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

Probabilistic Volcanic Hazard Analysis Update

Presented to:
Nuclear Waste Technical Review Board

Presented by:
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Arlington, Virginia

Objectives of Presentation

- To summarize formal expert elicitation methodologies for hazard analysis and regulatory criteria
- To define the essential steps in an expert elicitation
- To review the context for Probabilistic Volcanic Hazard Analysis (PVHA) (1996) and the PVHA-Update (PVHA-U)
- To review the ongoing activities on PVHA-U

Context for Formal Expert Elicitations on the YMP

- **SSHAC 1997. *Recommendations for Probabilistic Seismic Hazard Analysis: Guidance on the Uncertainty and Use of Experts.* NUREG/CR-6372. (sponsored by NRC, EPRI, and DOE).**
- **Kotra et al. 1996. *Branch Technical Position on the Use of Expert Elicitation in the High-Level Radioactive Waste Program.* NUREG-1563.**
- **CRWMS M&O 1996. *Probabilistic Volcanic Hazard Analysis for Yucca Mountain, Nevada.* BA0000000-01717-2200-00082 REV 00. Las Vegas Nevada: CRWMS M&O.**
- **CRWMS M&O 1998. *Probabilistic Seismic Hazard Analyses for Fault Displacement and Vibratory Ground Motion at Yucca Mountain, Nevada.***

Steps in Expert Elicitation

- **NRC Branch Technical Position (Kotra et al. 1996)**
  - **Definition of objectives**
  - **Selection of experts**
  - **Refinement of issues and problem decomposition**
  - **Assembly and dissemination of basic Information**
  - **Pre-elicitation training**
  - **Elicitation of judgments**
  - **Post-elicitation feedback**
  - **Aggregation of judgments (including treatment of disparate views)**
  - **Documentation**

Steps in Expert Elicitation (continued)

- **SSHAC (1997)**
  - Identification and selection of technical issues
  - Identification and selection of experts
    - Role of experts as evaluators, not proponents
    - Technical facilitator/integrator (TFI)
  - Discussion and refinement of the technical issues
  - Training for elicitation
  - Facilitated group interactions and individual elicitation
  - Feedback and sensitivity analysis
  - Analysis, aggregation
  - Documentation and communication

Basic Elements of PVHA

- **Addresses first two elements of risk triplet**
  - **What can occur?**
  - **How likely is it to occur?**
  - **What are the consequences?**
- **What can occur?**
  - **Igneous event definition**
    - **Intrusions (dikes)—Dimensions, geometry, complexity**
    - **Eruptions—Geometry of conduits, number, magnitude**

Basic Elements of PVHA (continued)

- **How likely is it to occur?**
  - **Spatial models—Relative event density within region of interest**
  - **Temporal models—Recurrence rates within region of interest and their time variation**
- **Characterization of both aleatory variability and epistemic uncertainty**

Attributes of the Methodology—PVHA-96

- **Purpose of study—To develop a defensible probabilistic assessment of the volcanic hazard at Yucca Mountain, with particular emphasis on the quantification of uncertainties**
- **Product—Probability distribution of the annual frequency of intersection of a basaltic dike with the repository footprint**

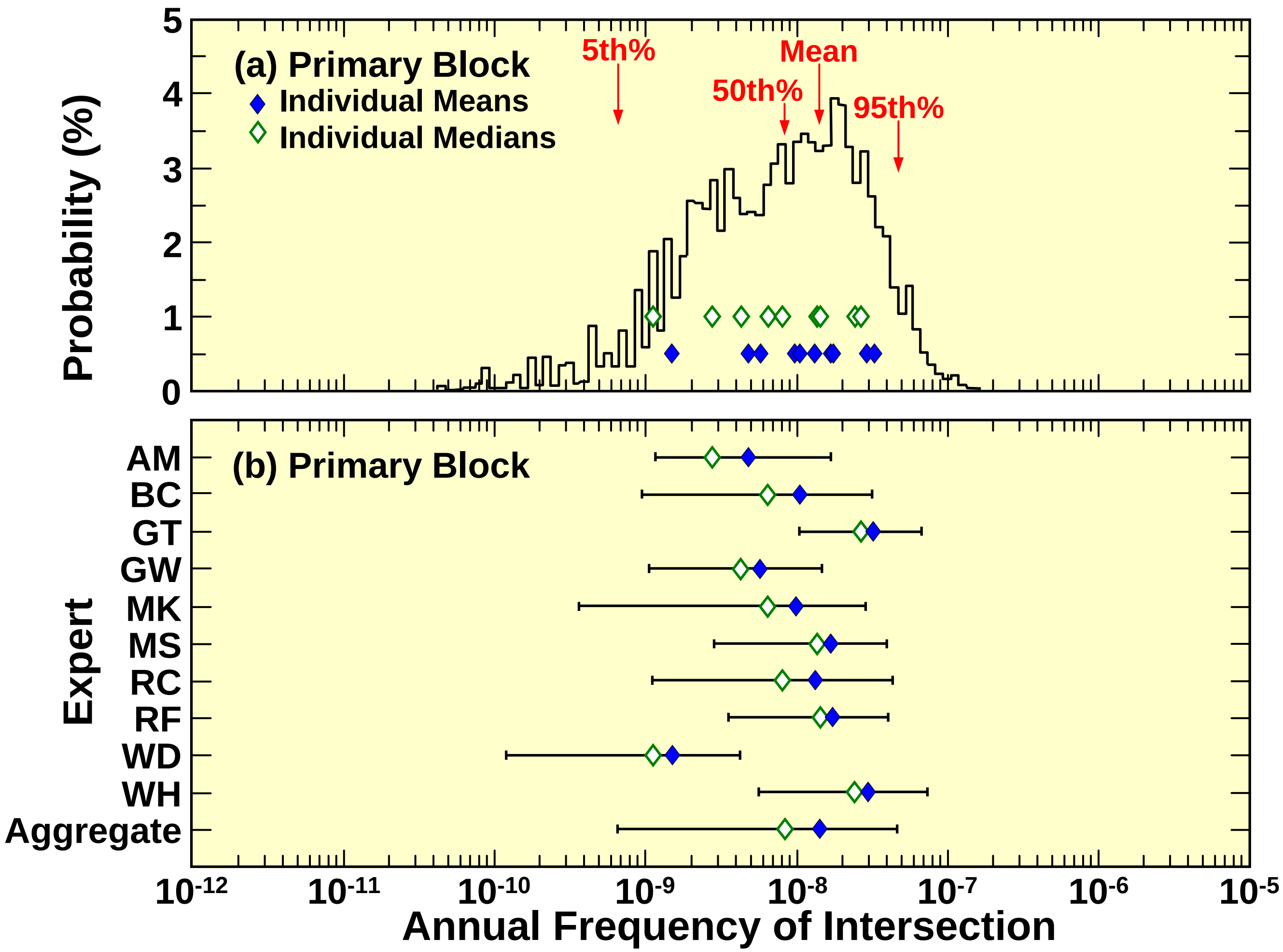
Attributes of the Methodology—PVHA-96
(continued)

- **Development of strategic plan**
- **Selection of the expert panel**
- **Data compilation and dissemination**
- **Workshop on data needs**
- **Field trip to Crater Flat**
- **Workshop on alternative hazard models**
- **Field trip to Sleeping Butte and Lathrop Wells**
- **Interactive meeting on hazard methods**
- **Workshop on elicitation training and alternative interpretations**
- **Trial elicitation**
- **Elicitation of experts**
- **Calculation of preliminary results**
- **Workshop to review preliminary assessments**
- **Finalization of expert assessments**
- **Preparation of project report**

Expert Selection Process PVHA-96 (continued)

Expert	Affiliation
Dr. Richard Carlson	Carnegie Institute of Washington
Dr. Bruce Crowe	Los Alamos National Laboratory
Dr. Wendell Duffield	USGS, Flagstaff
Dr. Richard Fisher	UC Santa Barbara
Dr. William Hackett	WRH Associates, Salt Lake City
Dr. Mel Kuntz	USGS, Denver
Dr. Alexander McBirney	University of Oregon
Dr. Michael Sheridan	University at Buffalo (Formerly SUNY, Buffalo)
Dr. George Thompson	Stanford University
Dr. George Walker	University of Hawaii, Honolulu

Annual Frequency of Intersection (PVHA-96)



History Leading to PVHA-U

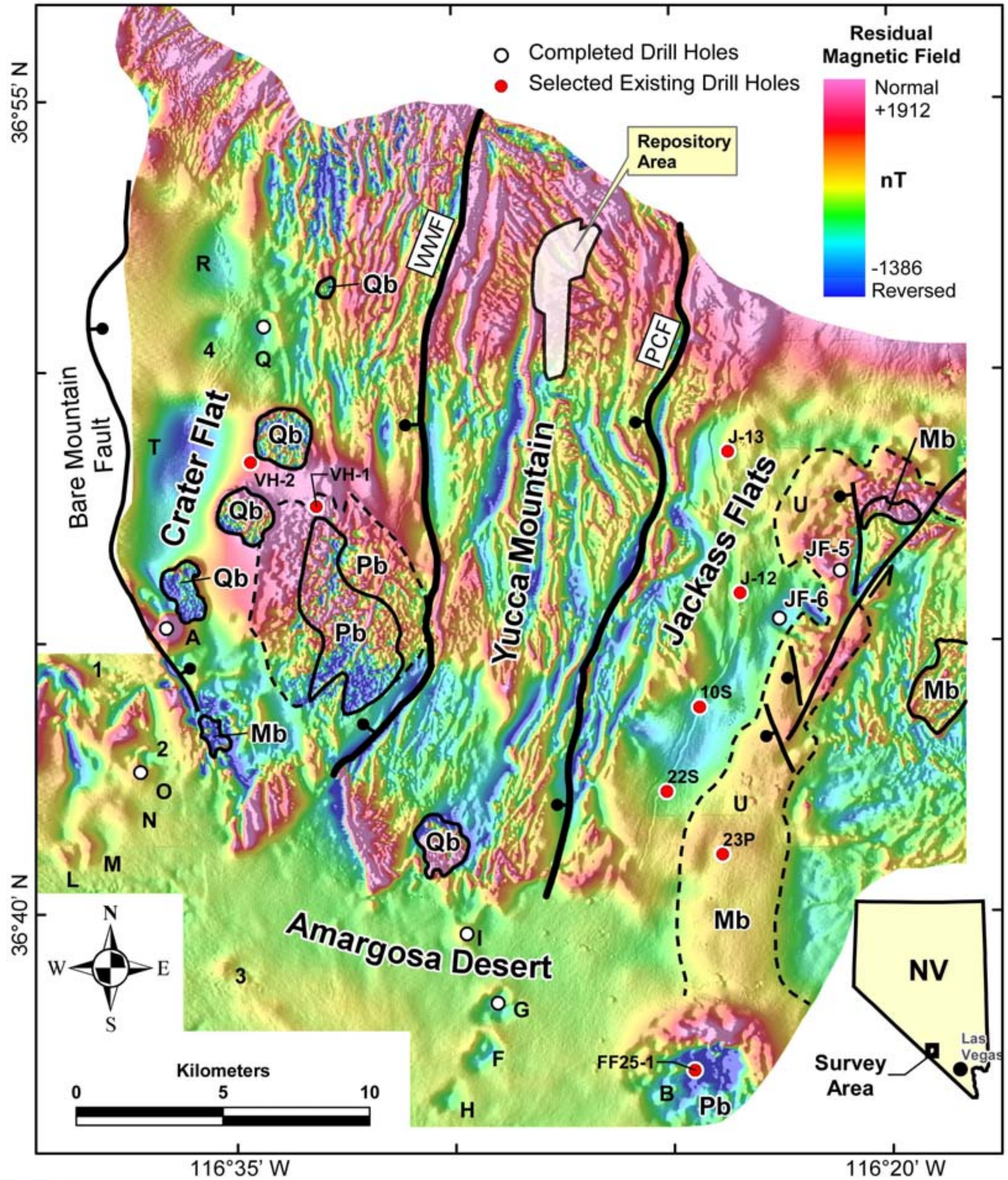
- **Following completion of the PVHA, new aeromagnetic and ground magnetic data became available suggesting possible buried volcanic centers in Crater Flat**
- **DOE sensitivity study indicated a modest increase in the mean annual frequency of intersection of the repository; transmitted to NRC for review**
- **The NRC staff concluded DOE did not provide an adequate technical basis and that additional information was needed**
- **DOE made a regulatory commitment to complete a program of field studies (aeromagnetic survey, drilling, and sampling), data analysis, and to plan an update to the PVHA; final documentation is planned for Fiscal Year 2008 during License Application review**

PVHA-U Experts

Expert	Affiliation
Dr. Chuck Connor	University of South Florida
Dr. Bruce Crowe	Battelle
Dr. William Hackett	Integrated Science Solutions, Inc.
Dr. Mel Kuntz	U.S. Geological Survey (Retired)
Dr. Alexander McBirney	University of Oregon (Emeritus)
Dr. Michael Sheridan	University at Buffalo
Dr. Frank Spera	UC Santa Barbara
Dr. George Thompson	Stanford University

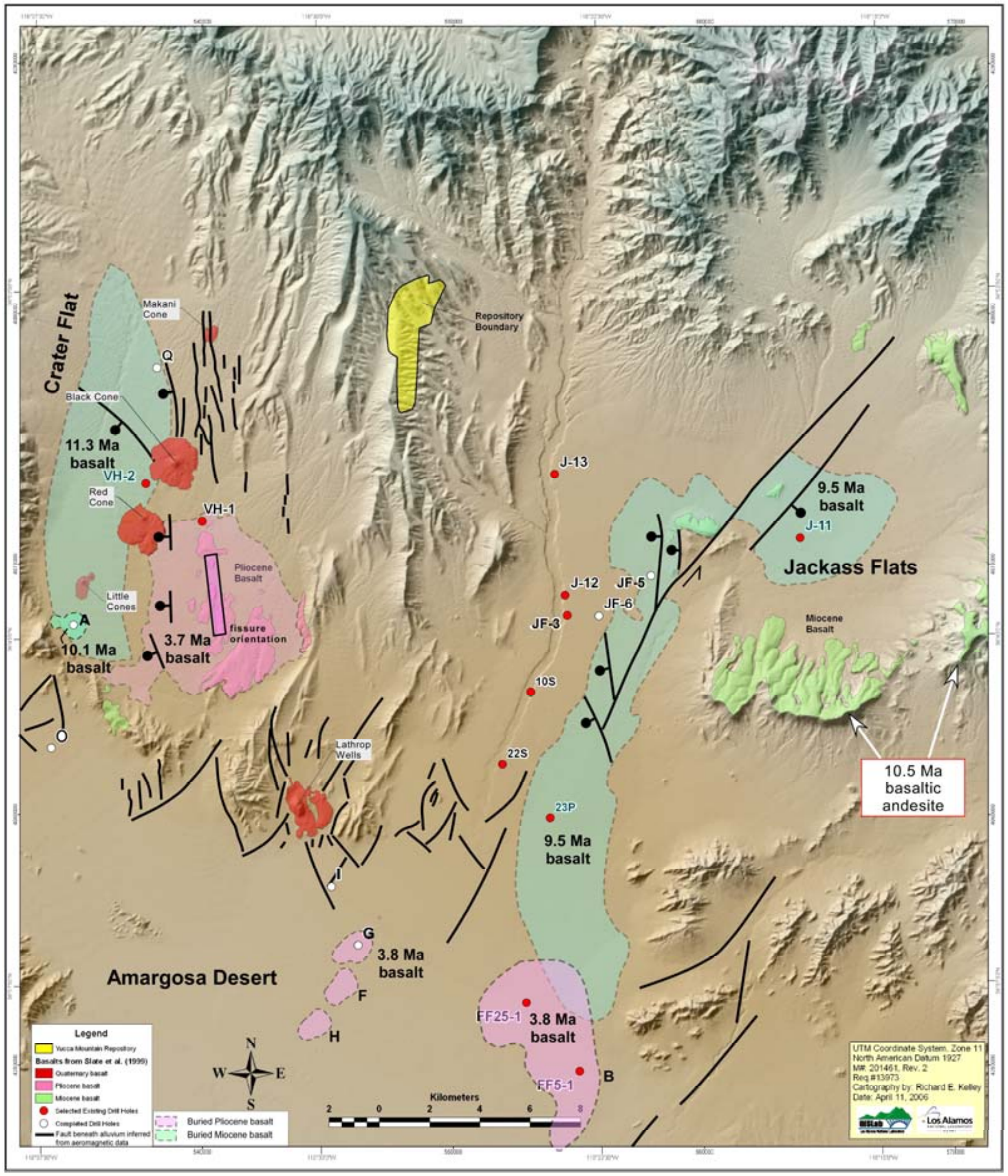
Overview of Aeromagnetic Survey and Drilling Program

- **Low-altitude helicopter-borne aeromagnetic survey carried out to increase resolution related to potential buried basalts**
- **Drilling of seven anomalies to determine origin of anomalies, depth, and age**
- **Laboratory analyses of basalt age (K-Ar, 40Ar-39Ar) and geochemistry**
- **Provides information on location and age of buried basalts, lengths of vent alignments, dike azimuths and lengths**



Aeromagnetic Map and Drillhole Locations

Synthesis of Aeromagnetic Survey and Drilling Interpretations



- **Four basalts in new drill holes represent four different basalt units erupted between ~11 and 3.8 Ma**
- **Some anomalies represent faulted tuff blocks**
- **No post-Miocene basalt in Jackass Flats; extensive buried Miocene basalt**
- **Several volcanoes fed by feeder dikes captured by NNW-trending faults**

Issues Addressed in PVHA-U

- **Spatial Evaluation**
  - **Region of interest**
  - **Spatial model**
    - **Source zones**
      - **Alternative zonations**
      - **Nature of zone boundaries**
    - **Spatial smoothing**
      - **Smoothing operator**
      - **Smoothing distance**
    - **Other conceptual models**

Issues Addressed in PVHA-U (continued)

- **Temporal Evaluation**
  - Homogeneous
  - Nonhomogeneous
  - Time period of interest
  - Event rates (for various magnitudes)
  - Undetected events

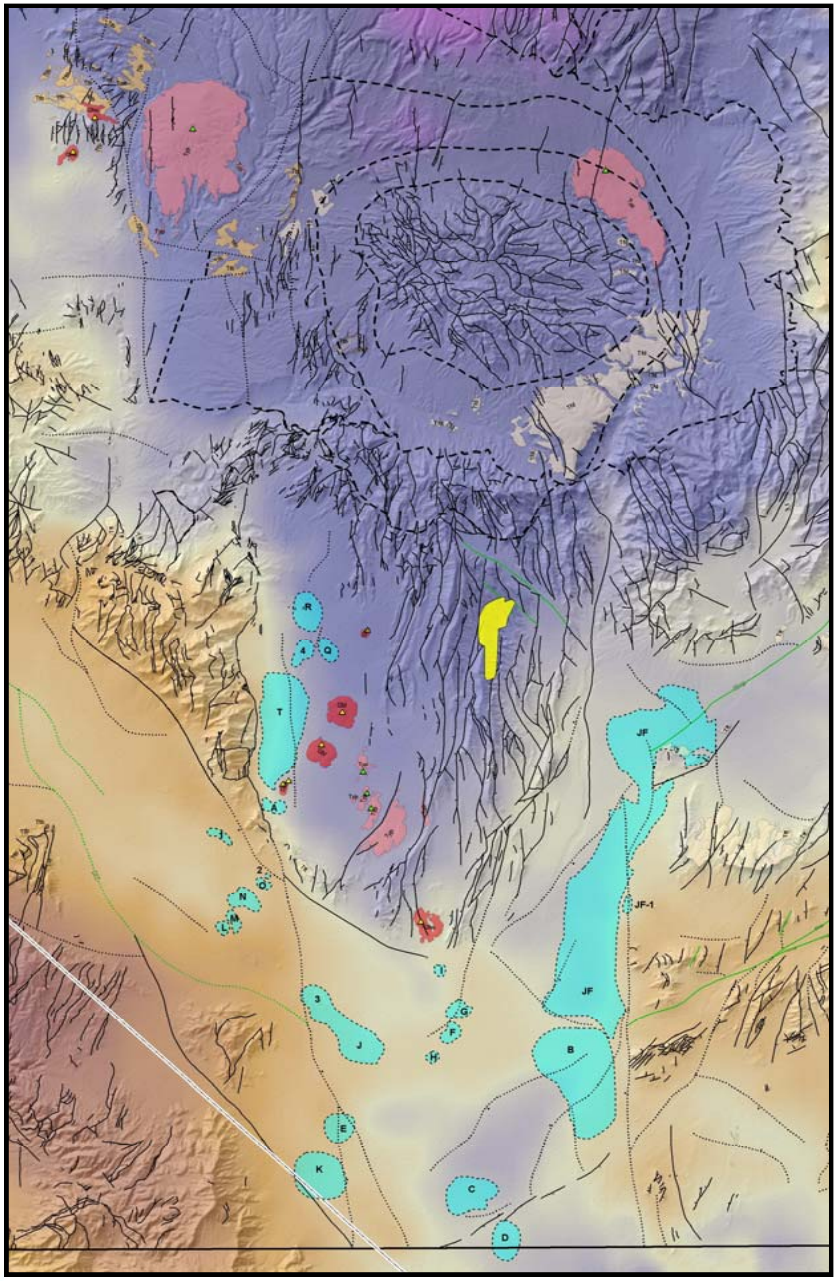
Issues Addressed in PVHA-U (continued)

- **Event Definition**
  - "Magnitude" of event (e.g., violent strombolian)
  - Intrusive event geometry
    - Dike system length, azimuth, and location relative to point event and dike width (similar to 1996 assessment)
    - Description of dike swarm (e.g. number and spacing of parallel dikes along length of dike system)
    - Influence of repository opening on dike intersection

Issues Addressed in PVHA-U (continued)

- **Extrusive event geometry**
  - Number and location of eruptive centers (conduits) associated with volcanic event
  - Conduit diameter at repository level
  - Influence of repository opening on eruptive conduit location

Assessments made for future 10 kyr and 1 Myr



Example of Map Created Using GIS to Display Multiple Data Sets

- **Basalt units, caldera margins, and faults from Slate et al. (2000)**
- **Vent locations**
- **Topography**
- **Isostatic gravity**
- **Aeromagnetic anomalies**

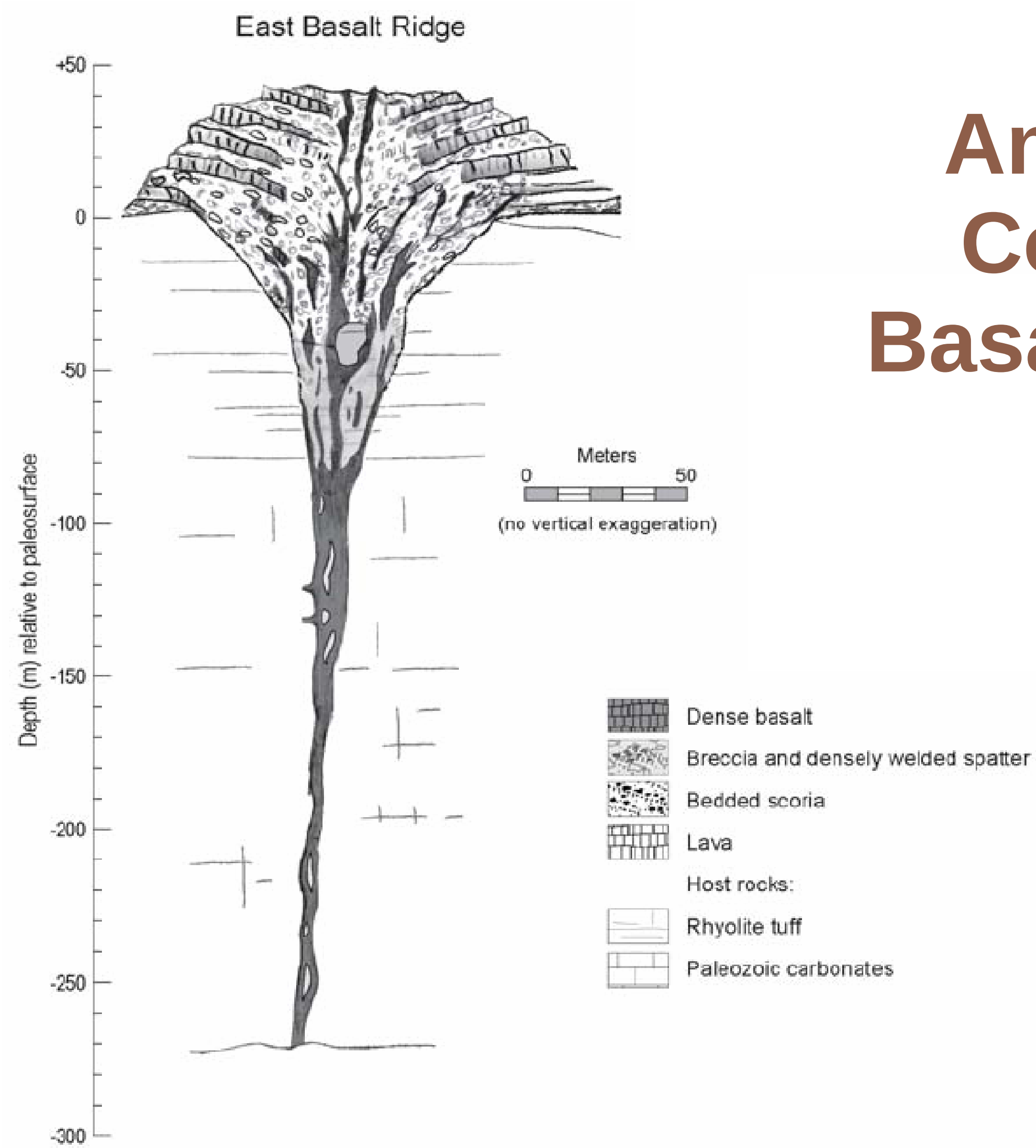
Analog Studies

- **Characteristics**
  - **Age**
  - **Volume**
  - **Dike length, azimuth**
  - **Number of dikes in swarm, spacing**
  - **Eruption fissure length**
  - **Number of major and minor vents**
  - **Spacing of vents**
  - **Location of major vents along dike/fissure**
  - **Dike/conduit diameter (at depth, if available)**

Analog Studies (continued)

- **Locations**
  - Basalt Ridge
  - East Basalt Ridge
  - Paiute Ridge
  - Thirsty Mountain
  - Southeast Crater Flat
  - Buckboard Mesa
  - Makani Cone
  - SW Little Cones
  - NE Little Cones
  - Black Cone
  - Red Cone
  - Hidden Cone
  - Little Black Peak
  - Lathrop Wells Volcano

xample of Analog Studies—Conduits at East Basalt Ridge (8.8 Ma)



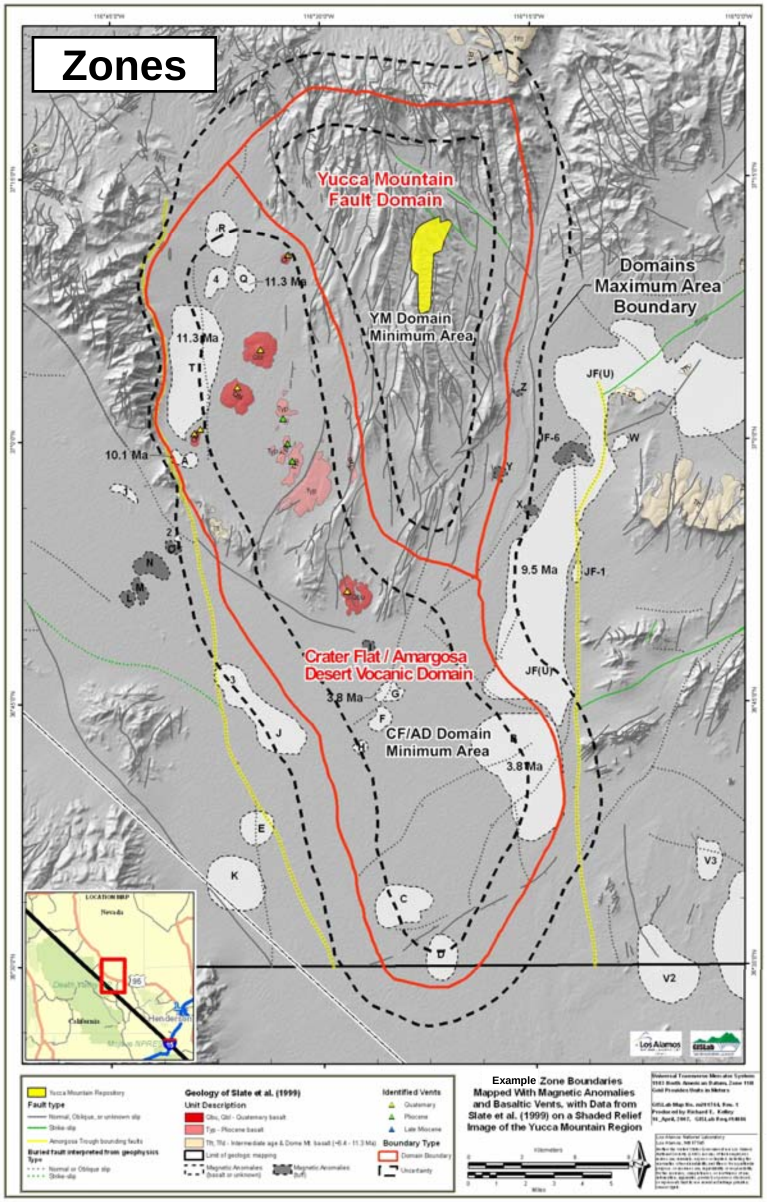
- **Exposure to ~250-m depth**
- **Dike system flares at ~90-m depth**
- **Apparent dike:fissure ratio is ~2:1**

Schedule

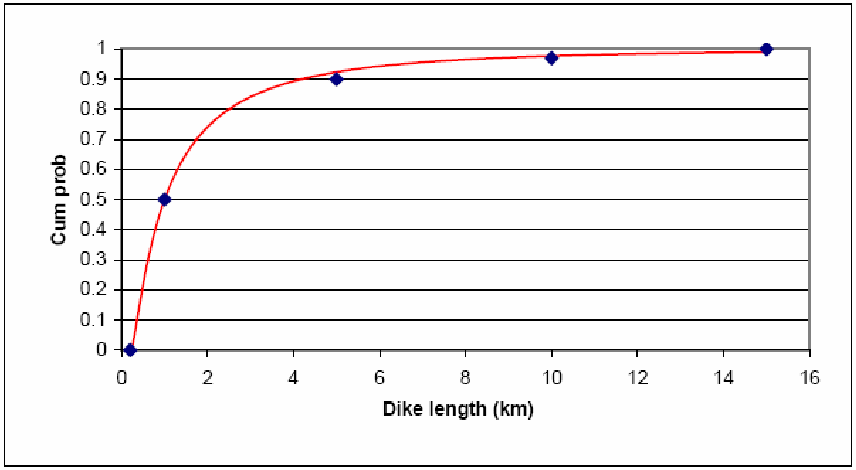
Activity	Schedule
Planning	July to September 2004
Select and Retain Experts	August to September 2004
Distribute Information to Experts for Review	September 2004
Workshop 1 Key Issues and Available Data	October 11 to 15, 2004
Workshop 2 Alternative Models	February 15 to 18, 2005
Workshop 2A Approaches to Volcanic Hazard Modeling	August 30 to 31, 2005
Field trip to event-definition analogue sites	May 2 to 4, 2006
First Round of Elicitation Interviews	July to August 2006
Workshop 3 Preliminary Expert Assessments	September 26 to 27, 2006
Second Round of Elicitation Interviews	November to December 2006
Preliminary Hazard Calculations and Sensitivity Analyses	January to April 2007
Workshop 4 Feedback	May 10-11, 2007
Experts Finalize Elicitation Summaries	July 2007
Final Hazard Calculations and Aggregation of Expert Assessments	July 2007 to January 2008
Report Preparation/Finalization	November 2007 to June 2008

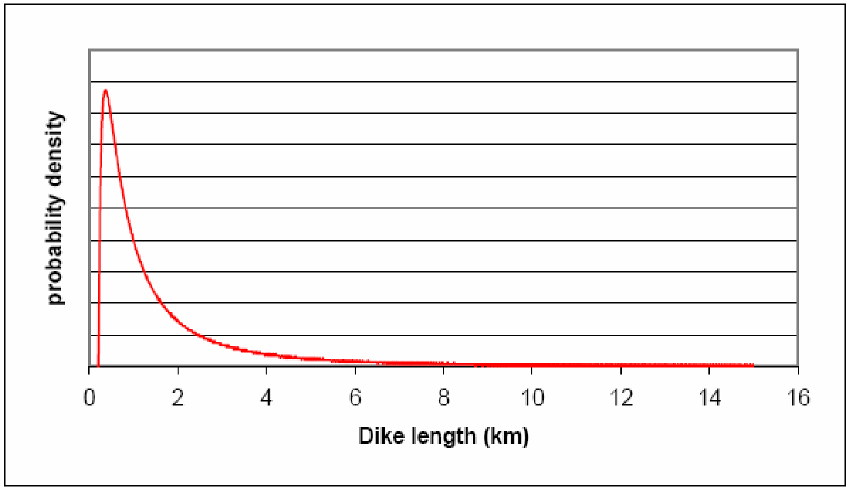
Complete

Example of Spatial Zonation and Uncertainties

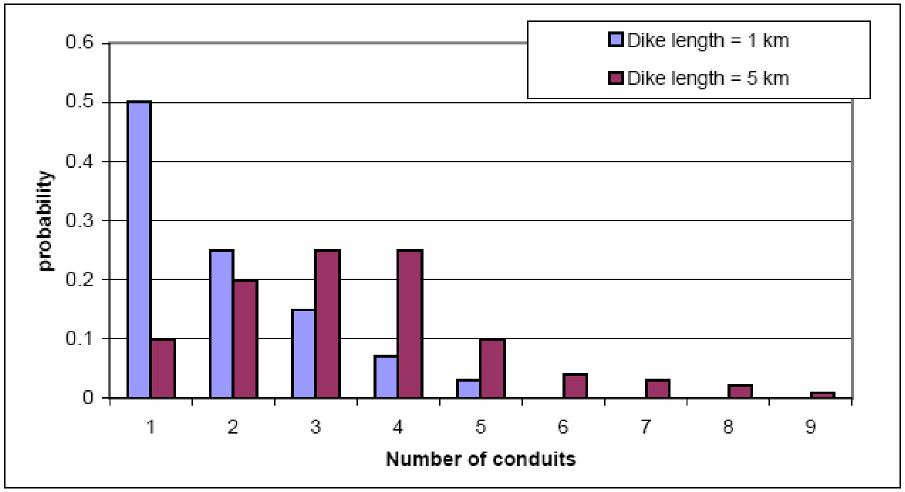


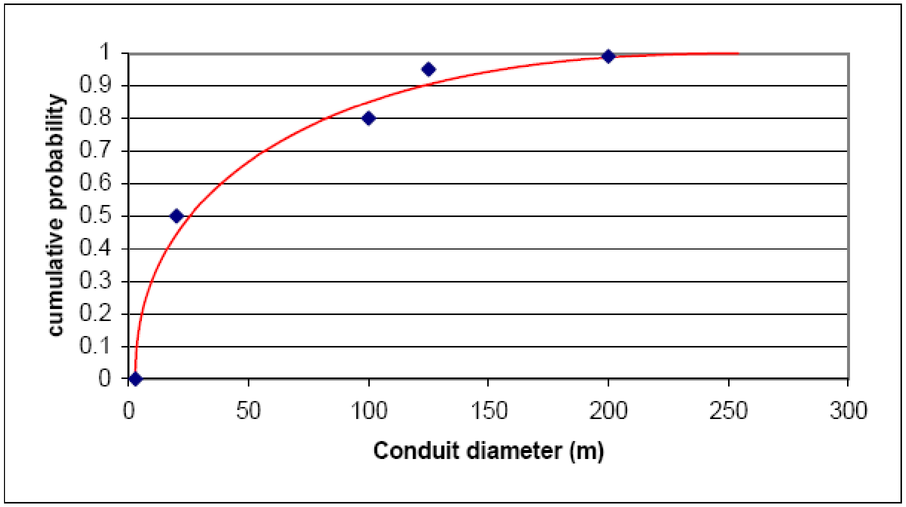
Example of Event Characteristic—Dike Length





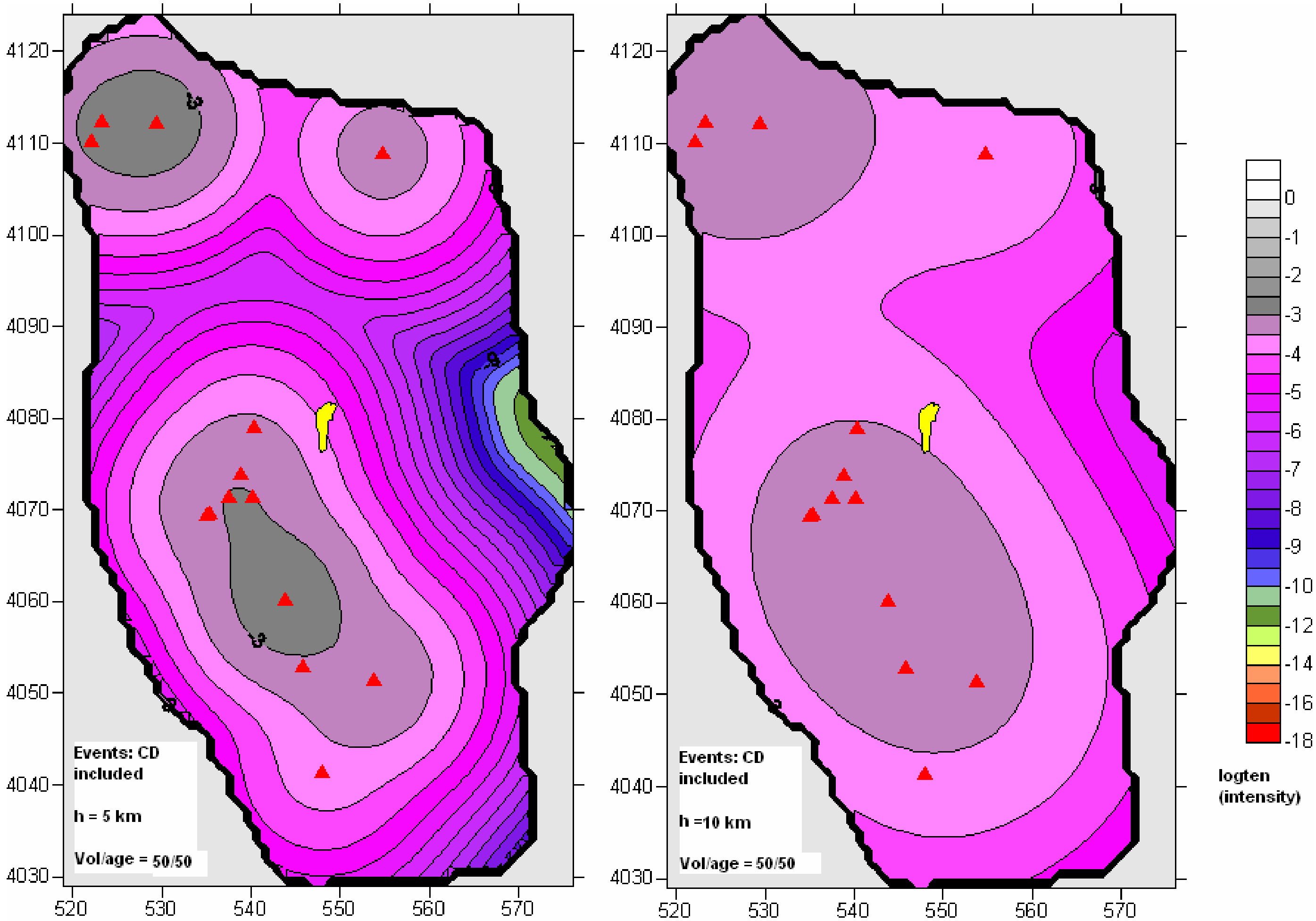
Example of Event Characteristic—Number and Diameter of Conduits



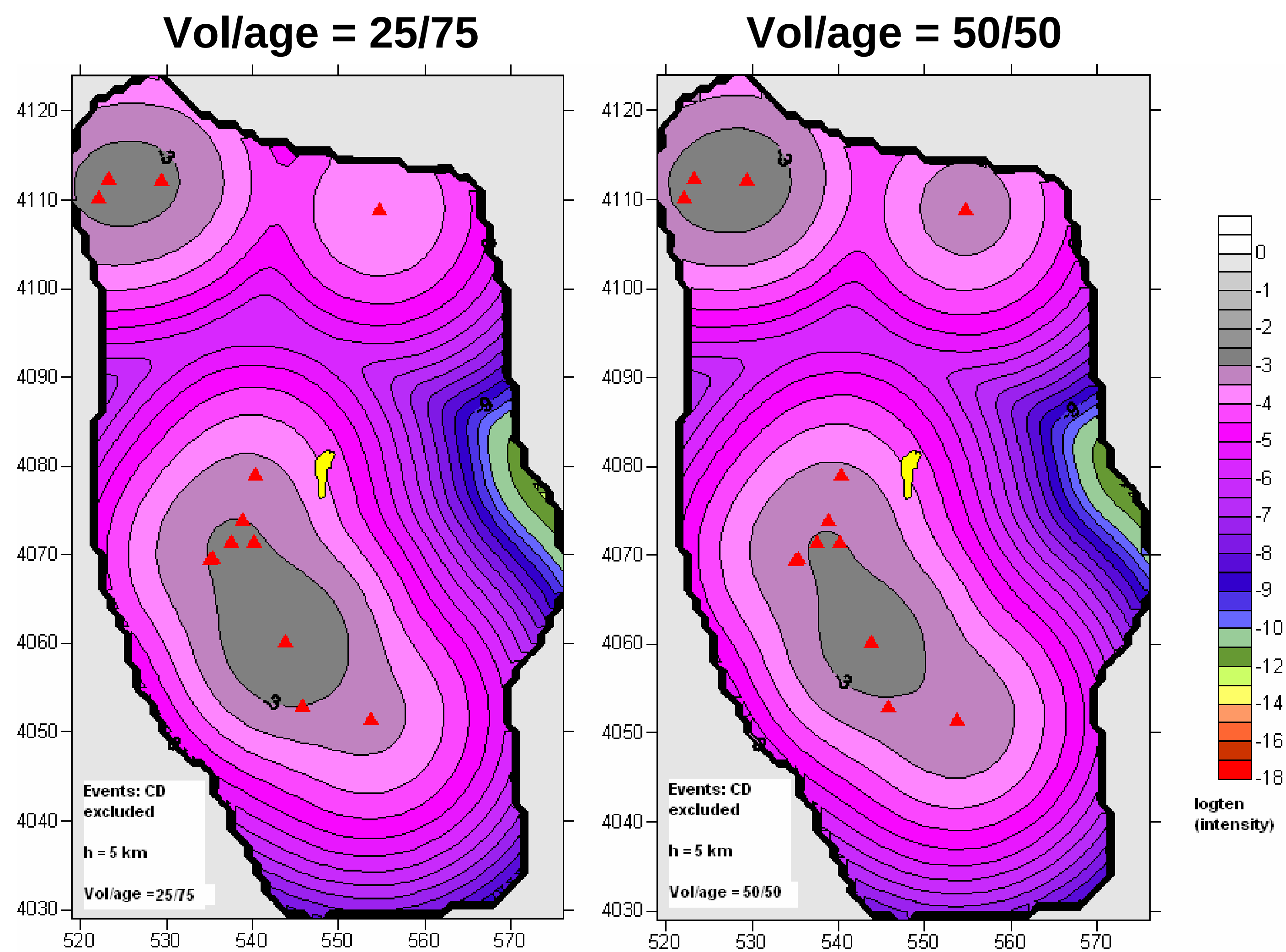


Example of Feedback—Alternative Smoothing Distances

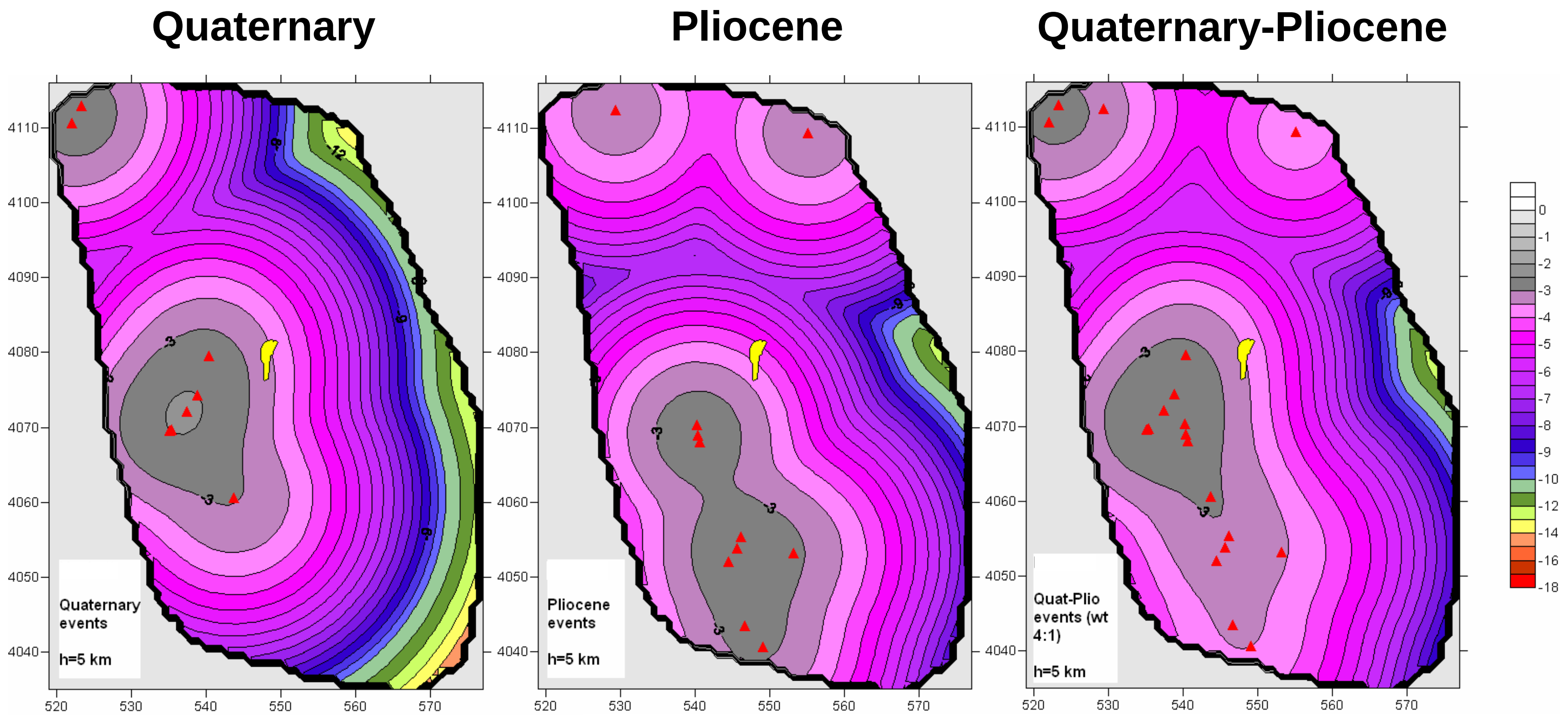
h = 5 km | h = 10 km



Example of Feedback—Alternative Volume/Age Weighting



Example of Feedback—Weighting of Events for Spatial Intensity



Summary

- **PVHA-U methodology consistent with guidance for formal expert elicitation processes within regulated environment**
- **PVHA-U takes advantage of the lessons learned and opportunities for refinement**
- **Process structured around workshops and expert interactions**
- **PVHA-U results will be documented in Fiscal Year 2008 during the NRC's License Application review**