDCFs would be affected by climate change. Climate change was included in the revised FEP analysis only for the nominal case. Reference: CRWMS M&O. 2000. *Analysis Model Report -- Disruptive Event Biosphere Dose Conversion Factor Analysis*. ANL-MGR-MD-000003 REV 00	*Disruptive Event Biosphere Dose Conversion Factor Analysis*. ANL-MGR-MD-000003 REV 01 indicates that inhalation pathway is dominant for the volcanic eruption BDCFs. Therefore, climate change will have a negligible effect on the BDCFs for the volcanic eruption exposure scenario. Climate change was not considered in the nominal and disruptive scenario in the REV 00 AMRs. It was considered for only nominal case in REV.1. Increased precipitation would lead to more rapid stabilization and increased loss from leaching (solubility limited) and thus lead to reduced resuspension of radionuclides. The above logic applies to BDCFs using the approach adopted for TSPA-SR, i.e., where "global surficial redistribution" of ash is considered in Biosphere and not DE, then increased precipitation could increase fluvial transport of contaminated ash to the location of the critical group.
(10) TSPAI NRC Comment DOSE3.TT.2	More references should be made to other documents that contain related analyses. Irrigation with contaminated ground water is the only deposition process considered in this AMR. The ingestion analyses within this AMR did not include root uptake. Neither deposition from airborne releases or effluents from preclosure operations nor ash	*Identification of Ingestion Exposure Parameters* AMR (ANL-MGR-MD-000006 Revision 00) has a very limited scope. This AMR is one of many AMRs that develop input parameters for the biosphere model implementing code, GENII-S. It does not, in itself document any analyses of radionuclide transport to

Biosphere		
Topic	**NRC Comment**	**DOE Response**
	deposition and remobilization were addressed in this AMR. It would be helpful if the appropriate documents that account for these processes and factors be referenced within this AMR. In addition, it appears that food washing and crop retention fraction after food washing has not been sufficiently discussed in this AMR.	plants. Parameters for the root uptake were developed in another model input AMR, *Transfer Coefficient Analysis*, (ANL-MGR-MD-000008). Input parameters related to retention fraction for various crops are documented in another AMR, *Environmental Transport Analysis*, (ANL-MGR-MD-000007). The model uses many different parameters, which are documented in several input AMRs. Deposition of radionuclides from the preclosure operations is outside the scope of the postclosure analysis. With exception of resuspension of contaminated particles (ANL-MGR-MD000001 Rev 01), the same values for the input parameters were used to generate the BDCFs for the transition and steady state periods and the groundwater release Biosphere PMR (TDR-MGR-MD-000002 Rev 00 ICN 01) explains the relationship between AMRs, and scope of work for each AMR. Food processing (washing, boiling, steaming, etc) which results in the removal of radionuclides from edible parts of crops, was not included in the biosphere model. This approach is conservative. As credit was not taken, the AMR did not discuss the process.

Biosphere		
Topic	**NRC Comment**	**DOE Response**
(11) TSPAI NRC Comment DOSE 2.5.1	DOE has not provided support to justify that the mass loading model does not underestimate the concentration of radionuclides in the air.	Revision 01 of the *Input Parameter Values for External and Inhalation Radiation Exposure Analysis* (ANL-MGR-MD-000001) documents development of the mass loading distributions and provides justification for why it is believed that the selected mass loading values are conservative. The mass loading distribution, which was used to calculate BDCFs for the TSPA-SR, represents the annual average outdoor levels, rather than the instantaneous mass loading values. Such values include both static and dynamic conditions. The maximum values were based primarily on the Mount St. Helens data, and the selected Montserrat and Cerro Negro data for corroboration. The conclusion was that the selected annual average PM_{10} value of 1,000 $\mu g/m^3$ adequately represents the maximum annual average mass loading and that people would modify their behavior to avoid health hazards from exposure to higher levels of PM_{10}. [EPA indicated that severe health effects (not radiological) occur at such PM_{10} levels.] However, this argument may be strengthened if additional information (e.g. Cerro Negro data) becomes available.

Magma-Drift Interactions		
Topic	**NRC Comment**	**DOE Response**
(1) Thermal mechanical	Models that propose stress accumulation due to HLW	Related to FEP 1.1.02.00.00 (Excavation/Construction)

Magma-Drift Interactions		
Topic	**NRC Comment**	**DOE Response**
effects of HLW emplacement	thermal-mechanical effects need to evaluate appropriate strain response on existing or new structures, in addition to spatial and temporal variations in thermal loading.	Changes in stress due to excavation and their possible effects on dike interactions with the drift are addressed in a simplified manner in the *Dike Propagation Near Drifts Analysis/Model Report* (ANL-WIS-MD-000015, Section 6.3.1). This effect is considered in the evaluation of FEP 1.2.04.03.00, *Igneous Intrusion into the Repository* (ANL-WIS-MD-000005), and thus consideration under FEP 1.1.02.00.00 is not needed. Magma flow through drifts to a ventilation shaft and then to the surface is not considered in the current DOE analysis because the DOE model includes blocking of drifts with debris, and because the DOE model features upward continuation of the dike above the point of intersection with the repository.
(2) Magma Ascent and Flow	Evaluate effects of DOE proposed design alternatives on magma ascent and flow processes for the duration of an igneous event.	DOE has examined the effects of certain design alternatives on the probability and consequences of intersection of a dike with the repository (ANL-MGR-GS-000001 and ANL-WIS-MD-000017)
(3) Incomplete Closure of Drifts	Evaluate mechanical strength of debris accumulations or barriers that may occur at ends of intersected drifts, for an appropriate range of physical conditions that occur during an igneous event	DOE analysis documented in the *Dike Propagation Near Drifts Analysis/Model Report* (ANL-WIS-MD-000015) does not assume or rely upon drift seals to contain magma. In the analysis DOE considered that the high energy nature of the system causes the drifts to become plugged or clogged with debris and materials from flowing magma and gases, cooling magma, and repository components.

Magma-Drift Interactions		
Topic	**NRC Comment**	**DOE Response**
(4) Mechanical Degradation or Collapse of Drift	Evaluate how the presence of backfill or rockfall may affect magma flow processes for the duration of the eruption.	Related to FEP 2.1.07.02.00 (Mechanical Degradation or Collapse of Drift). For FEPs screening, any effects of drift collapse can be covered in the screening evaluation for FEP 1.2.04.03.00, "Igneous Intrusion into the Repository." As noted previously, DOE's analysis does not rely on presence of backfilled emplacement drifts. Further, DOE expects drifts to become clogged with debris and materials from flowing magma and gases, cooling magma, and repository components as documented in the AMR *Dike Propagation Near Drifts* (ANL-WIS-MD-0000015).
(5) Conduit localization	Evaluate how the ascent of basaltic magma may be affected by the presence of subsurface repository structures. In particular, evaluate how vertical ascent may localize conduit formation at intersected drifts rather than randomly or in pillars.	See items 1 and 4 of this table.
(6) Volcanic Source Term	Evaluate how the presence of repository drifts may alter magma ascent pathways (e.g., Woods et al, 2001) and potentially entrain more HLW than currently modeled with circular conduit.	See items 1 and 4 of this table.
(7) TSPAI NRC Comment DIRECT1.1.2	While the text was updated to reflect the "backfill" to "no-backfill" design change, the model and analysis were not modified to account for this design change. (CRWMS M&O, *Dike Propagation Near Drifts,* ANL-WIS-MD-000015 REV 00 and REV 00 ICN1)	*Dike Propagation Near Drifts*, ANL-WIS-MD-000015 REV 00 and REV 00 ICN1 does include simplified analyses of processes that are appropriate for no-backfill design, including the development of shock waves and "pyroclastic flows" (mixtures of gas and magma clots or particles) in drifts.

Magma-Waste Package Interactions		
Topic	**NRC Comment**	**DOE Response**
(1) Canister Failure (long term)	Evaluate aging effects on materials strength properties when exposed to basaltic magmatic conditions for duration of event.	The effect of magma on waste packages is considered under FEP 1.2.04.04.00, "Magma Interacts with Waste." Therefore, consideration of FEP 1.1.04.01.00 and FEP 2.1.03.12.00 with respect to igneous intrusion is not needed. The end-cap breach is used because it is the locus for the largest stress and deformation resulting from increased heat and pressure. The end cap weld damage is used as a "surrogate" as a means to estimate the extent of damage. As stated in the igneous consequence modeling Analysis/Model Report (ANL-WIS-MD-000017) in Section 6.2 "Although the mean value can be thought of conceptually as corresponding to a 1-mm-wide crack that propagates for 1 m along a weld, or a 2-mm-wide crack that extends 50 cm, it was not chosen to represent any specific dimensions of a weld failure. Rather, it was chosen as an approximation of the size of opening necessary to permit rapid gas flow and pressure equilibration. Sampling the area of the breach from a distribution that includes much larger hole sizes is intended to account for both uncertainty regarding the nature of the magmatic fluids and the package response and spatial variability in the extent of damage within the drifts."
(2) Canister failure	Evaluate canister response to stress from dynamic	The behavior of waste packages exposed to magmatic

Magma-Waste Package Interactions		
Topic	**NRC Comment**	**DOE Response**
	magmatic repressurization, gravitational loading, and potential differential thermal expansion, using appropriate at-condition strength properties and flow paths, for duration of event. Analyses also need to consider impact and creep failure at elevated temperatures.	conditions was addressed in the calculation, *Waste Package Behavior in Magma* (CAL-EBS-ME-000002). The effect of magma on waste packages is considered under FEP 1.2.04.04.00, Magma Interacts with Waste. End-cap breach is used because the end cap is the locus for the largest stress and deformation resulting from increased heat and pressure. The end cap weld damage is used as a "surrogate" as a means to estimate the extent of damage. The end-cap breach was chosen as an approximation of the size of opening necessary to permit rapid gas flow and pressure equilibration. Sampling the area of the breach from a distribution that includes much larger hole sizes is intended to account for both uncertainty regarding the nature of the magmatic fluids and the package response and spatial variability in the extent of damage within the drifts (ANL-WIS-MD-000017, Section 6.2).
(3) Canister degradation due to degassing	Evaluate Zone 3 canisters, or canisters covered by backfill, response when exposed to magmatic gases at conditions appropriate for a basaltic igneous event.	See item 2 of this table.
(4) Damage to waste packages (remaining	Number of waste packages intersected by magma	DOE has analyzed the number of waste packages intersected by magma in the calculation *Number of*

Magma-Waste Package Interactions		
Topic	**NRC Comment**	**DOE Response**
8/00 agreements)		*Waste Packages Hit* (CAL-WIS-PA-000001). This issue is covered by an existing agreement item related to conduit elongation (KIA0205).
(5) Damage to waste packages (remaining 8/00 agreements)	Thermo-mechanical effects on waste package damage in zones 1 and 2	Damage to waste packages in Zones 1 and 2 has been described in the AMR, *Igneous Consequences Modeling for TSPA-SR* (ANL-WIS-MD-000017) Relative contributions from Zones 1 and 2 are covered by agreement KIA0210. See items 1 and 2 of this table.
(6) Damage to waste packages (remaining 8/00 agreements)	Relative contributions to dose from releases in zones 1 and 2	Agreement item KIA0210. The results of current models will be discussed at the technical exchange. Supplemental sensitivity studies have shown that Zone 1 releases are the major contributors to the igneous groundwater dose (*FY01 Supplemental Science and Performance Analyses: Vol. 2, Performance Analyses.* TDR-MGR-PA-000001 REV 00). (See presentation on supplemental sensitivity analyses).
(7) System description and model integration are adequate TSPAI NRC Comment DIRECT1.1.1	DOE has not yet assembled the information relating to the potential for volcanic disruption of the waste package needed for a potential license application, and DOE does not yet have a reasonable approach to do so by the time of license application. Available information shows that variations in the amount of HLW disrupted during extrusive and intrusive igneous events can affect significantly the probability-weighted doses to the proposed critical group. (CRWMS M&O, *Dike Propagation Near Drifts,* ANL-WIS-MD-000015 REV	As noted in the comment, DOE has analyzed the potential for volcanic disruption of the potential repository (ANL-WIS-MD-000015 REV 00 ICN1 and ANL-WIS-MD-000017 REV 00 ICN1). DOE recognizes that additional information relative to the state of the science of volcanism for Yucca Mountain is now available. DOE acknowledges that additional work to evaluate the new consequence models may be warranted and desirable to support any potential license application but requires further study of NRC's

Magma-Waste Package Interactions		
Topic	**NRC Comment**	**DOE Response**
	00 ICN1, CRWMS M&O, *Igneous Consequence Modeling for the TSPA-SR,* ANL-WIS-MD-000017 REV 00 ICN1)	consequence models before defining that additional work.
(7a) TSPAI NRC Comment ENG2.2.2	Insufficient data are available to evaluate the extent of damage to proposed waste packages during potential igneous events.	DOE has analyzed the extent of damage to waste packages in the definition of damage zones in the AMR, *Igneous Consequences Modeling for TSPA-SR* (ANL-WIS-MD-000017). DOE recognizes that additional information relative to the state of the science of volcanism for Yucca Mountain is now available. DOE acknowledges that additional work to evaluate the new consequence models may be warranted and desirable to support any potential license application but requires further study of NRC's consequence models before defining that additional work.
(7b) TSPAI NRC Comment ENG2.1.2	Insufficient information is available to evaluate the extent of damage to proposed waste packages during potential intrusive igneous events. The analyses for limited waste-package damage in Zone 2 do not consider physical conditions representative of likely igneous events and do not evaluate the range of physical processes likely to affect waste package response during potential igneous events.	DOE has evaluated the range of physical processes it considers likely to affect waste package response during potential igneous events (CAL-WIS-PA-000002, ANL-WIS-MD-000015, ANL-WI-MD-000017). These analyses were based on information that was considered appropriate at the time. DOE recognizes that additional information relative to the state of the science of volcanism for Yucca Mountain is now available.

Magma-Waste Form Interactions		
Topic	**NRC Comment**	**DOE Response**
(1) Magma Interacts w/	Evaluate the physical and chemical response of HLW	In the eruptive scenario, no credit is taken for

Magma-Waste Form Interactions		
Topic	**NRC Comment**	**DOE Response**
Waste	and cladding after heating and potential disruption of WP and contents, for WP remaining in drifts. In particular, evaluate effects that may result in increased solubility potential relative to undisturbed HLW forms.	cladding. For groundwater release scenario, analyses of the waste response to magmatic conditions was based on defining damage to waste packages in zones 1 and 2. Damage in zone 2 further assumed very conservative conditions for the in-package environment that was used to model the waste made available for groundwater transport.
(2) TSPAI NRC Comment DIRECT2.2.1	The TSPA model abstraction for incorporation of waste particles into erupting magma makes use of unsupported assumptions related to the size distribution of particles. CRWMS M&O. *Total System Performance Assessment for the Site Recommendation*. TDR-WIS-PA-00001 REV 00 ICN 01. Las Vegas, NV 2000.	TSPA-SR REV 00, ICN 01 used a log-triangular distribution of particle sizes with a minimum diameter of 0.0001 cm, a mode of 0.002 cm, and a maximum of 0.05 cm. The AMR, *Igneous Consequences Modeling for TSPA-SR* (ANL-WIS-MD-000017, Section 5.3.5) provides the basis for the assumptions of the range of particle sizes, and notes that the glass waste form than comprises most of the waste is likely to have particle sizes similar to those of erupting ash. Supplemental sensitivity analyses (*FY01 Supplemental Science and Performance Analyses: Vol. 2, Performance Analyses,* TDR-MGR-PA-000001 REV 00, under development), which will be discussed during the technical exchange, have shown that calculated probability-weighted mean annual doses are relatively insensitive to uncertainties in waste particle size within the range analyzed.

Miscellaneous Items		
Topic	**NRC Comment**	**DOE Response**

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Topic	**NRC Comment**	**DOE Response**
(1) Remobilization of waste	Develop a technical basis to support conclusions that the effects of eolian and fluvial remobilization are bounded by conservative modeling assumptions in the TSPA-SR REV 0 ICN 01. Demonstrate how more realistic models that account for: i) rate of mobilization off slopes ii) rate of transport in Fortymile Wash drainages iii) rate of transport from eolian processes iv) deposition rate at proposed critical group location v) changes in particle-size distributions during fluvial transport would not lead to higher calculations of risk.	The *FY01 Supplemental Science and Performance Analyses: Volume 2, Performance Analyses* (TDR-MGR-PA-000001 REV 00, under development) uses a conservative approach to analyze the effects of ash redistribution (See supplemental sensitivity presentation). Analytical conservatisms include (1) Fixing the wind direction toward the critical group, which overestimates the dose due to ashfall by about a factor of 5 versus estimates based on current wind direction data. (2) Using transition-phase BDCFs for all times, which overestimates air mass loading for all but the first decade following eruption and concentrates all radionuclides in the upper 1 cm of soil. (3) Using a soil erosion factor consistent with agricultural land (4) Not accounting for soil buildup due to possible surface redistribution These conservatisms were used to estimate a conditional dose, which shows that the dose does not get worse than that in the first year.
(2) Aeromagnetic data	Develop technical basis to determine location and age of buried basaltic features, Provide forward model of aeromagnetic data to demonstrate that additional basaltic features are not present but undetected in magnetically "noisy" areas within about 30 km of the proposed repository site.	DOE provided the results of the initial evaluation of the aeromagnetic data to the NRC during the Structural Deformation and Seismicity Technical Exchange in October 2000. DOE is continuing to evaluate the information. Related to agreement item KIA0102.
(3) ASHPLUME: Wind velocity	Discuss incorporation of new wind velocity data into the DOE TSPA model. Discuss method used to average wind	New wind velocity information has been incorporated in sensitivity analyses as described in SSPA Vol 1 and

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Topic	**NRC Comment**	**DOE Response**
	velocity in TSPA models (i.e., account for time laterally advecting in plume).	2. Results of the sensitivity studies indicate that use of the Desert Rock data increases the probability-weighted mean annual dose by about a factor of 2. Related to agreement item KIA0209.
(4) ASHPLUME: Incorporation ratio	Develop an independent technical basis for the method of waste incorporation used in DOE models.	Results reported in TSPA-SR REV 00, ICN 01, Section 5.2.9.11 indicate that the TSPA is relatively insensitive to variations in incorporation ratio. TSPA results are relatively insensitive to uncertainties in this parameter because most waste particles are being incorporated in the eruption using the base case value, and even with the smaller ratio, only the largest waste particles are too small to be incorporated. Related to agreement items KIA0201 and KIA0202
(5) Model Validation	Develop methodology to validate models of basaltic igneous processes in the TSPA. Of particular concern are the models that account for interactions between magma and engineered systems, which lack apparent natural analogs.	The basis for DOE's model of interactions between magma and engineered systems are documented in the *Disruptive Events PMR* (TDR-NBS-MD-000002), and 3 supporting AMRs (ANL-WIS-MD-000015, ANL-WIS-MD-000017, ANL-MGR-GS-000002) and one calculation (CAL-WIS-PA-000001).
(6) Model Uncertainties	Develop methodology to evaluate the uncertainty associated with models of basaltic igneous processes in the TSPA. Demonstrate that uncertainties arising from model validation (item 5) are incorporated into the TSPA results.	Uncertainties in the relative contributions to calculated dose will be described in the discussion of supplemental sensitivity analyses, which include discussions of modifications to the cumulative distribution functions for the number of waste packages damaged by intrusion and the effects of those recalculations. (*FY01 Supplemental Science and Performance Analyses: Volume 2, Performance Analyses,* TDR-MGR-PA-000001 REV00, under

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Topic	**NRC Comment**	**DOE Response**
		development)`
(7) Alternative Conceptual Models	Develop methodology to evaluate the risk significance of alternative conceptual models, such as models presented in Woods et al (2001). Include an evaluation of the cumulative effects of multiple alternative conceptual models	DOE documented its analysis of alternative conceptual models of dike-drift interactions in the AMR, *Dike Propagation Near Drifts* (ANL-WIS-MD-000015, REV 00, ICN 01). DOE recognizes that additional information related to the state of the science of volcanism at Yucca Mountain is now available. DOE acknowledges that additional work to evaluate the new consequence models may be warranted and desirable to support any potential license application but requires further study of NRC's consequence models before defining that additional work.
(8) FEP NRC Comment 75 Excavation/ Construction Incomplete/Closure Canister Failure (long term) Mechanical Degradation or Collapse of Drift	A number of FEPs that could potentially influence the evolution of an igneous event intersecting the repository have not been identified as being relevant for disruptive events. These include: FEP 1.1.02.00.00 (Excavation/Construction) - changes to the rock around the repository due to excavation and construction could affect dike/repository interactions and influence how a dike behaves near the surface. Additionally, repository features such as ventilation shafts could provide a path to the surface that would bypass the repository. FEP 1.1.04.01.00 (Incomplete Closure) - if the design of the repository includes a seal at the end of the drifts	FEP 1.1.02.00.00 (Excavation/Construction) – It is not clear which specific rock changes due to excavation and construction with which the NRC is concerned. Changes in stress due to excavation and their possible effects on dike interactions with the drift are addressed in the *Dike Propagation Near Drifts* Analysis/Model Report (ANL-WIS-MD-000015, Section 6.3.1). This effect is considered in the evaluation of FEP 1.2.04.03.00, Igneous Intrusion into the Repository, and thus consideration under FEP 1.1.02.00.00 is not needed. Magma flow through drifts to a ventilation shaft and then to the surface is not considered in the current DOE analysis because the DOE model includes blocking of drifts with debris, and because the DOE model features upward continuation of the

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Topic	**NRC Comment**	**DOE Response**
Topography & Morphology	strong enough to contain magma which is relied upon for performance calculations, failure to complete these seals could significantly affect repository performance. FEP 2.1.03.12.00 (Canister Failure (Long-Term)) - for intrusive volcanism, credit is taken for the waste packages remaining mostly intact other than an end cap breach following magma interactions. The only waste package failure mechanism that is investigated to take this credit is internal gas pressure buildup. Other waste package failure mechanisms such as differential expansion of the inner and outer waste packages and phase changes in the Alloy 22 due to the long term exposure to elevated temperatures are not considered. FEP 2.1.07.02.00 (Mechanical Degradation or Collapse of Drift) - could affect magma-repository interactions and affect the dose as a result of an igneous event. FEP 2.3.01.00.00 (Topography and Morphology) - the topography may affect dike propagation near the surface and dike propagation probably should be discussed under this FEP.	dike above the point of intersection with the repository. FEP 1.1.04.01.00 (Incomplete Closure) – The DOE analysis documented in the *Dike Propagation Near Drifts* Analysis/Model Report (ANL-WIS-MD-000015) does not assume or rely upon drift seals to contain magma. Rather, the high energy nature of the system causes the drifts to become plugged or clogged with debris and materials from pyroclastic flows, cooling magma, and repository components. Therefore, consideration of FEP 1.1.04.01.00 with respect to igneous intrusion is not needed. FEP 2.1.03.12.00 Canister Failure (Long-Term) –The effect of magma on waste packages is considered under FEP 1.2.04.04.00, "Magma Interacts with Waste." Therefore, consideration of FEP 1.1.04.01.00 with respect to igneous intrusion is not needed. The end-cap breach is used because it is the locus for the largest stress and deformation resulting from increased heat and pressure. The end cap weld damage is used as a "surrogate" as a means to estimate the extent of damage. As stated in the igneous consequence modeling Analysis/Model Report in Section 6.2 (ANL-WIS-MD-000017). "Although the mean value can be thought of

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		conceptually as corresponding to a 1-mm-wide crack that propagates for 1 m along a weld, or a 2-mm-wide crack that extends 50 cm, it was not chosen to represent any specific dimensions of a weld failure. Rather, it was chosen as an approximation of the size of opening necessary to permit rapid gas flow and pressure equilibration. Sampling the area of the breach from a distribution that includes much larger hole sizes is intended to account for both uncertainty regarding the nature of the magmatic fluids and the package response and spatial variability in the extent of damage within the drifts." DOE has evaluated this issue under the FEPs "Igneous Intrusion Into the Repository" or "Magma Interacts with Waste. Consideration under FEP 2.1.03.12.00 is not needed. FEP 2.1.07.02.00 (Mechanical Degradation or Collapse of Drift) - To address this comment, DOE needs to know by what process the NRC believes collapse of the drift will increase dose determined for igneous disruption of a repository. Any effects of drift collapse can be covered in the screening evaluation for FEP 1.2.04.03.00, "Igneous Intrusion into the Repository." FEP 2.3.01.00.00 (Topography and Morphology) - To address this comment, the DOE needs to know in what

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Topic	**NRC Comment**	**DOE Response**
		manner the NRC believes topography will affect dike propagation. Any effects can be covered in the screening evaluation for the FEP 1.0.04.06.00, "Basaltic Cinder Cone Erupts Through the Repository."
(9) FEP NRC Comment 76 Hydrothermal activity	Detailed processes related to the interaction of the ascending dike with the repository drift are not described as FEPs. Instead, the FEP database includes only general categories like "Magma interacts with waste" and "Igneous Activity". This very high level treatment of the igneous FEPs likely has caused the DOE to miss many of the FEPs that are relevant to repository/dike interactions and interactions between magma and waste packages and fuel, particularly for Type 2 waste package failures (waste packages that fail, but whose contents are not removed by the event) and the determination of the number of waste packages affected. FEPs related to magma/repository interactions that are not included in the FEP database include: mechanical and fluid dynamics at the dike tip; fragmentation; vesiculation; plume dynamics; effect of drip shield on magma/repository interactions; geologic factors; threshold flow characteristics; gas segregation; alternate models of vent formation; effects of air shafts and drifts; consideration of flow segregation; localization of magma; recirculation of magma; and evolution of flow conditions. Canister/magma interactions that appear to have been missed include hoop stress due to differential expansion of the inner and outer waste packages; melting of	The issues identified in the NRC's comment do not require definition of new features, events and processes. The processes listed are already included in existing features, events and processes. For example, Secondary features, events and processes that have been evaluated in conjunction with the Primary feature, event and process "Magma Interacts with Waste" (1.2.04.04.00) include: Magma volatiles attack waste (1.2.04.04.01) Dissolution of spent fuel in magma (1.2.04.04.02) Dissolution of other waste in magma (1.2.04.04.03) Heating of waste container by magma (without contact) (1.2.04.04.04) Failure of waste container by direct contact with magma (1.2.04.04.05) Fragmentation (1.2.04.04.06). Screening evaluation of these features, events and processes is based on simplified analyses. The DOE's approach has been to combine its simplified analyses with reasonable assumptions to appropriately abstract

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Topic	**NRC Comment**	**DOE Response**
	materials; thermal shock; and phase changes in the Alloy 22 due to the long-term exposure to elevated temperatures. Fuel/magma interactions that may have been missed could include: cladding burning at high temperatures in the presence of air; cladding/fuel chemical reactions causing damage to the fuel form (no credit is taken for cladding); dissolution of fuel in magma; mechanical shear; oxidation (during and post-eruption); reworking of spent fuel in conduit; and evolution of flow conditions.	the consequences of dike/drift interactions for inclusion in the Total System Performance Assessment. This approach is documented in the following Analysis/Model Reports, which have been provided to the NRC: *Dike Propagation Near Drifts* (ANL-WIS-MD-000015), *Igneous Consequence Modeling for TSPA-SR* (ANL-WIS-MD-000017), *Number of Waste Packages Hit by Igneous Intrusion* (CAL-WIS-PA-000001). The DOE does not attempt to model in detail the complicated interactions between an ascending dike and a waste emplacement drift containing waste packages and other engineered barrier system components. Rather, the DOE assumes that waste packages within and near an intersecting dike are damaged such that they provide no further protection. Beyond the immediate vicinity of the intersecting dike, magma processes, such as those identified by the NRC, are assumed to damage all waste packages in an intersected drift, although not to the extent that they provide no further protection. Damage to end-cap welds is used as a surrogate for all types of waste package damage. Damage is characterized by a distribution of induced crack apertures ranging up to the size of an end-cap (ANL-WIS-MD-000017, Section 6.2). In this way DOE has reasonably taken

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		into account dike/drift interactions.
(10) FEP NRC Comment 80 Radionuclide Accumulation in Soil	FEP 2.3.02.02.00 (Radionuclide Accumulation in Soil) is included for irrigation deposition only. However, this screening argument is too limited since it excludes transport of volcanic ash from other areas to the critical group location. DOE has indicated that redistribution will be accounted for by conservatively assuming that the wind is blowing towards the critical group location and maintaining a high mass load in years following the event. DOE has not provided a demonstration that these conservatisms actually bound the effects of redistribution. Similar comment applies to the following FEPS: **FEP 2.3.02.03.00** (Soil and Sediment Transport) Claims that 100% south-blowing wind direction assumption accounts for aeolian and fluvial transport processes. **FEP 2.3.13.02.00** (Biosphere Transport) Excludes transport in surface water. **FEP 2.3.11.02.00** (Surface Runoff and Flooding) Excludes transport in surface water (?). **FEP 2.3.01.00.00** (Topography and Morphology) Does not consider how it effects redistribution of radionuclides following an igneous event.	DOE has agreed to revisit the issue of surface-redistribution of contaminated ash and soil as part of the resolution of agreement item for Igneous Activity Agreement KIA0206. Specifically, DOE has agreed to develop a linkage between soil removal rate and surface remobilization processes characteristics of the Yucca Mountain region and to document its approach to include uncertainty related to surface-redistribution processes in *Total System Performance Assessment-Site Recommendation* (TDR-WIS-PA-000001 REV 00 ICN 01). Section 14.3.6.7 of *FY01 Supplemental Science and Performance Analyses, Volume 1: Scientific Bases and Analyses* (TDR-MGR-MD-000007 REV 00, under development), will provide an overview of the work that may be conducted to address this issue. (Response applicable to each listed feature, event and process) No additional work is required beyond the existing agreement.

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Topic	**NRC Comment**	**DOE Response**
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