Understanding the Process of Volcanism is Important for Calculating the Probability of Future Volcanism at Yucca Mountain

Eugene Smith
gene.smith@unlv.edu
Deborah Keenan
UNLV and Geoscience Consultants

Contact Information

Eugene Smith
Department of Geoscience
University of Nevada, Las Vegas
Las Vegas, NV 89154-4010
(702) 895-3971
gene.smith@unlv.edu

Deborah Keenan
Geoscience Consultants
Henderson, NV 89014

State of Nevada
Agency for
Nuclear Projects

We acknowledge support from the Nevada Agency for Nuclear Projects and the Nuclear Waste Division of Clark County, Nevada.

Main Point

- It is important to understand the process of volcanism before calculating the probability of future events.

Models of Volcanism

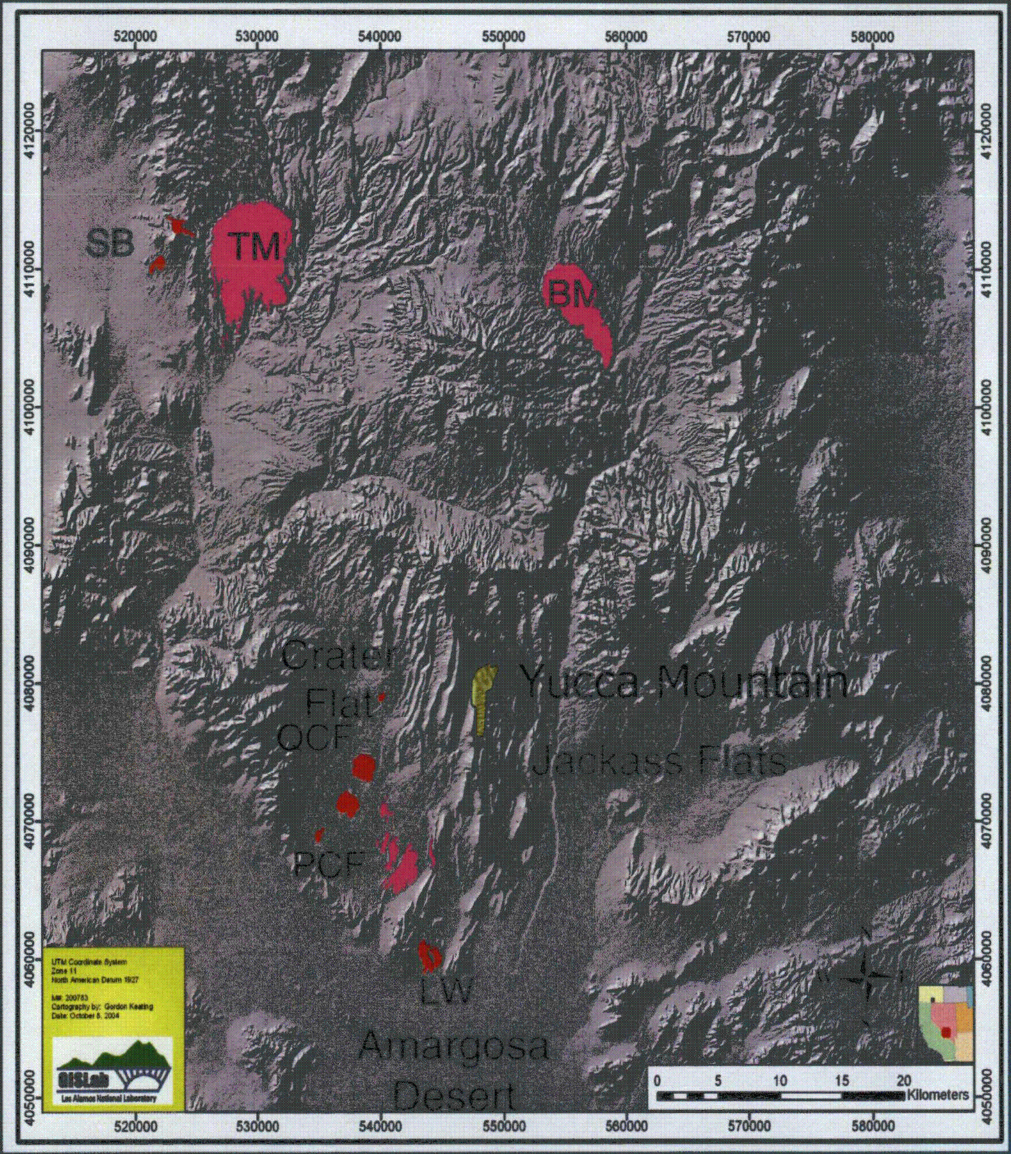
- *Traditional model* focuses on the Yucca Mt area, assumes lithospheric mantle melting and implies waning volcanism
- *Deep melting model* focuses on the Lunar Crater-Death Valley belt and implies that a new peak of volcanism is possible.

Models of Volcanism

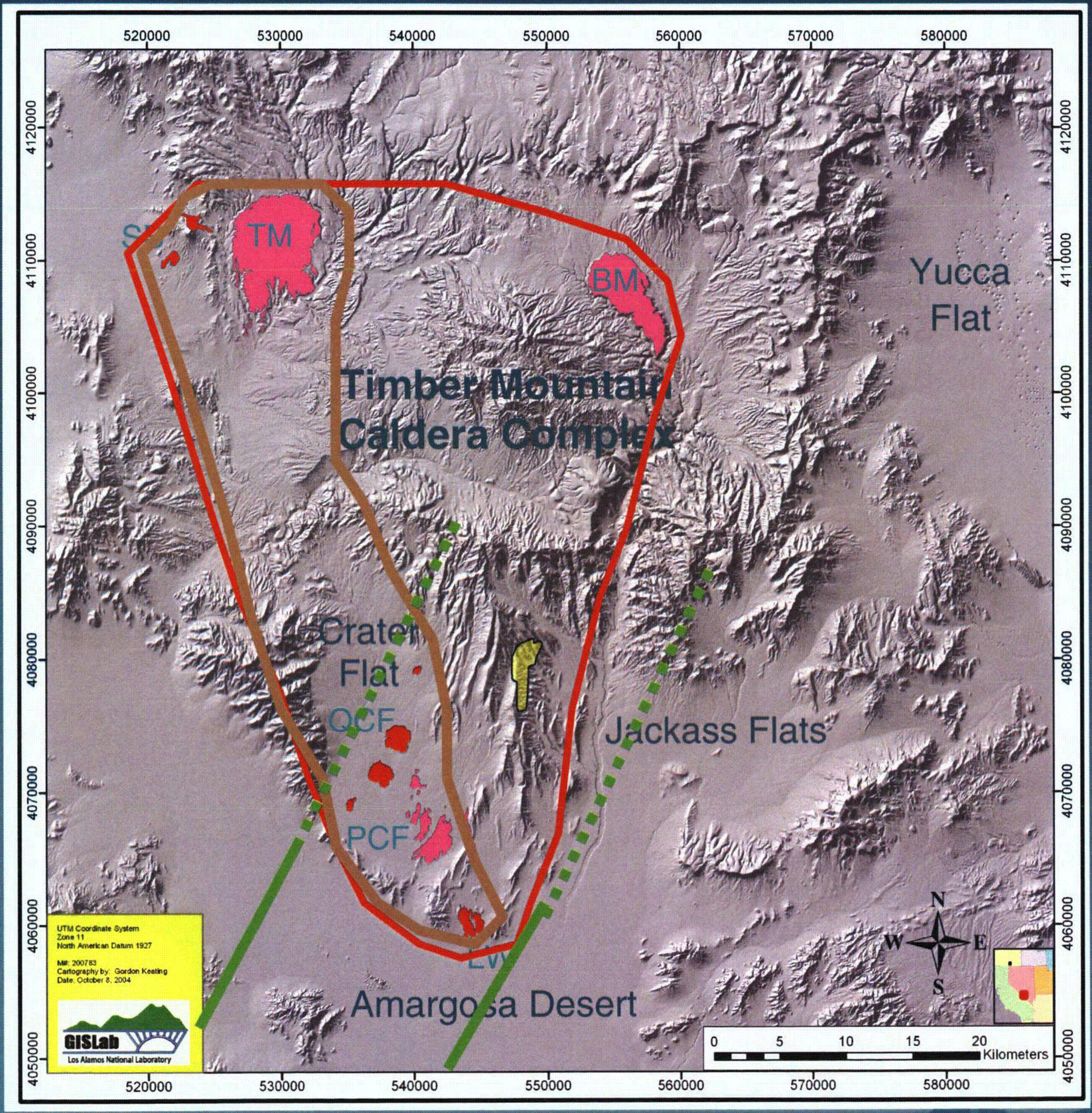
- *Traditional model* focuses on the Yucca Mt area, assumes lithospheric mantle melting and implies waning volcanism
- *Deep melting model* focuses on the Lunar Crater-Death Valley belt and implies that a new peak of volcanism is possible.

Traditional Model

- Focus is on Yucca Mt area



Base map from F. Perry (LANL)

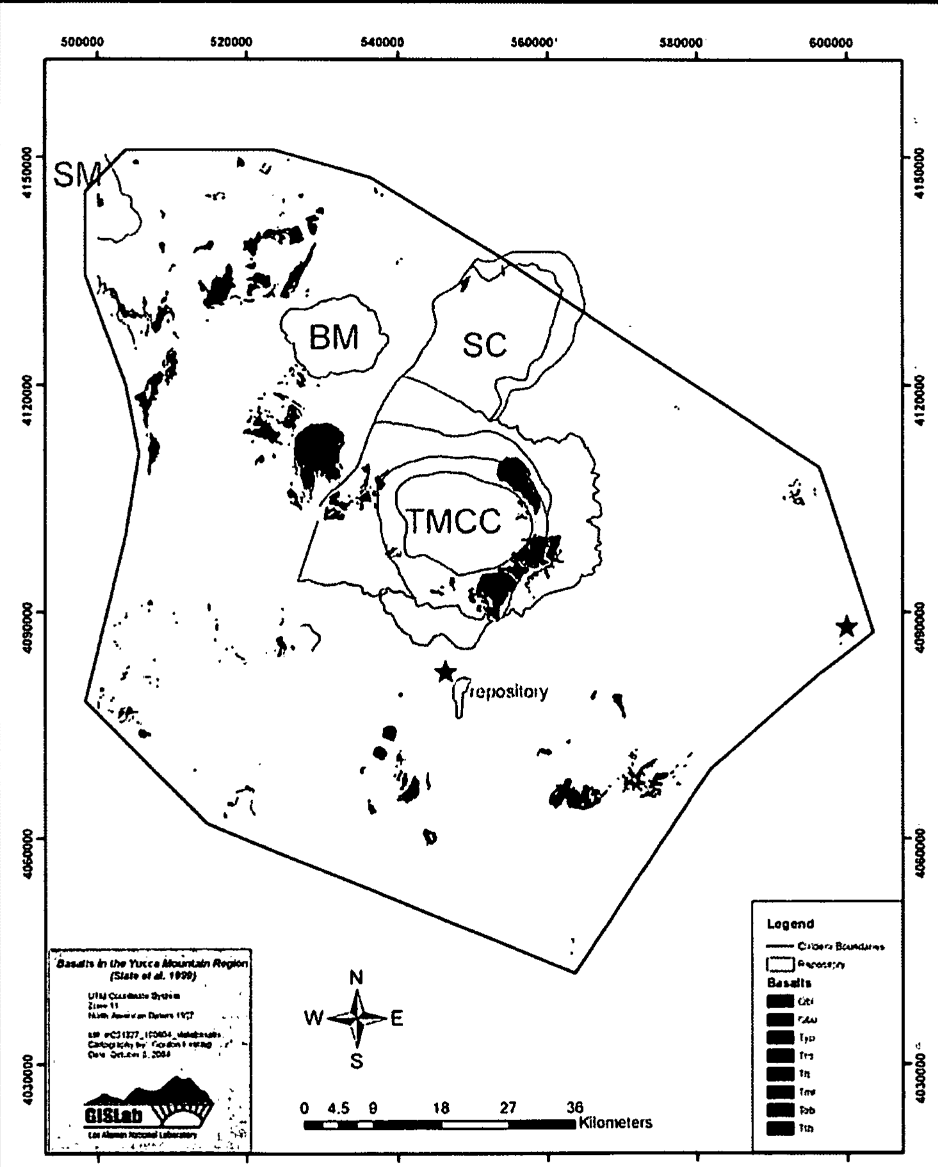


AMRV

Crater Flat zone

Amargosa Trough

Base map from F. Perry (LANL)



From presentation by Richard Carlson (PVHA-U)

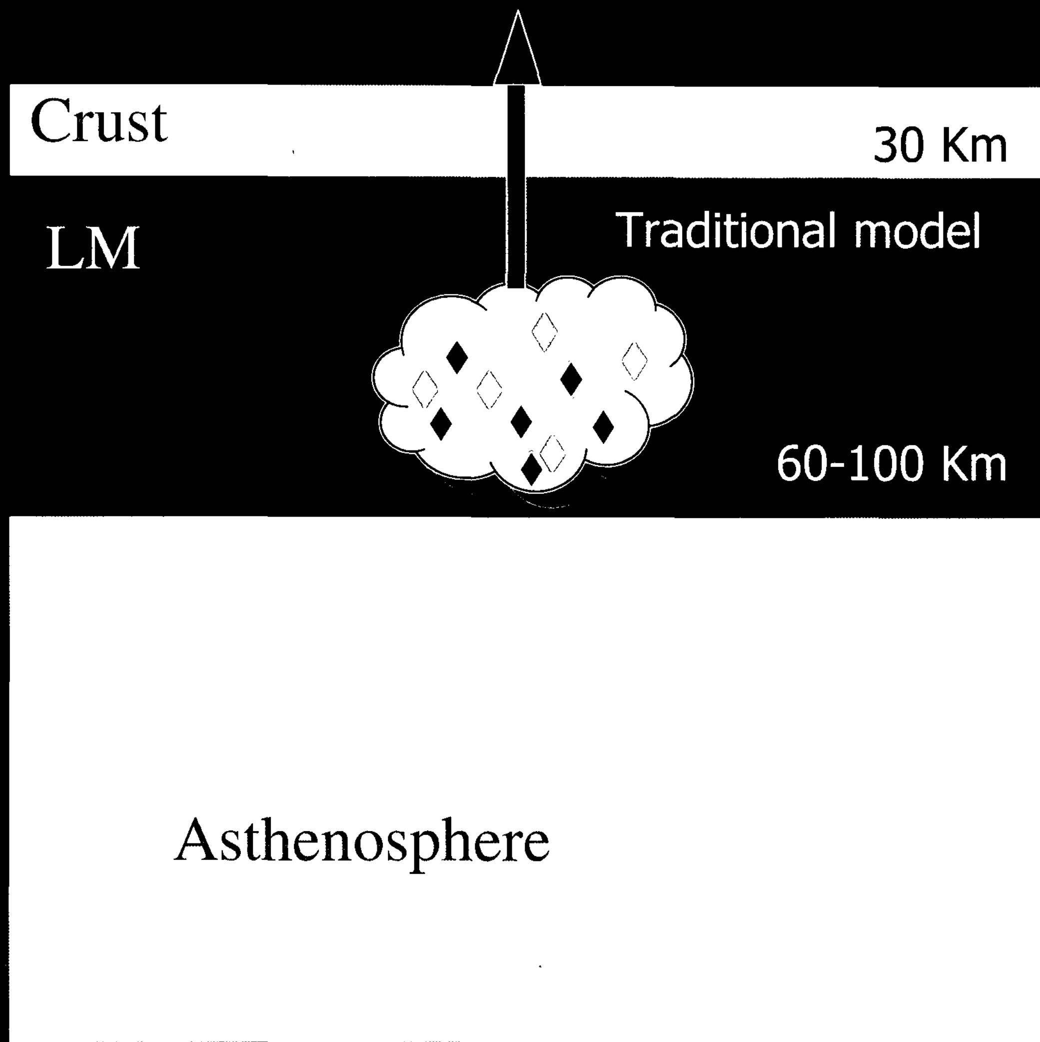
A shrinking field
More or less centered on the Timber Mountain caldera

Based on the Amargosa Valley Isotope Province (AVIP) of Yogodzinski and Smith (1995)

Traditional Model

Melting of lithospheric mantle (LM). The LM has been isolated from convecting mantle for as long as several billion years. This mantle has high initial Sr ratios and low epsilon Nd.

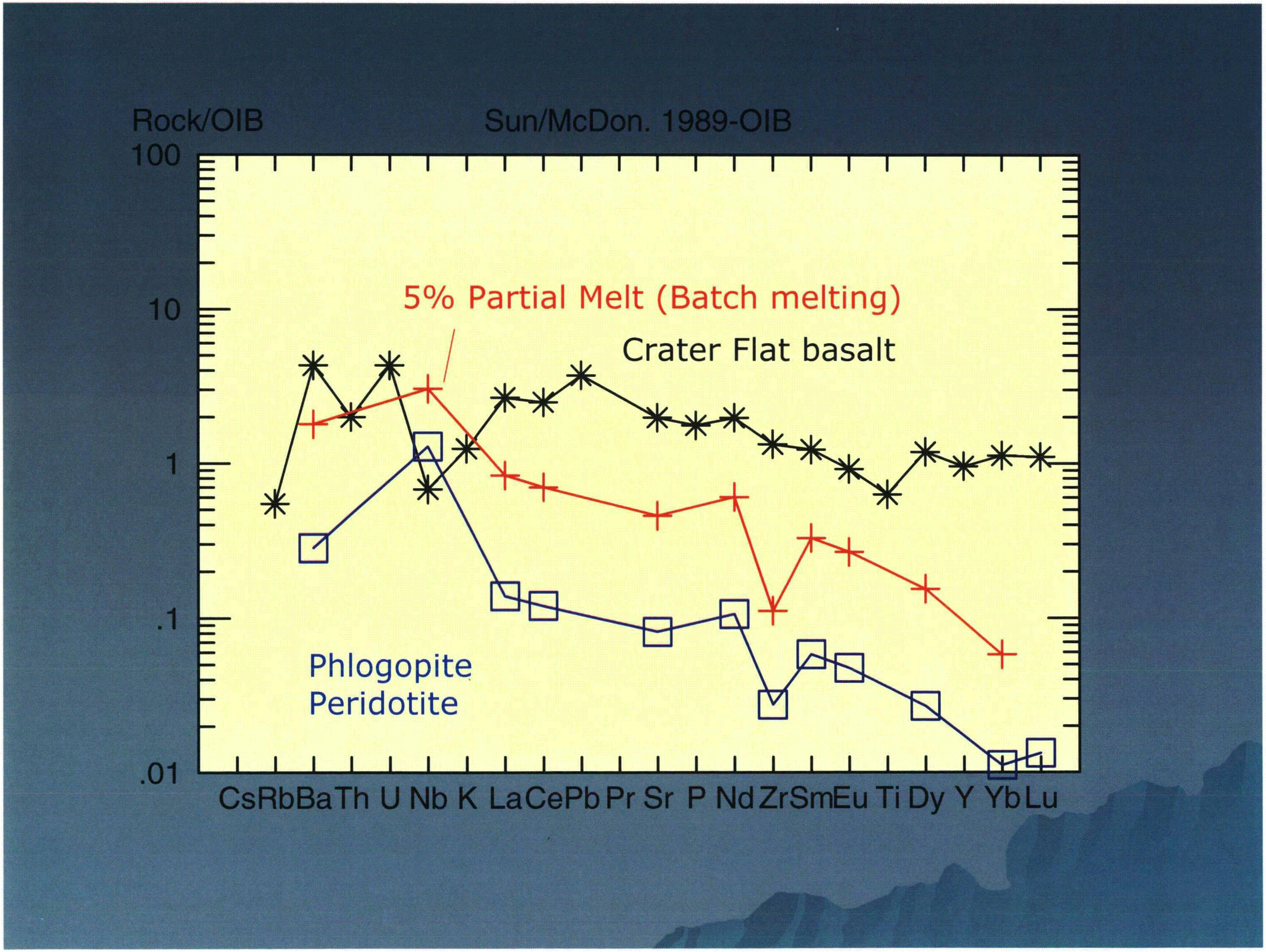
Melting of LM peridotite due to elevated water contents (0.5 wt. %).* Alternatively, melts may be produced from isolated fusible zones (mafic veins or hydrous components) in the mantle. Fusible material added as much as several billion years ago.**



*Hawkesworth et al. (1995); **Harry and Leeman (1995)

Assessment of Model

- Melting of a water rich lithospheric mantle.
  - Water in the LM is commonly hosted in minerals such as hornblende and mica.
  - Amphibole and mica are hosts for elements such as Nb and Ta (Ionov and Hoffmann (1995).
  - Partial melting of peridotite containing 3-10% mica (phlogopite) will produce basaltic melts with a positive Nb anomaly.

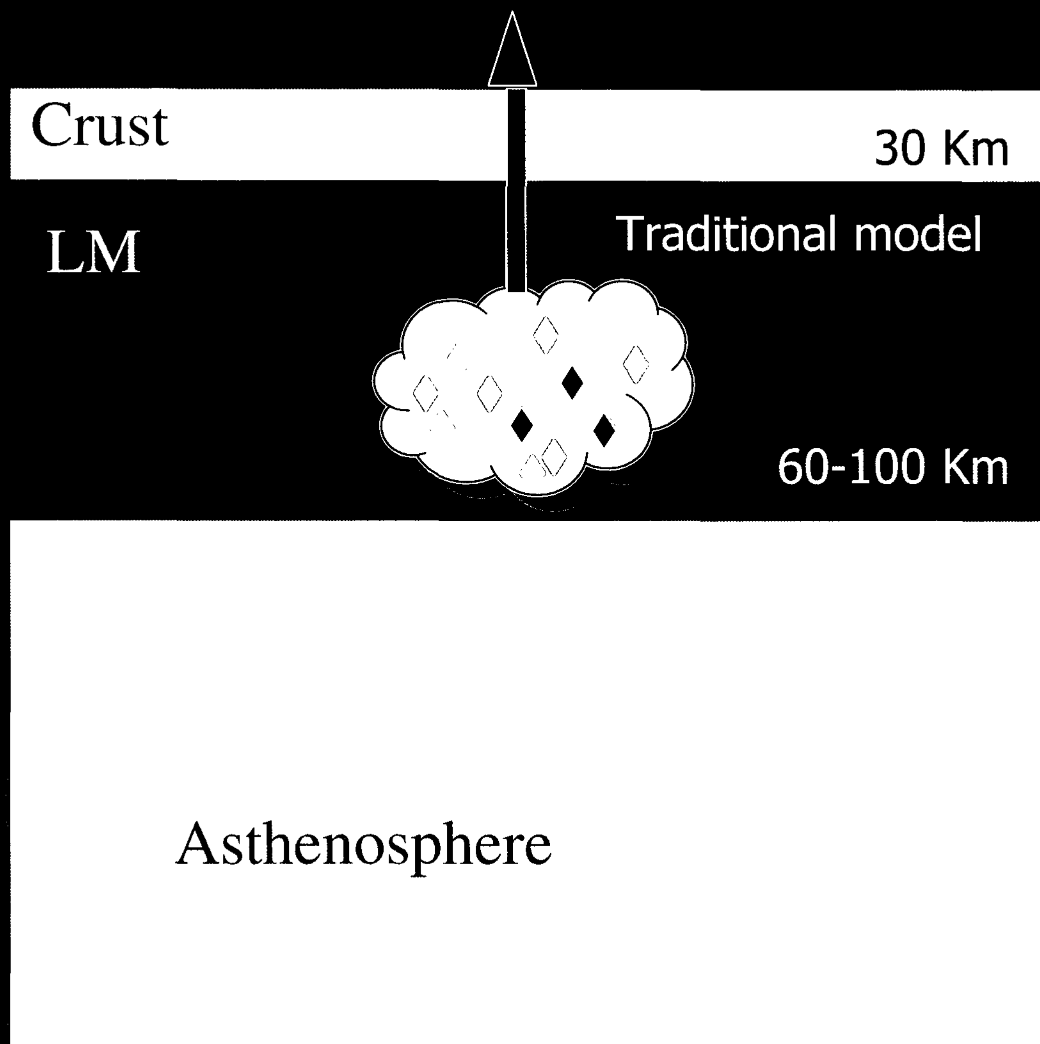

Rock/OIB
Sun/McDon. 1989-OIB
100
10
1
.1
.01
5% Partial Melt (Batch melting)
Crater Flat basalt
Phlogopite
Peridotite
CsRbBaTh U Nb K LaCePbPr Sr P NdZrSmEu Ti Dy Y YbLu

Assessment

- Therefore, hydrous phases in peridotite assemblages simply cannot produce the characteristic HFSE-depleted trace-element patterns observed in many continental basalts (Pearson and Nowell, 2002).

Assessment

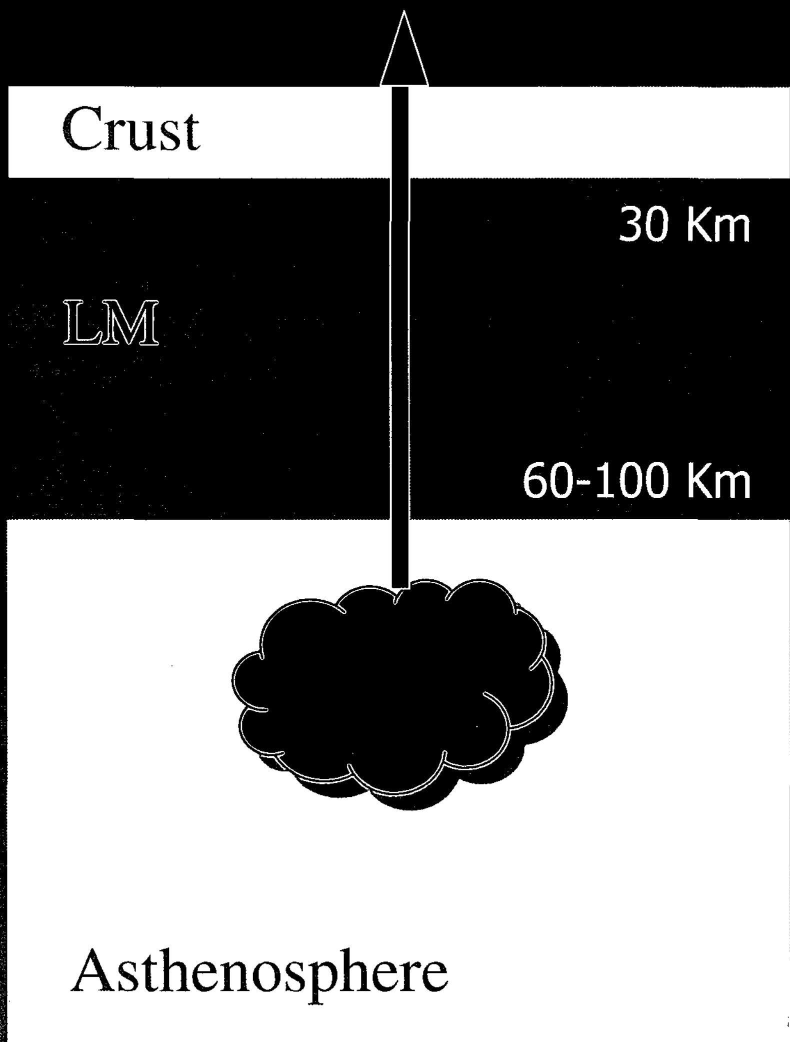
- Melting of mafic veins or hydrous material in the lithospheric mantle
  - Most of this material in the mantle melted during earlier volcanism. Very little left for future events.
  - If mafic rock contains water it would not produce Crater Flat type magmas by partial melting.



Assessment

- "the production of negative Nb anomalies...is unlikely to originate from melting of lithospheric mantle compositions. The exact nature of such a chemical signature remains unclear...trace element chemistry in this case is not a simple reflection of source characteristics (Pearson and Nowell, 2002)."

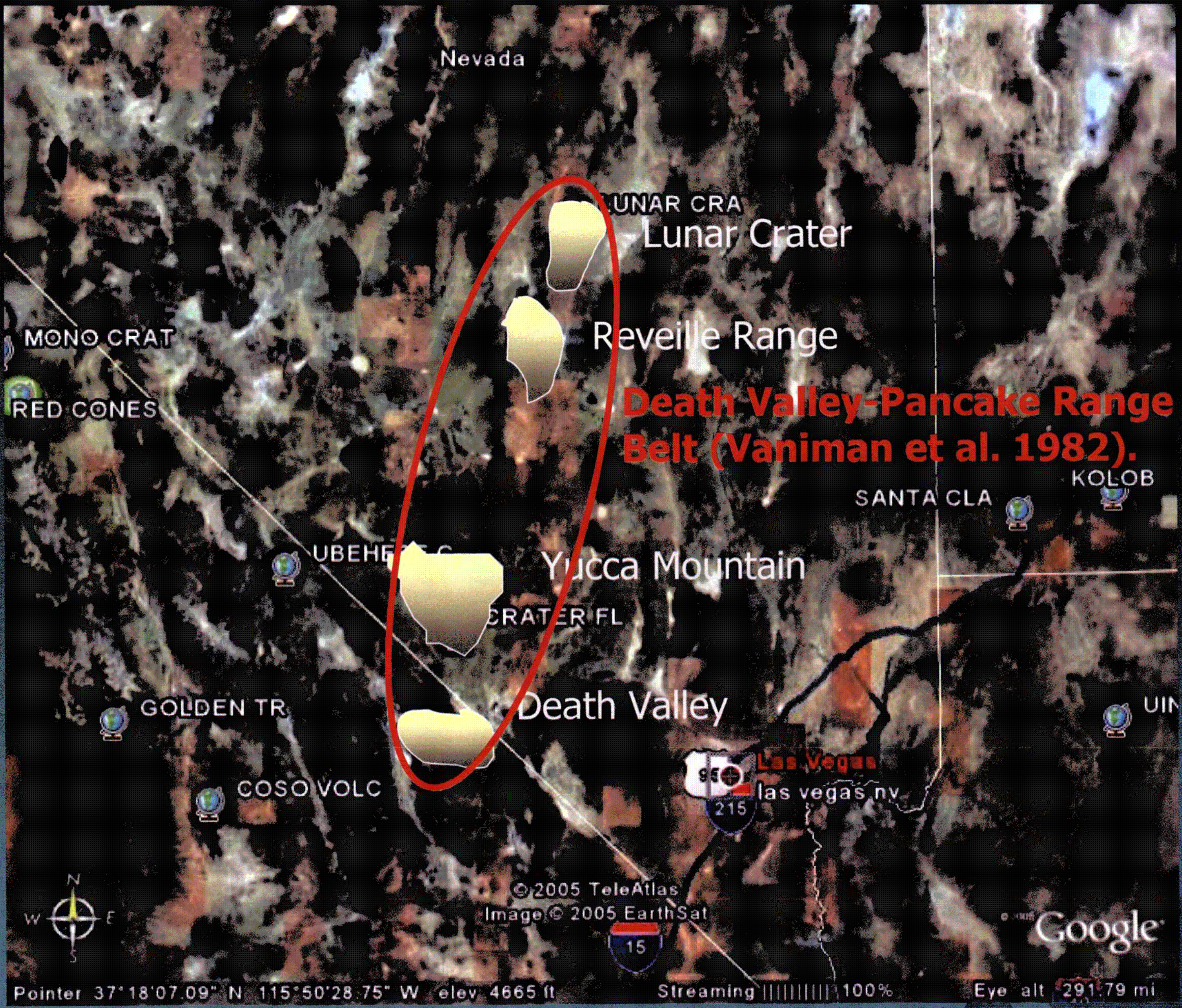
Deep Melting Model



Melting of asthenospheric mantle. Lithospheric mantle does not melt. Model focuses on a larger area extending from Lunar Crater to Death Valley.

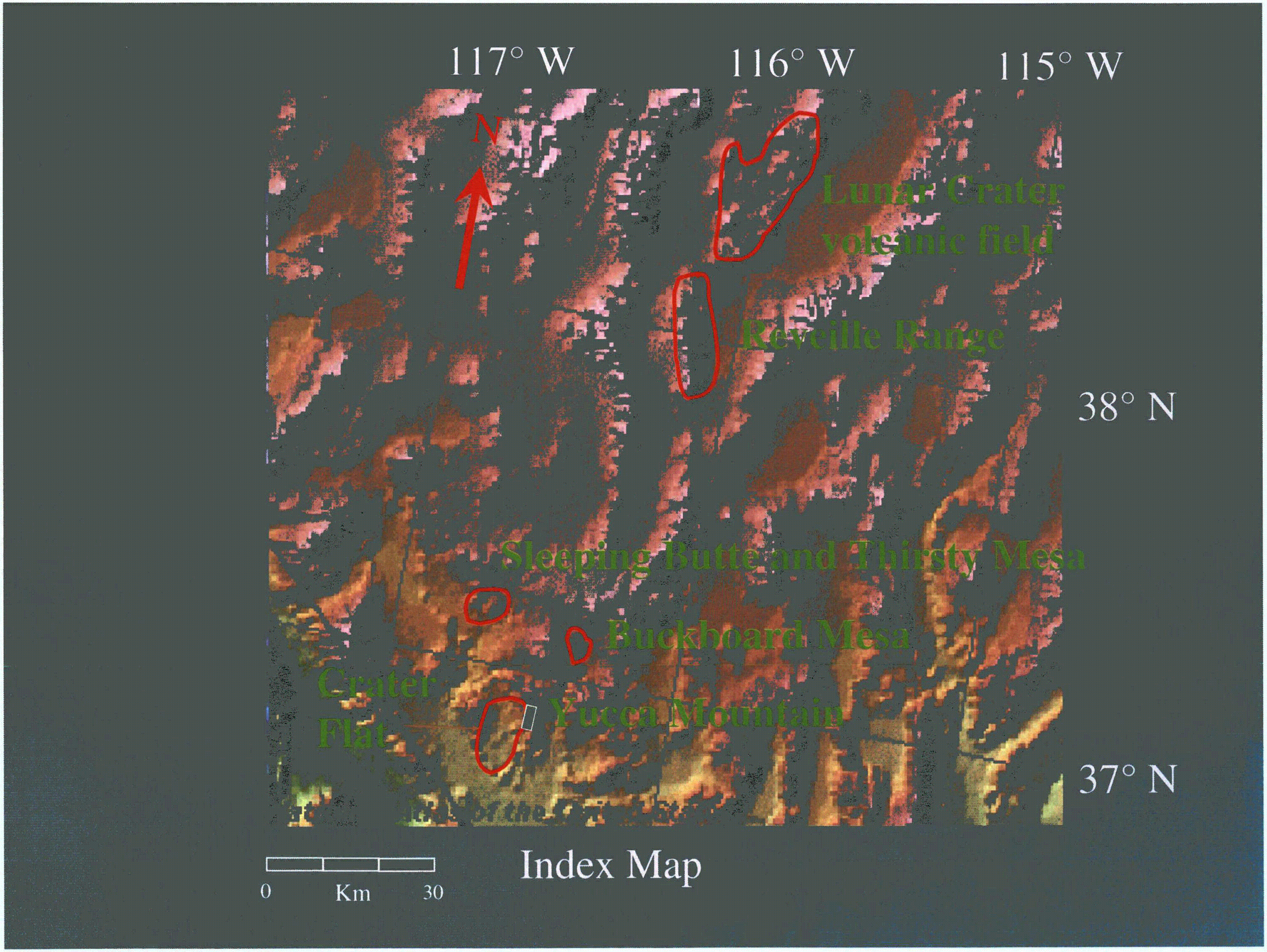
Model supported by similar episodic patterns of volcanism and depth of melting calculations

Wang et al. (2002); Smith et al. (2002) Smith and Keenan (2005).

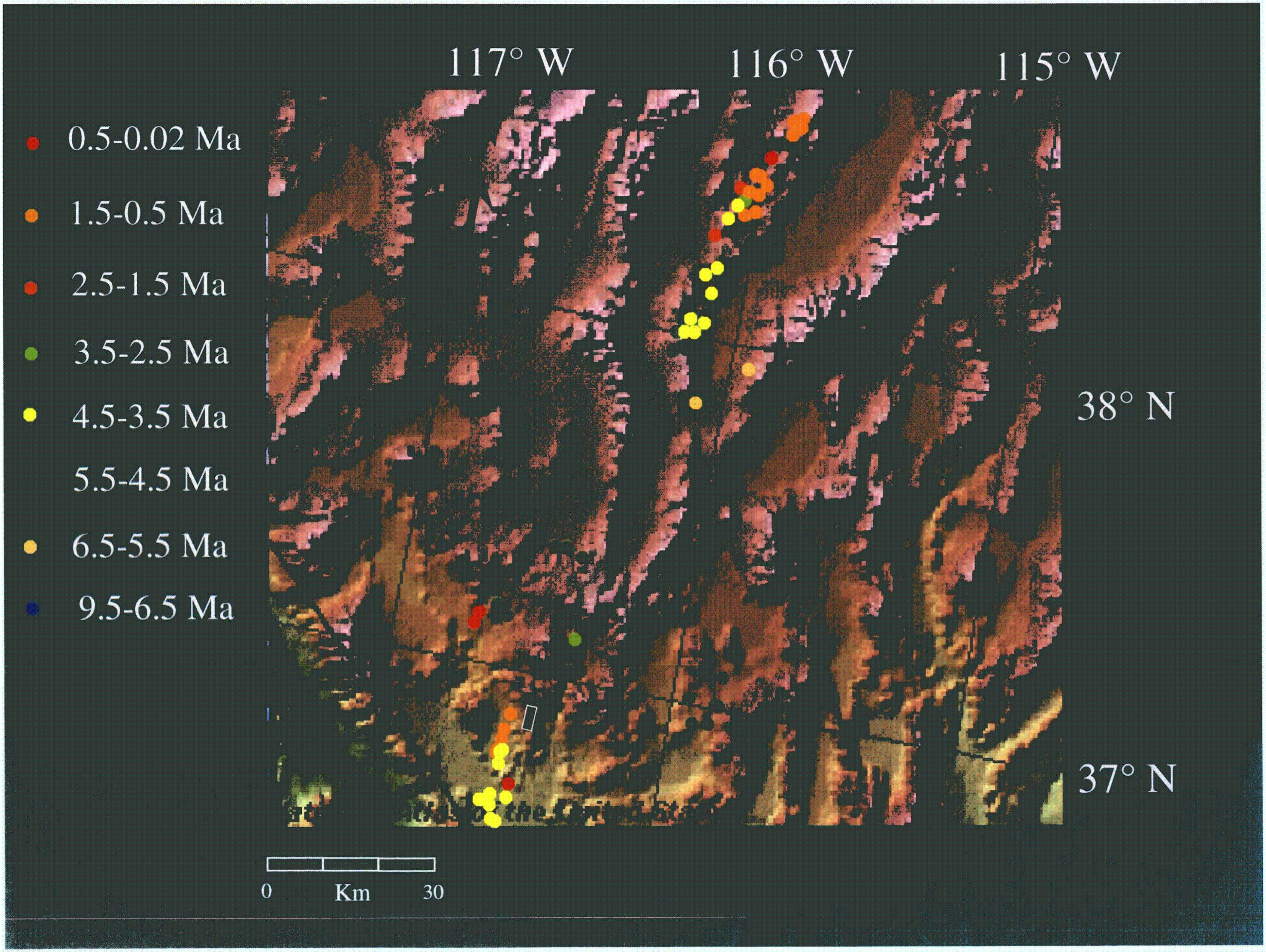


Nevada
LUNAR CRA
Lunar Crater
Reveille Range
MONO CRAT
RED CONES
Death Valley-Pancake Range Belt (Vaniman et al. 1982).
SANTA CLA
KOLOB
UBEHE
Yucca Mountain
CRATER FL
GOLDEN TR
Death Valley
UIN
Las Vegas
las vegas nv
215
COSO VOLC
© 2005 TeleAtlas
Image © 2005 EarthSat
15
Google
Pointer 37°18'07.09" N 115°50'28.75" W elev 4665 ft
Streaming 100%
Eye alt 291.79 mi

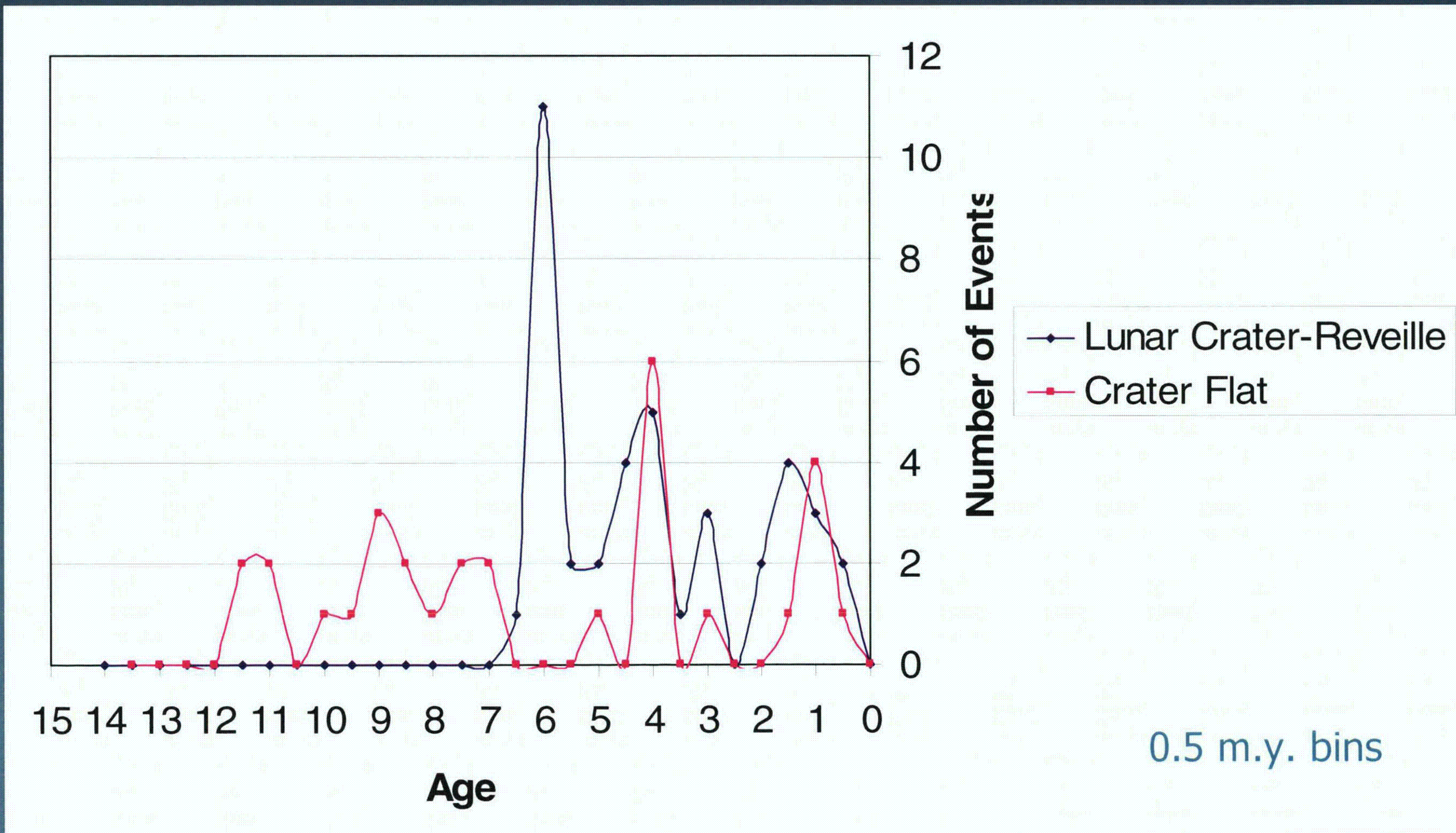
Cinder Cone in Death Valley Volcanic Field

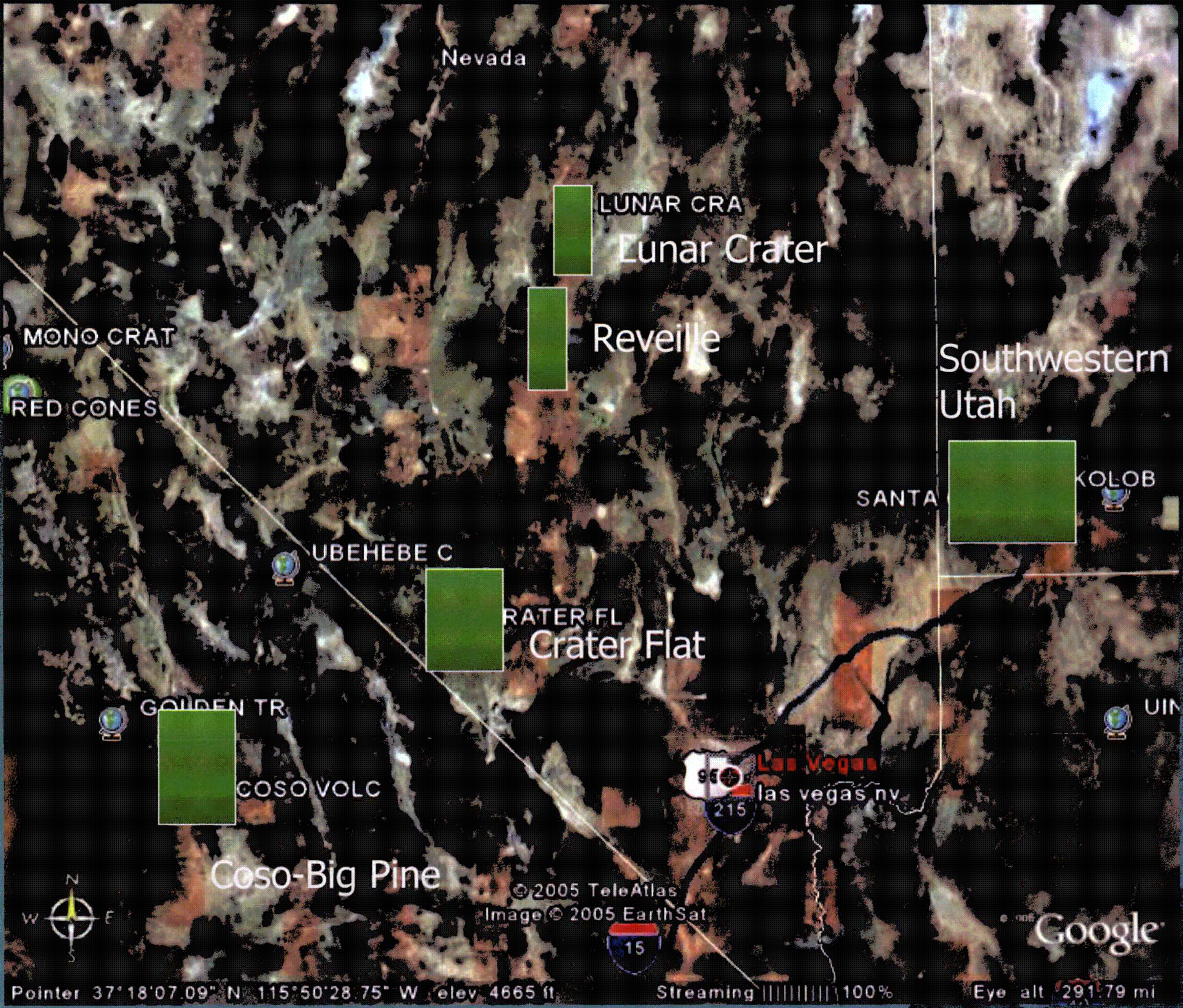

117° W
116° W
115° W
N
Lunar Crater volcanic field
Reveille Range
38° N
Sleeping Butte and Thirsty Mesa
Buckboard Mesa
Crater Flat
Yucca Mountain
37° N
0
Km
30

Index Map

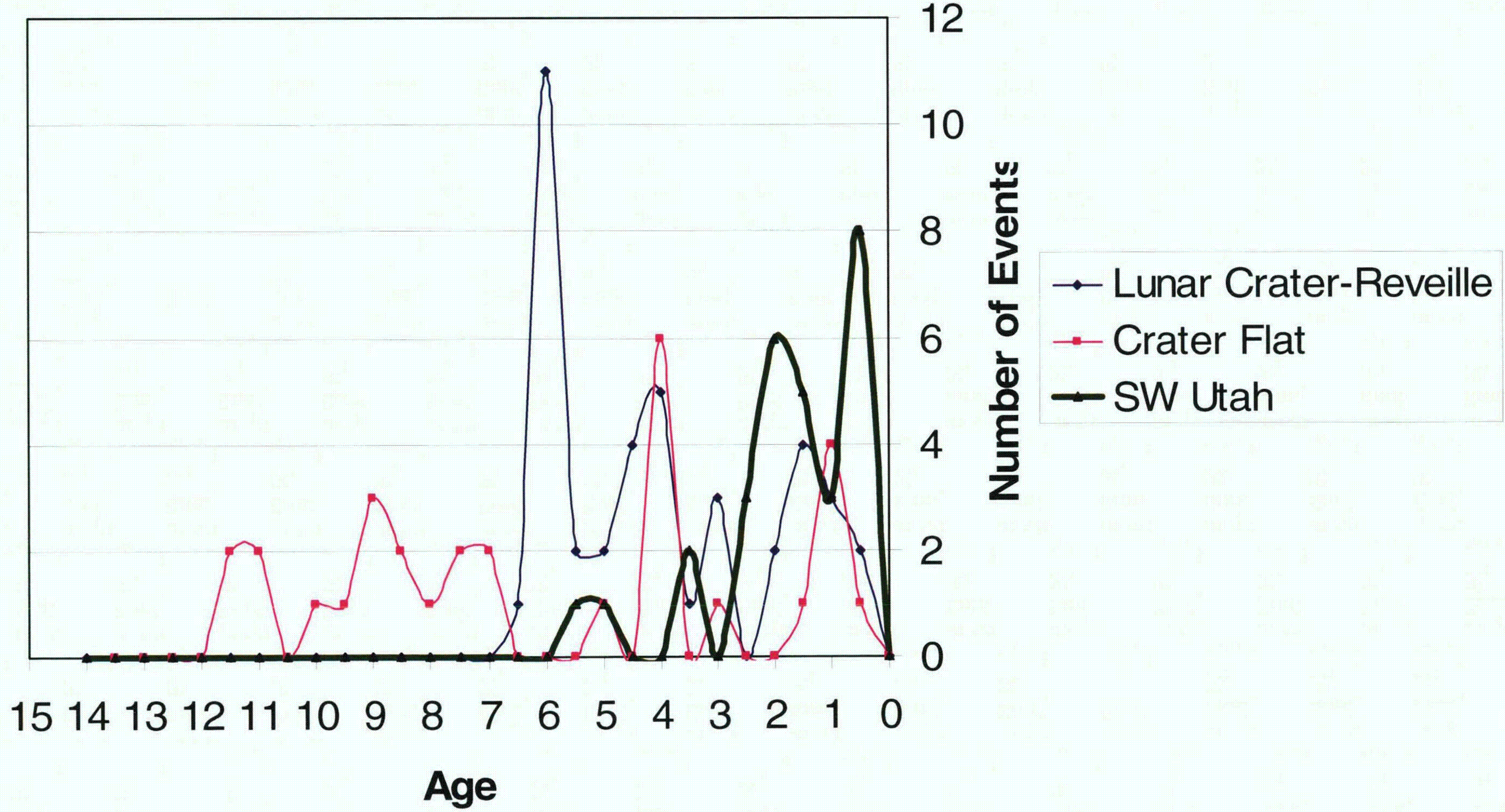

117° W
116° W
115° W
38° N
37° N
0.5-0.02 Ma
1.5-0.5 Ma
2.5-1.5 Ma
3.5-2.5 Ma
4.5-3.5 Ma
5.5-4.5 Ma
6.5-5.5 Ma
9.5-6.5 Ma
0
Km
30

Number of Dated Volcanic Events vs. Age

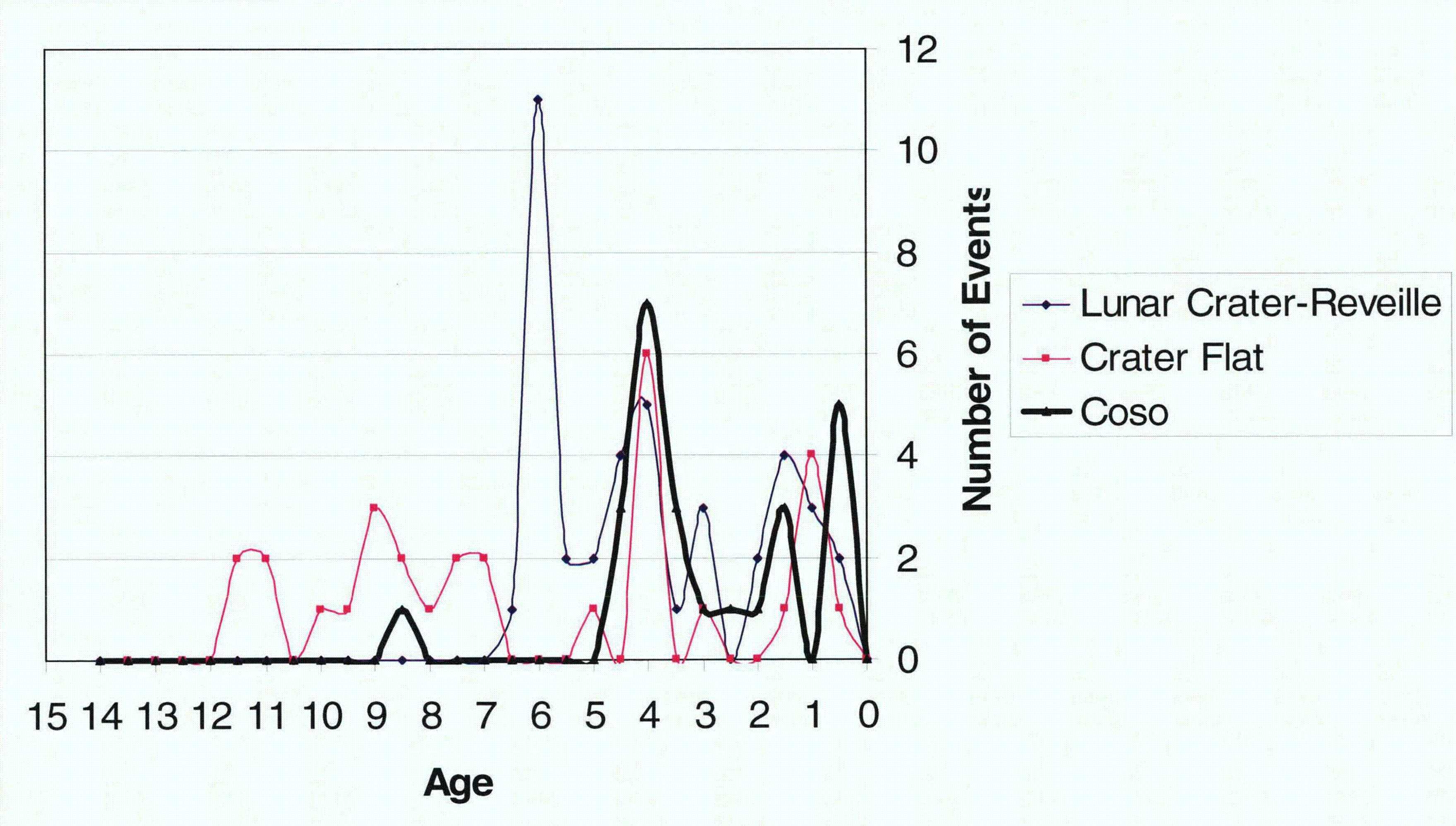



Nevada
LUNAR CRA
Lunar Crater
Reveille
MONO CRAT
RED CONES
Southwestern Utah
SANTA
KOLOB
UBEHEBE C
RATER FL
Crater Flat
GOLDEN TR
COSO VOLC
Coso-Big Pine
UIN
Las Vegas
las vegas nv
215
15
© 2005 TeleAtlas
Image © 2005 EarthSat
Google
Pointer 37°18'07.09" N 115°50'28.75" W elev 4665 ft
Streaming 100%
Eye alt 291.79 mi

Adding data from southwestern Utah



Coso-Lone Pine Volcanic Field



Depth of Melting

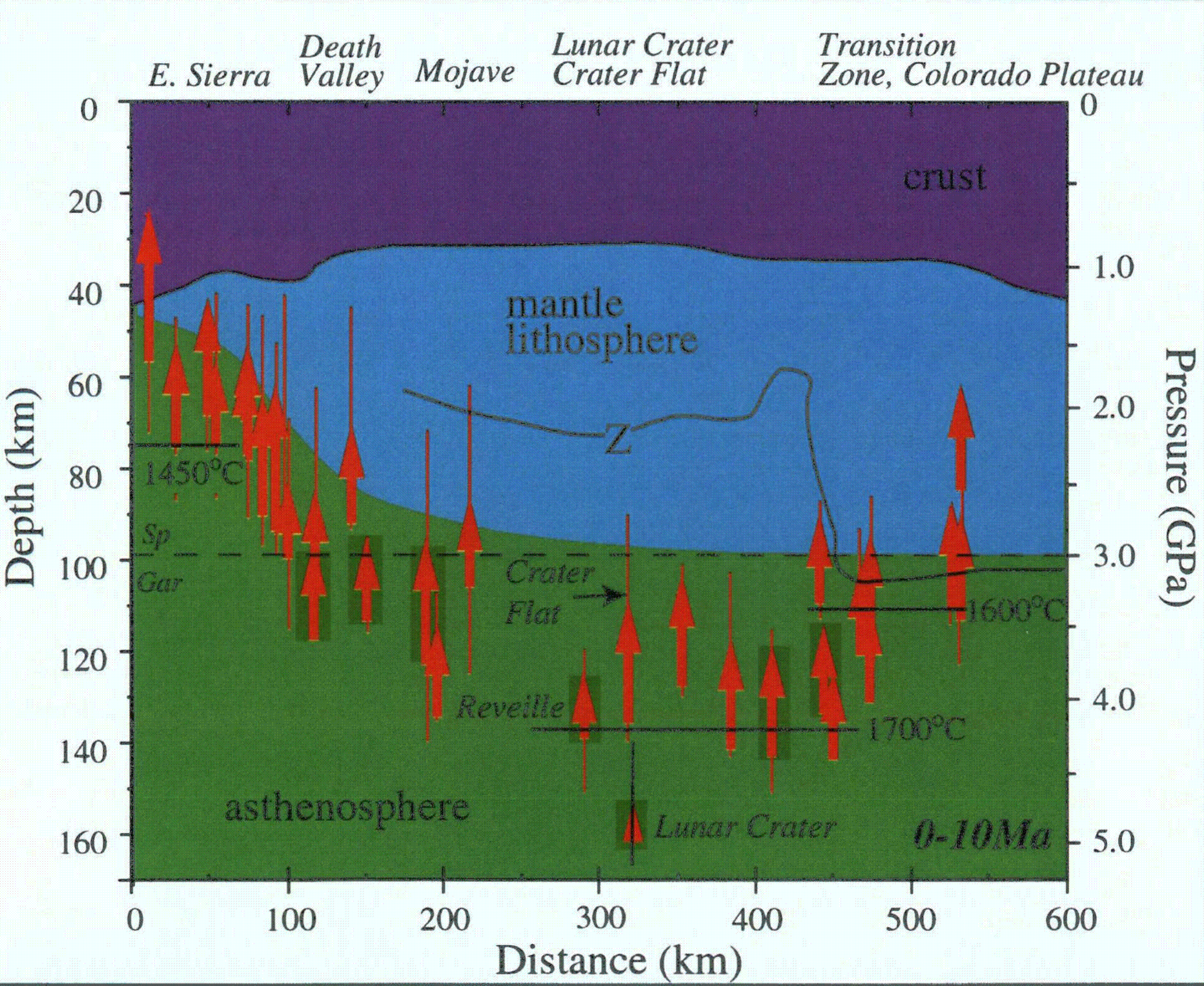
- Based on 1000 samples; 400 analyzed at UNLV (major and trace elements) and the University of Kansas (Pb, Sr and Nd isotopes).
- All basalts are younger than 8.5 Ma

- Reference: Wang, Plank, Walker, Smith, 2002, Journal of Geophysical Research, v. 107, p. 2017.

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

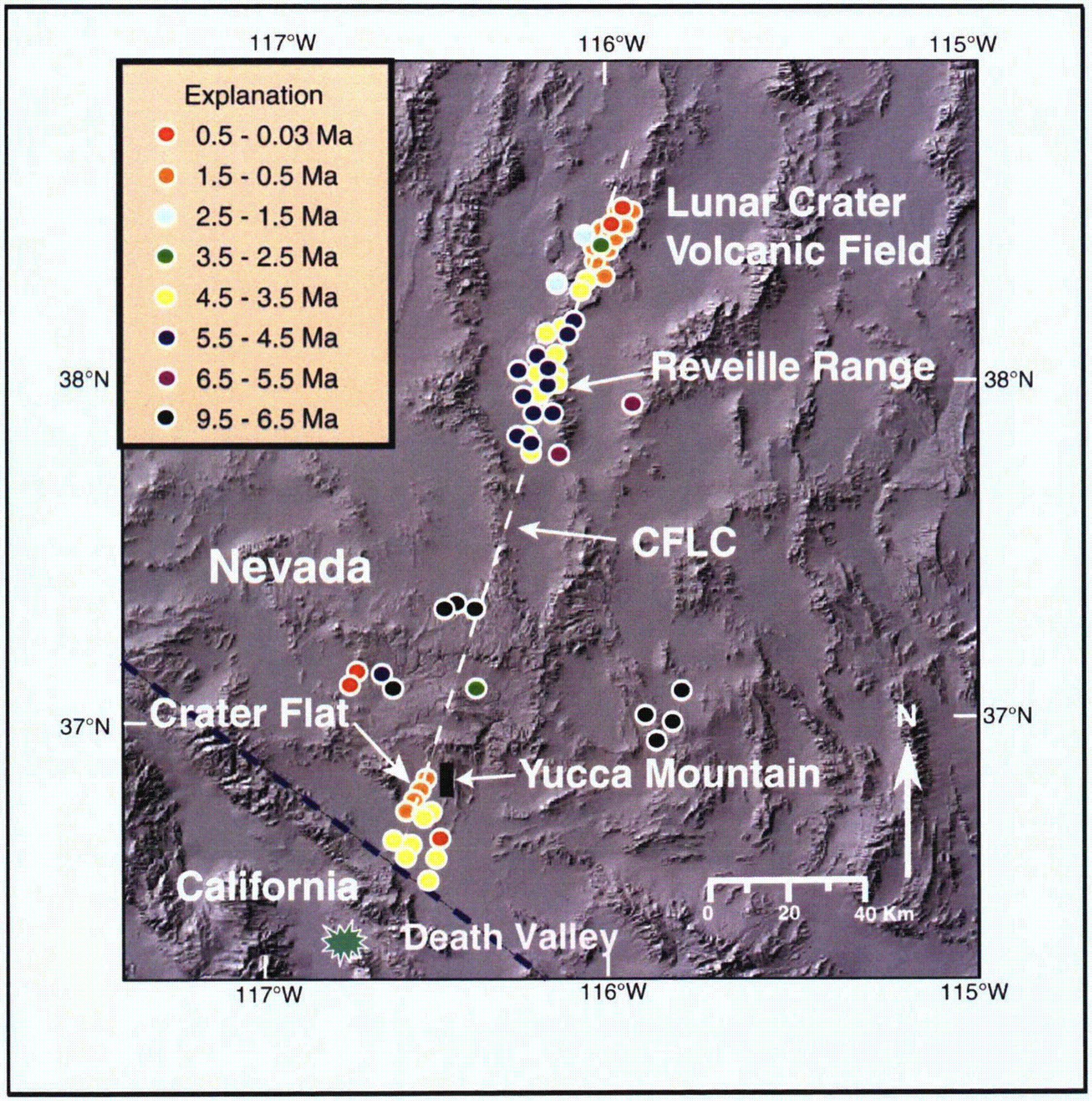


From Wang et al. (2002)

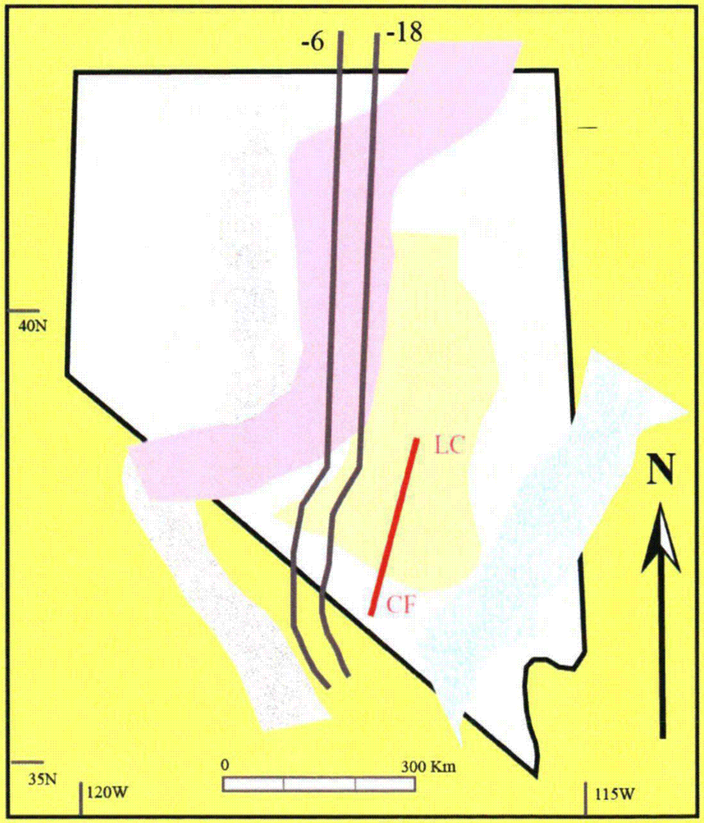
Melting beneath the Crater Flat–Lunar Crater zone is especially deep. Deep melting requires hot and buoyant mantle with mantle potential temperatures about 200 °C greater than those in the western Great Basin (Wang et al., 2002).

Blue LM from Jones et al. (1996). Z boundary from Zandt et al. (1995). References in Wang et al. (2002).

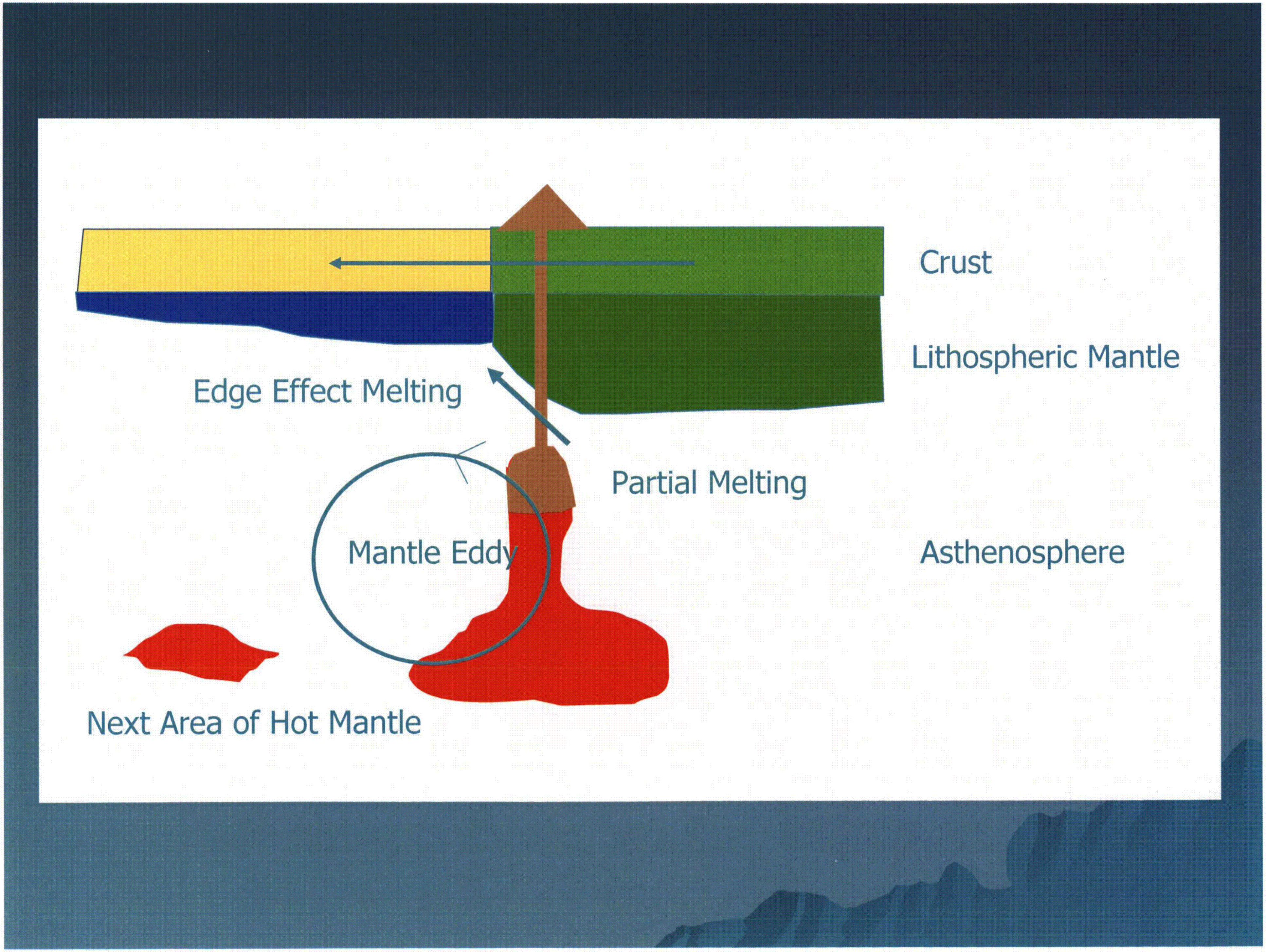
Crater Flat-Lunar Crater Volcanic Field



From Smith et al. (2002) and Smith and Keenan (2005)



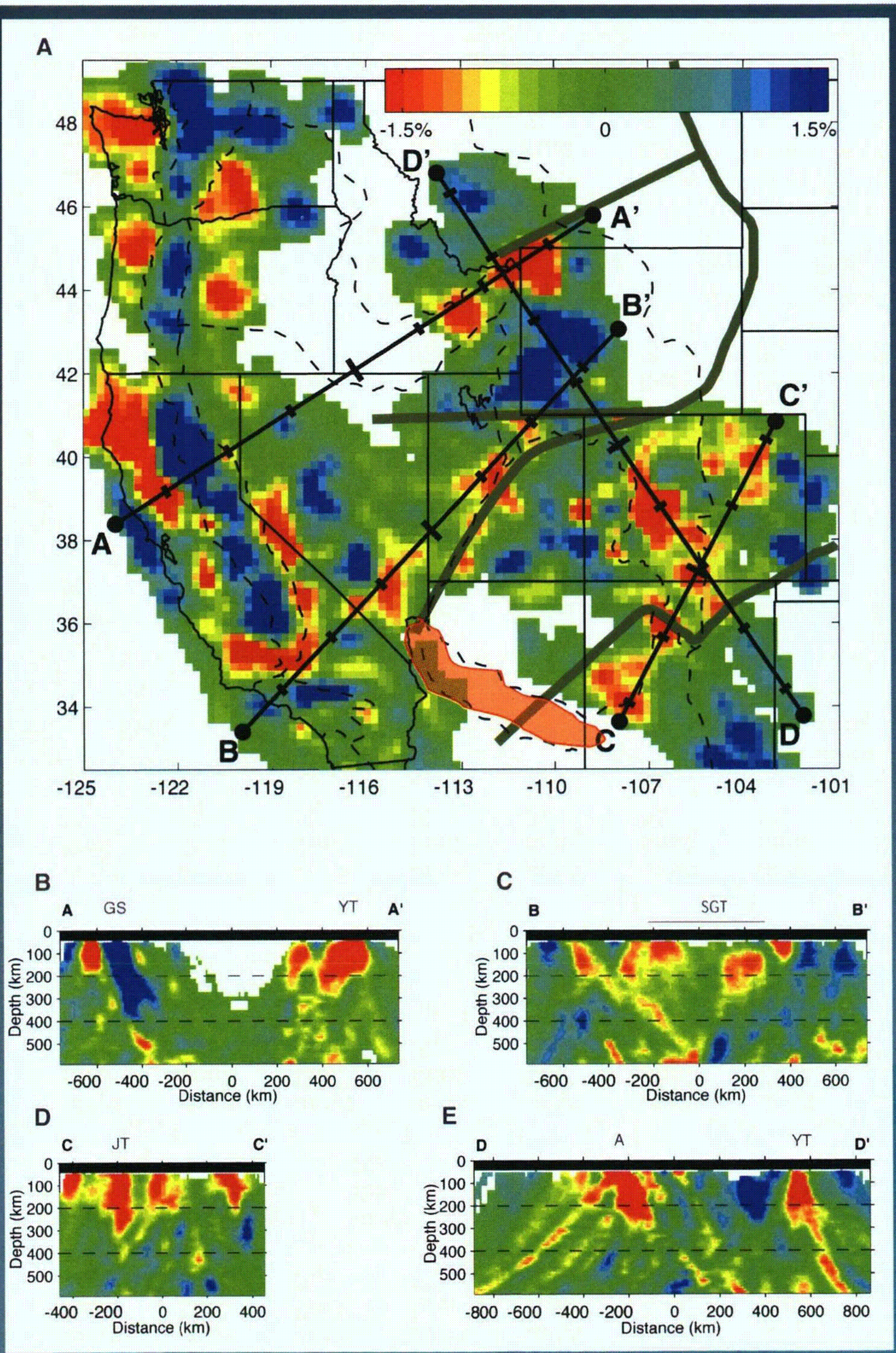
Thickening of lithosphere during Paleozoic and Mesozoic tectonic events along the western boundary of the craton, and thinning of lithosphere beneath the Sierra Nevada may have resulted in the formation of a mantle keel.


Crust
Lithospheric Mantle
Edge Effect Melting
Partial Melting
Mantle Eddy
Asthenosphere
Next Area of Hot Mantle

Western US relative P-velocity variations

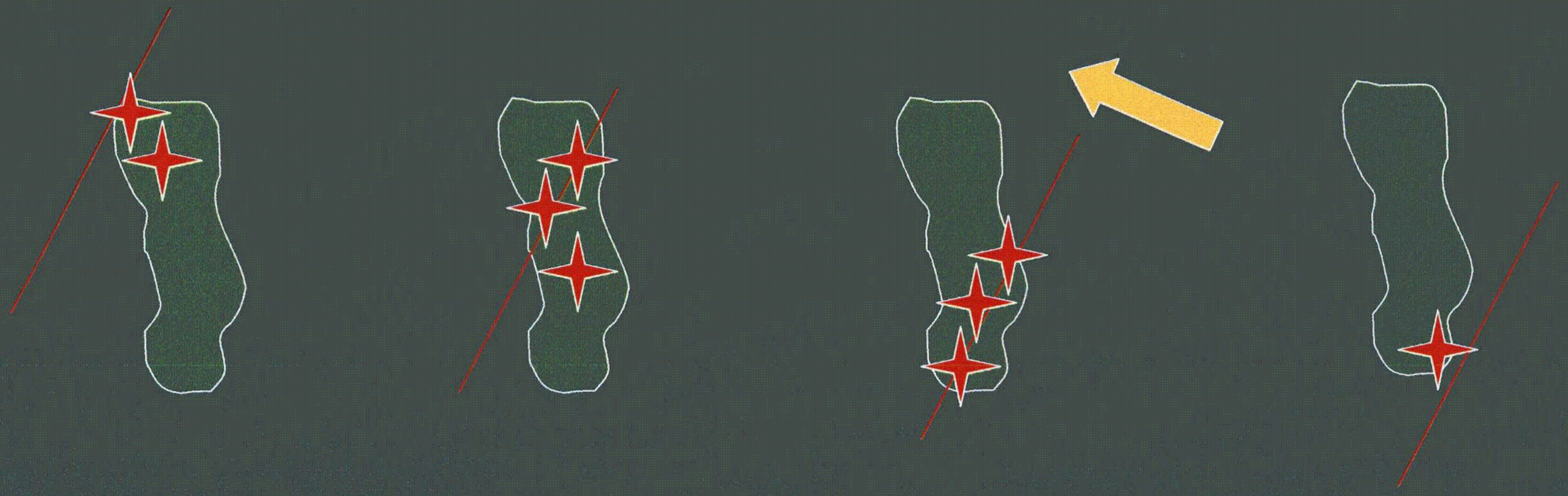
Low velocity zones (red) may be areas of hotter lithosphere or asthenospheric.

From presentation by K. Dueker, University of Wyoming



Size and Shape of a Future Volcanic Field

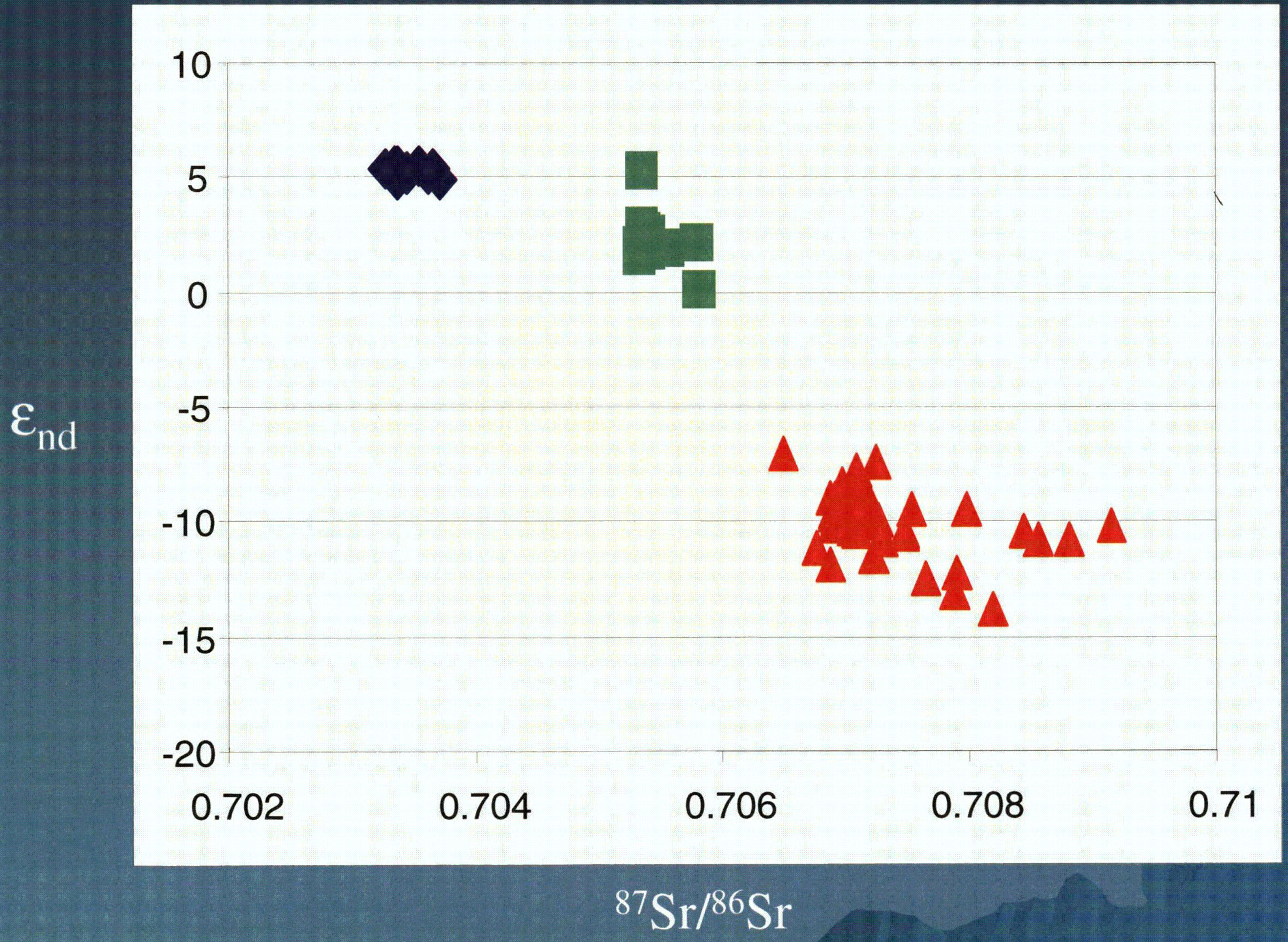
- Dependent on the 3D geometry of the area of hot asthenosphere.

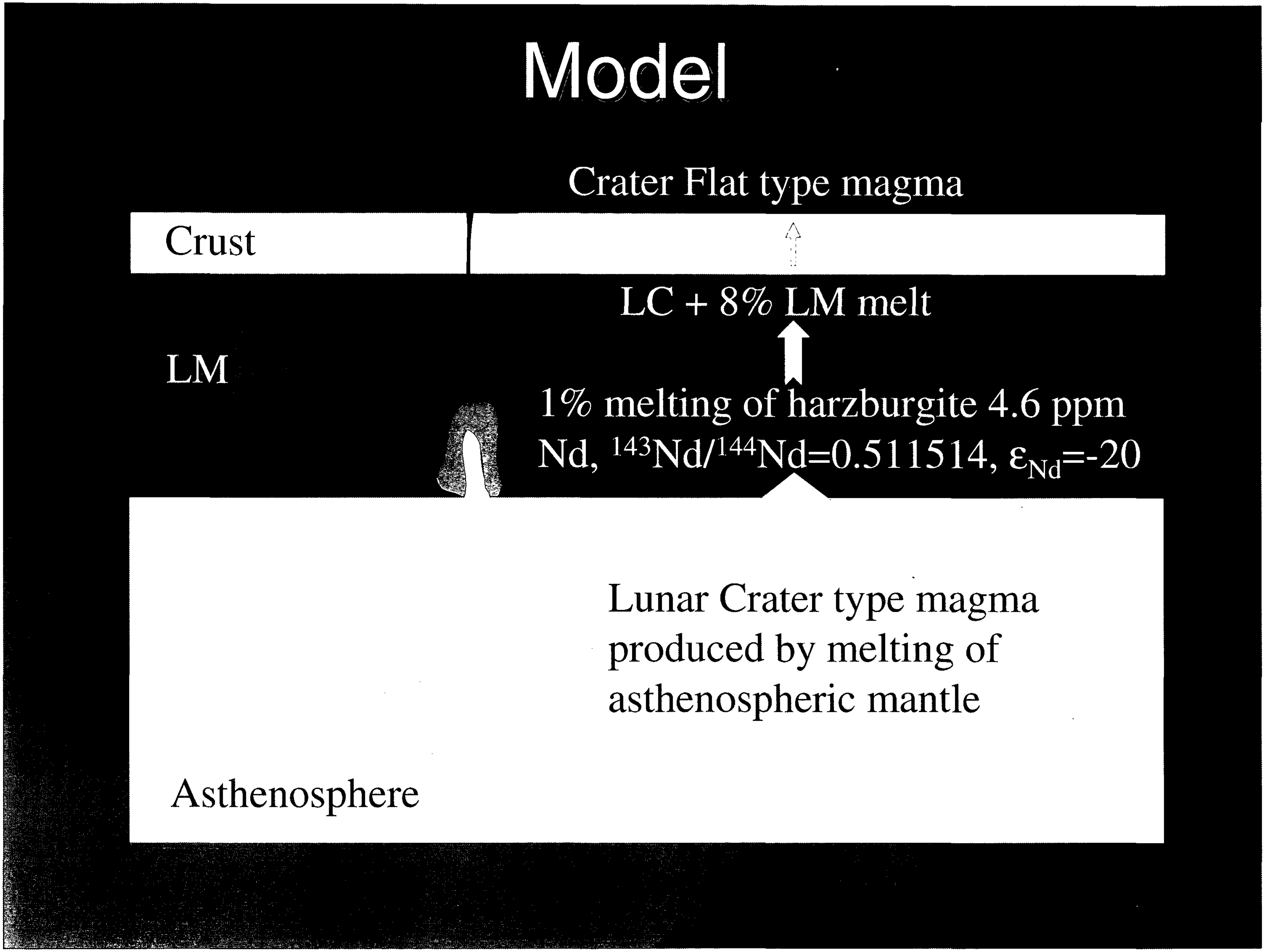


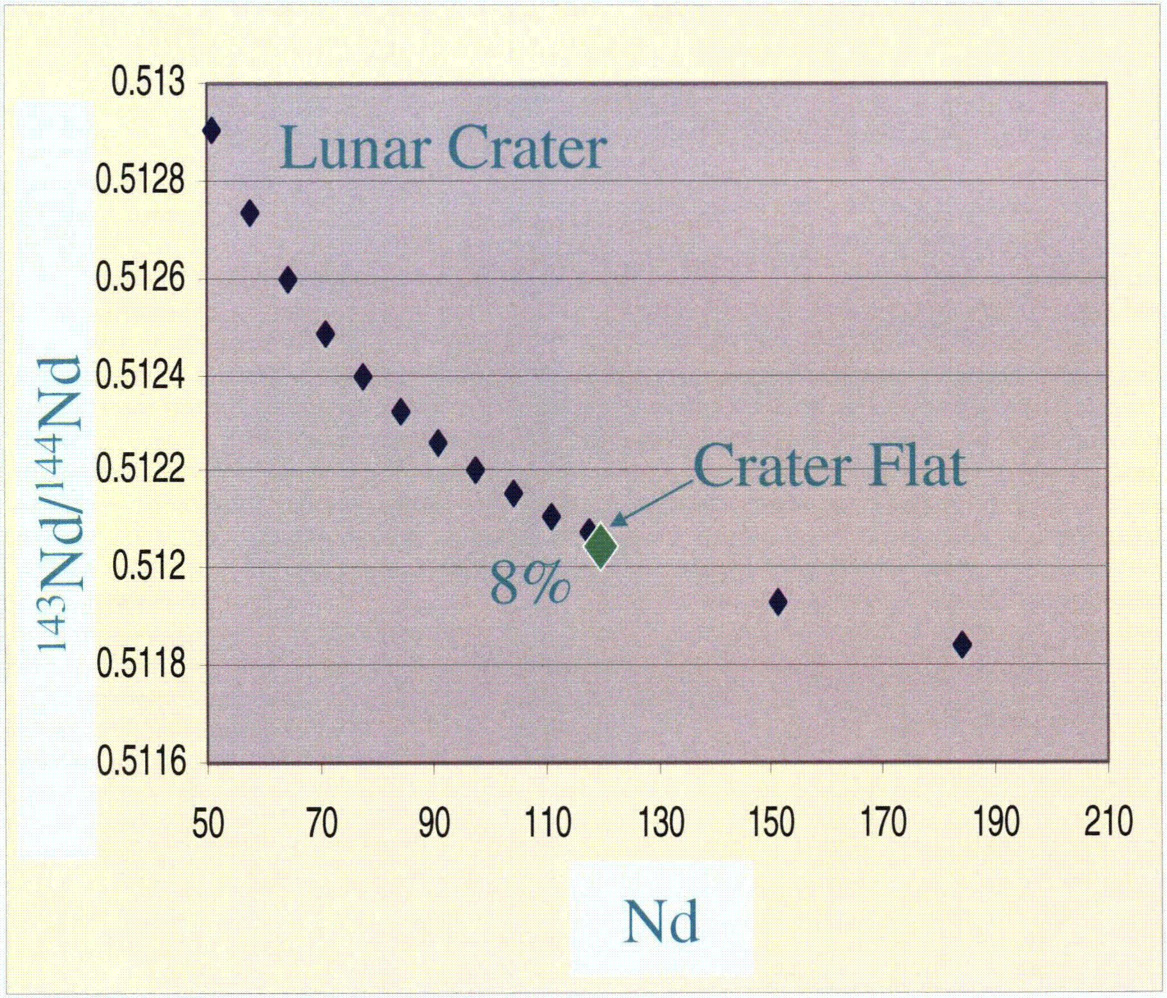
Volume of magma produced depends on the length of the Melting column

Red line represents rising hot asthenosphere

What is the explanation for the different isotopic and trace element characteristics between Lunar Crater and Crater Flat?




Model
Crater Flat type magma
Crust
LC + 8% LM melt
LM
1% melting of harzburgite 4.6 ppm
Nd, $^{143}Nd/^{144}Nd$=0.511514, ε_{Nd}=-20
Lunar Crater type magma
produced by melting of
asthenospheric mantle
Asthenosphere



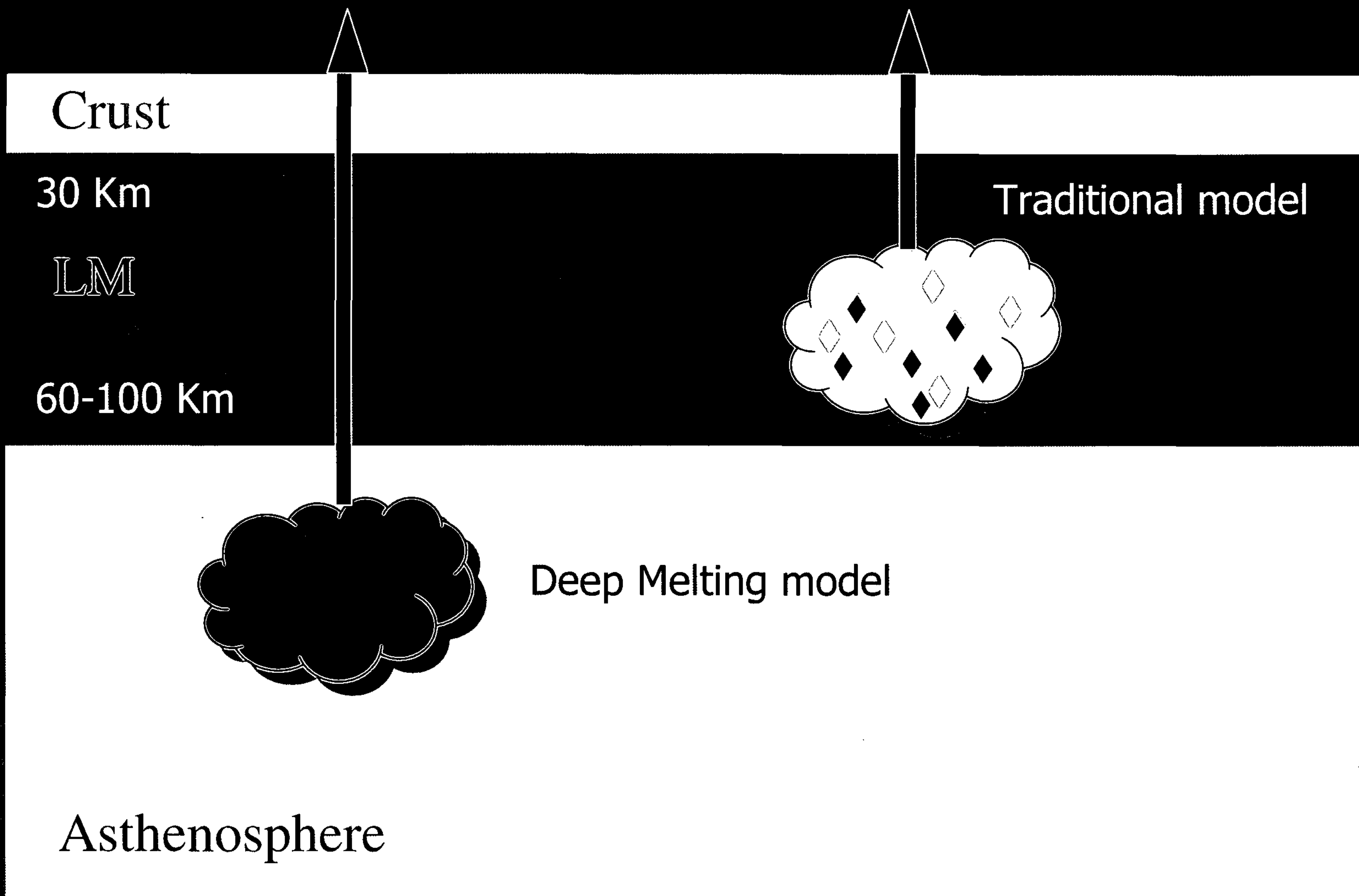
Is there an old Lithospheric mantle (early Proterozoic or late Archean) in the southern Great Basin?

Lee et al. (2000) in Nature Indicate that old LM exists in Great Basin. Re-Os model ages of 1.8 to 3.4 Ga.

Implications

- Probability studies are dependent on the petrologic model
- Shallow melting model implies waning volcanism
- Deep melting model implies that another peak of volcanism within the belt is probable.

Model


Crust
30 Km
LM
60-100 Km
Traditional model
Deep Melting model
Asthenosphere

Conclusion

- It is important to know why in order to determine when.
- Probability studies are dependent on the petrologic model.

Selected References

- Harry, D.L. and Leeman, W.P., 1995, Partial melting of melt metasomatized subcontinental lithospheric mantle and the magma source potential of the lower lithosphere: Journal of Geophysical Research, v. 100, p. 10255-10269.
- Hawkesworth, C., Turner, S., Gallagher, K., Bradshaw, T., and Rogers, N., 1995, Calc-alkaline magmatism, lithospheric thinning, and extension in the Basin and Range: Journal of Geophysical Research, v. 100, p. 10271-10286.
- Ionov, D.A. and Hoffmann, A.W., 1995, Nb-Ta rich amphiboles and micas: implications for subduction related metasomatic trace element fractionations: Earth and Planetary Science Letters, v. 131, p. 341-356.
- Lee, Cin-Ty, Yin, Qingzhu, Rudnick, R.L., Chesley, J.T., Jacobsen, S.B., 2000, Osmium isotopic evidence for Mesozoic removal of lithospheric mantle beneath the Sierra Nevada, California: Nature, v. 289, p. 1912-1916.
- Pearson, D.G. and Nowell, G.M., 2002, The continental lithospheric mantle: characteristics and significance as mantle reservoir: Phil. Transactions of the Royal Society of London Series A, v. 360, p. 2383-2410.
- Smith, E.I. and Keenan, D.L., 2005, Yucca Mountain could face greater volcanic threat: EOS (Transactions of the American Geophysical Union), v. 86, no. 35, p. 317,321.
- Smith, E.I., Plank, T., Keenan, D.L., 2002, Episodic volcanism and hot mantle: implications for volcanic hazard studies at the proposed Nuclear Waste Repository at Yucca Mountain, Nevada: GSA Today, v. 12, no. 4, p. 4-10.
- Wang, K., Plank, T., Walker, J.D., Smith, E.I., 2002, A mantle melting profile across the Basin and Range, southwestern USA: Journal of Geophysical Research, v. 107, DOI 10.1029/2001JB000209.
- Yogodzinski, G.M. and Smith, E.I., 1995, Isotopic domains and the area of interest for volcanic hazard assessment in the Yucca Mountain area: EOS (Transactions of the American Geophysical Union), v. 76, no. 46, p. 699.

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

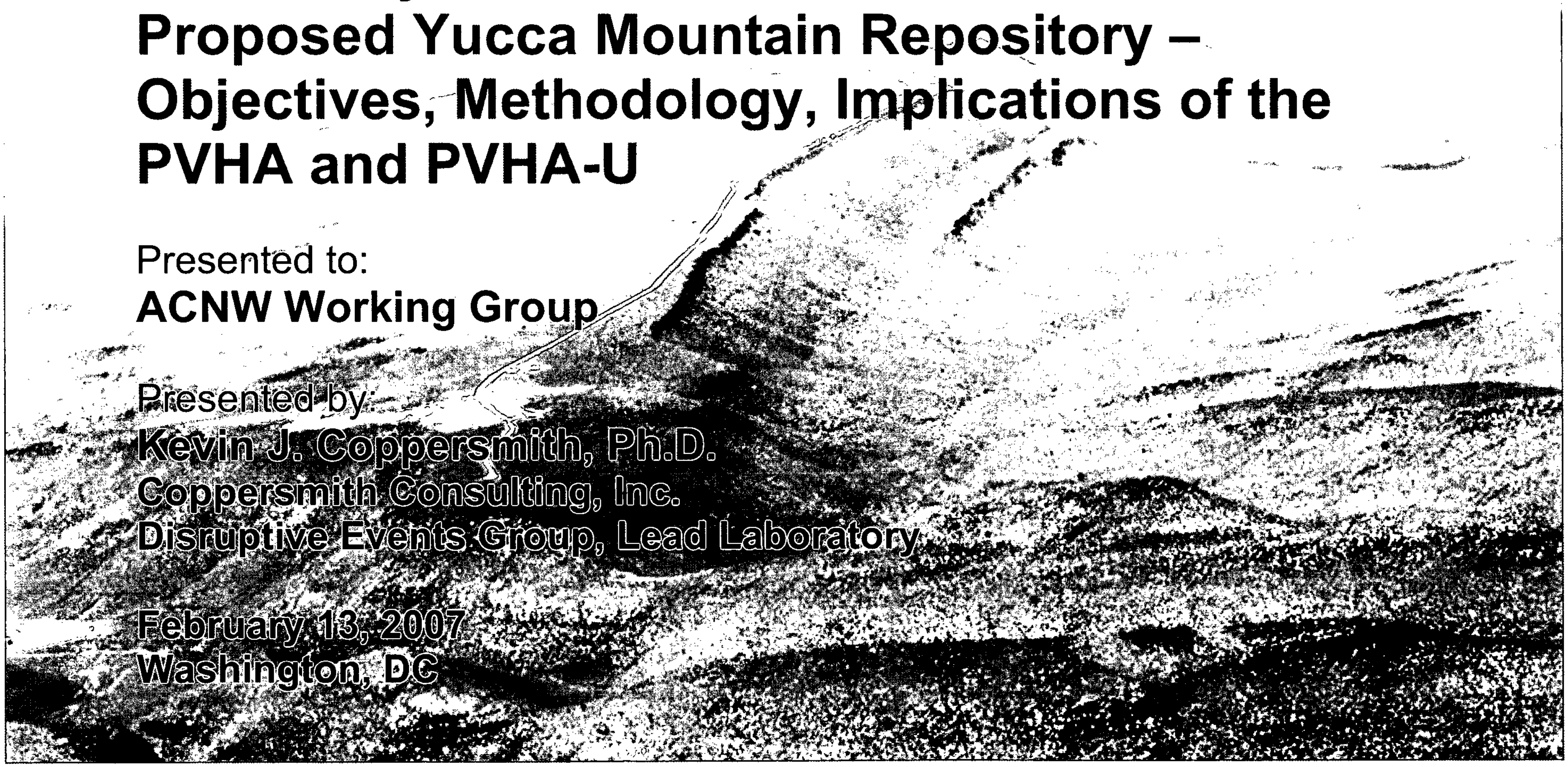
www.ocrwm.doe.gov

The Use of Expert Elicitation in Predicting the Probability of Volcanic Events at the Proposed Yucca Mountain Repository – Objectives, Methodology, Implications of the PVHA and PVHA-U

Presented to:
ACNW Working Group

Presented by:
Kevin J. Coppersmith, Ph.D.
Coppersmith Consulting, Inc.
Disruptive Events Group, Lead Laboratory

February 13, 2007
Washington, DC



Objectives of Presentation

- To summarize the evolution of formal expert elicitation methodologies for hazard analysis at US NRC-regulated facilities
  - Lessons learned
  - Solutions to identified problems
- To define the essential steps in an expert elicitation
- To describe the basic elements of a Probabilistic Volcanic Hazard Analysis (PVHA)
- To summarize the methodology used in PVHA-96 (CRWMS M&O 1996)
- To review the methodology being used in the PVHA-Update (PVHA-U)

Historical Context for Formal Expert Elicitations

- Two large expert elicitations conducted in mid-1980s of seismic hazard at central and eastern US nuclear power plant sites (Bernreuter et al. 1989; EPRI 1986)
- Substantial and significant uncertainties in large earthquake potential

Historical Context for Formal Expert Elicitations (continued)

- **Methodologies differed in several aspects**
  - Data dissemination
  - Experts versus expert teams
  - Interactions of experts
  - Interviews versus questionnaires
  - Feedback mechanisms
  - Documentation
  - Association of assessments to experts by name
  - Aggregation methodology

Historical Context for Formal Expert Elicitations (continued)

- **Hazard results differed significantly at individual sites**
  - **Mean hazard is especially different; medians similar**
  - **Analysis indicates that differences are due to *process* rather than *technical* issues**
- **SSHAC (1997) study carried out to address the problems with past studies and to establish guidance for future expert elicitations (sponsored by NRC, EPRI, and DOE)**

Historical Context for Formal Expert Elicitations (continued)

- **Problems identified from past studies**
  - Overly diffused responsibility
  - Insufficient face-to-face interaction
  - Inflexible aggregation schemes
  - Imprecise or overly narrow objectives
  - Outlier experts
  - Insufficient feedback

Elements of SSHAC Methodology

- **Goal of all probabilistic hazard analyses**

  "To represent the center, the body, and the range of the technical interpretations that the larger informed technical community would have if they were to conduct the study"

- **Recognition that PVHA is not a typical "expert elicitation" issue, but one that involves scientific assessments, interactions, and learning**

- **Probability training at outset of study to help avoid common cognitive and motivational biases**

Elements of SSHAC Methodology (continued)

- Notion of the "views of the larger informed technical community" leads to defined expert roles and responsibilities
- Experts must be "evaluators" not "proponents"
- Multiple opportunities for expert interaction, challenge, and defense to assist in understanding and integrating range of views in community
- Learning occurs throughout the process

Elements of SSHAC Methodology (continued)

- Experts encouraged to revisit and revise their assessments up until the time they finalize their Elicitation Summaries
- Technical Facilitator Integrator (TFI) is responsible for weighing the experts; fundamental criteria relate to expert's role as an evaluator
- Equal weighting of the expert assessments is a goal, but is only defensible if certain conditions are met

Steps in Expert Elicitation

- Keeney and von Winterfeldt (1991) and PRA Working Group (1994)
  - Selecting experts
  - Organizing assessments
  - Preparing for the elicitation
  - Processing expert judgment
  - Documenting

Steps in Expert Elicitation (continued)

- 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
  - Postelicitation 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
  - Discussion and refinement of the technical issues
  - Training for elicitation
  - Group interaction and individual elicitation
  - Analysis, aggregation, and resolution of disagreements
    - The role of TFI as a facilitator
    - The role of TFI as an integrator
  - Documentation and communication

Steps in Expert Elicitation (continued)

- PVHA-96
  - 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

Criteria for Conducting Expert Elicitation

NRC Branch Technical Position (Kotra et al. 1996, p. 15)

(1) In matters important to the demonstration of compliance, the use of formal expert elicitation should be considered whenever one or more of the following conditions exist:

(a) Empirical data are not reasonably obtainable, or the analyses are not practical to perform;

(b) Uncertainties are large and significant to a demonstration of compliance;

(c) More than one conceptual model can explain, and be consistent with, the available data; or

(d) Technical judgments are required to assess whether bounding assumptions or calculations are appropriately conservative.

Criteria for Conducting Expert Elicitation
(continued)

Senior Seismic Hazard Analysis Committee (SSHAC 1997, p. 24)

- *The selection of Level 4 (formal expert elicitation) will consider the following criteria:*
  - *The significance of the issue to the final hazard results*
  - *The issue's technical complexity and level of uncertainty*
  - *The amount of technical contention about the issue in the technical community*
  - *Important non-technical considerations such as budgetary, regulatory, scheduling, or other concerns*

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

- Aleatory variability: random variations, not reducible with additional data/information
  - E.g., location of next event, volume of next event

Basic Elements of PVHA (continued)

- Epistemic uncertainty: due to lack of knowledge, reducible with additional data/information
  - E.g., uncertainties in average rate; alternative models of temporal distribution (Poisson versus episodic)
- Tools
  - Influence diagrams
  - Logic trees; particularly useful for alternative conceptual models and dependencies among parameters
  - Probability distributions

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

- Pool of candidates developed with the assistance of acknowledged leaders in the field
- Panel of ten experts selected
- Expert selection criteria
  - Earth scientist of high professional standing and widely *recognized competence* based on academic training and relevant experience. Tangible evidence of expertise, such as written documentation of research in referred journals and reviewed reports is required.

Expert Selection Process PVHA-96 (continued)

- Expert selection criteria (continued)
  - Understanding of the general problem area through *experience* collecting and analyzing research data for relevant volcanic studies in the southern Great Basin or similar extensional tectonic environments; prior familiarity with the data available for the Yucca Mountain site will be an asset, but not a requirement for participation
  - Availability and willingness to participate as a named panel member, including a *commitment* to devoting the necessary time and effort to the project and a willingness to explain and defend technical positions

Expert Selection Process PVHA-96 (continued)

- **Expert selection criteria (continued)**
  - Personal attributes that include strong *communication and interpersonal skills*, flexibility and impartiality, and the ability to simplify. Individuals will be asked specifically not to act as representatives of technical positions taken by their organizations, but rather to provide their individual technical interpretations and assessments of uncertainties.
  - Selection would contribute to a *balanced panel* of experts with diverse opinions, areas of technical expertise, and institutional/organizational backgrounds (e.g., from government agencies, academic institutions, and private industry)

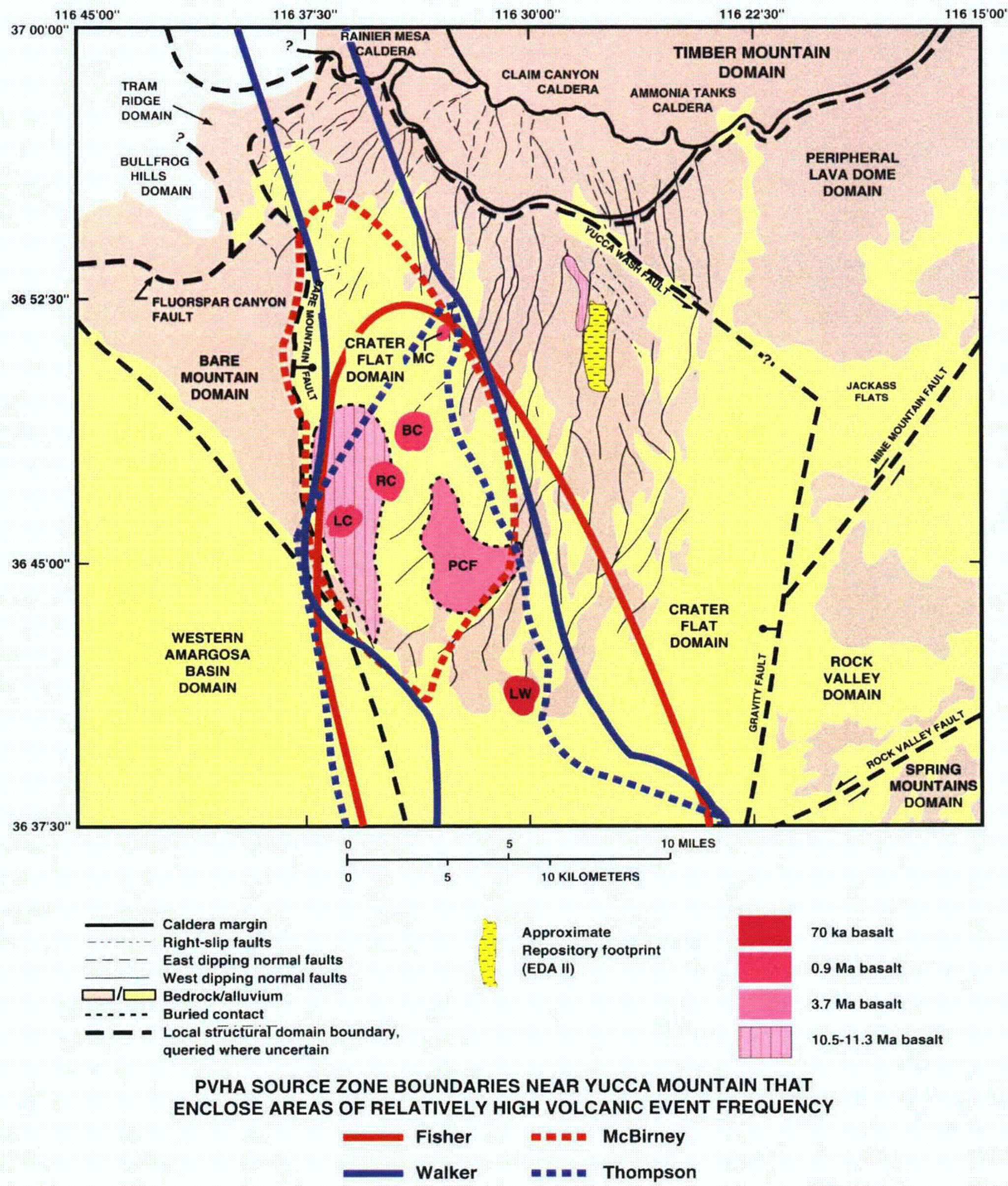
Expert Selection Process PVHA-96 (continued)

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

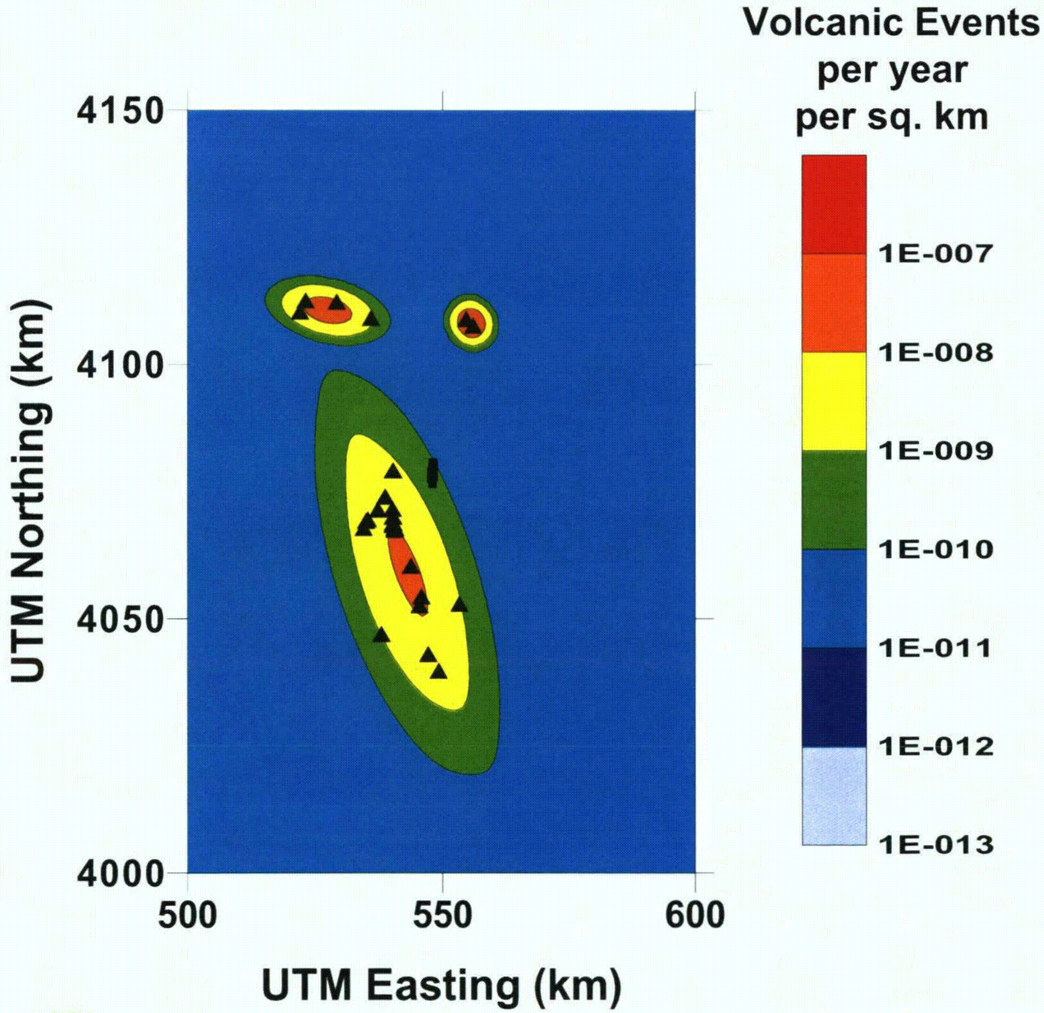
Examples of Temporal and Spatial Probability Models in PVHA-96

- Temporal models
  - Homogeneous Poisson models
  - Nonhomogeneous models: clustered, waxing or waning
- Spatial models
  - Locally homogeneous
    - "Source zones" defined by observed volcanoes, structural control, geochemical affinities, tectonic provinces, etc.
  - Nonhomogeneous
    - Parametric: bivariate Gaussian distribution for field
    - Nonparametric: kernel density function and smoothing operator

Examples of Volcanic Source Zones from PVHA-96

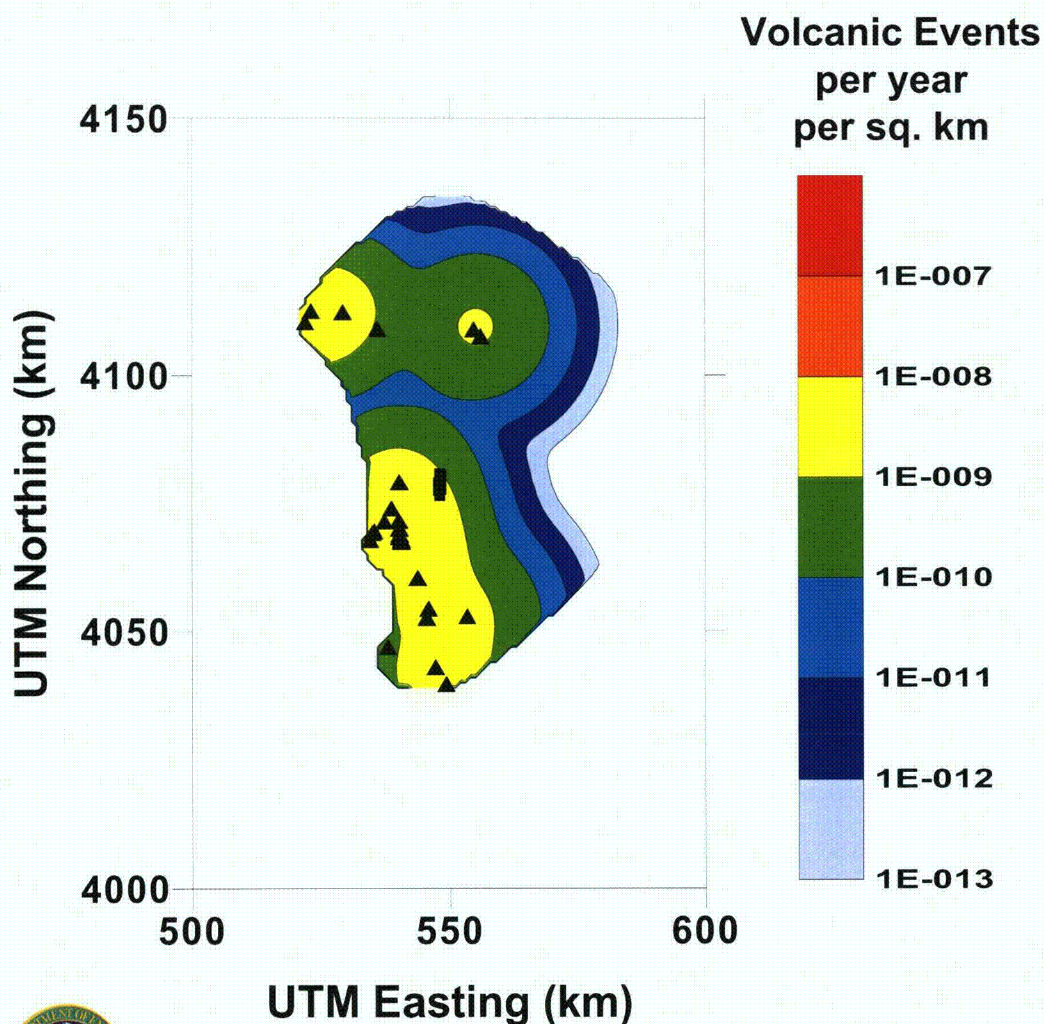


Bivariate Gaussian Field



- Fit of bivariate Gaussian distribution to locations of volcanic events
- Alternatives based on alternative interpretations of how to count volcanic cones as volcanic events

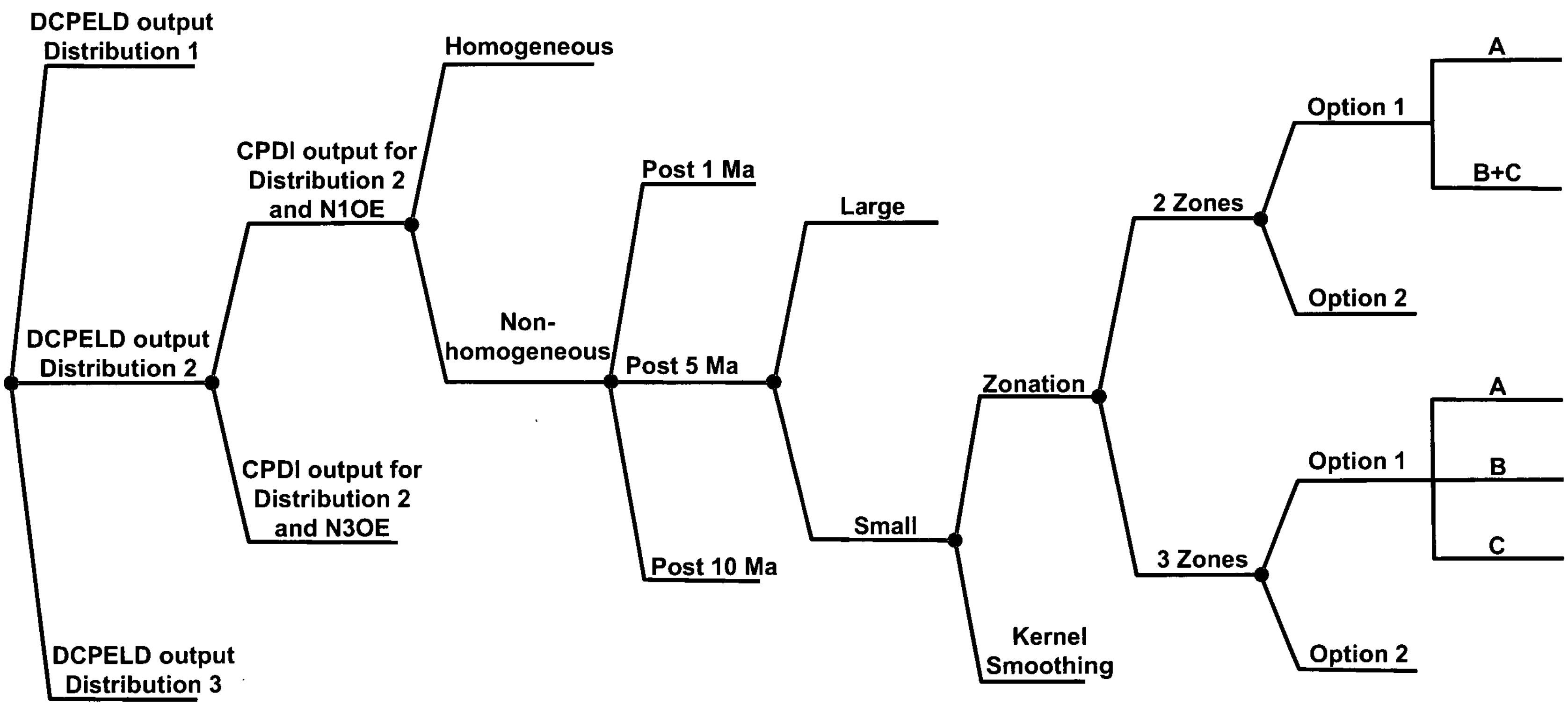
Nonparametric Distribution (Kernel Smoothing)



- Alternative smoothing parameters (kernel shapes) and alternative smoothing distances (parameter h)
- Alternatives based on alternative interpretations of how to count volcanic cones as volcanic events

Logic Tree Structure to Characterize Uncertainty in Volcanic Hazard

Event Length Distribution	Event Azimuth Distribution	Temporal Model	Time Period	Region of Interest	Spatial Model	Zonation Model	Zonation Boundaries	Sources



Routine VHTREE computes distribution over these levels of the logic tree.

Example Sensitivity Analysis PVHA-96

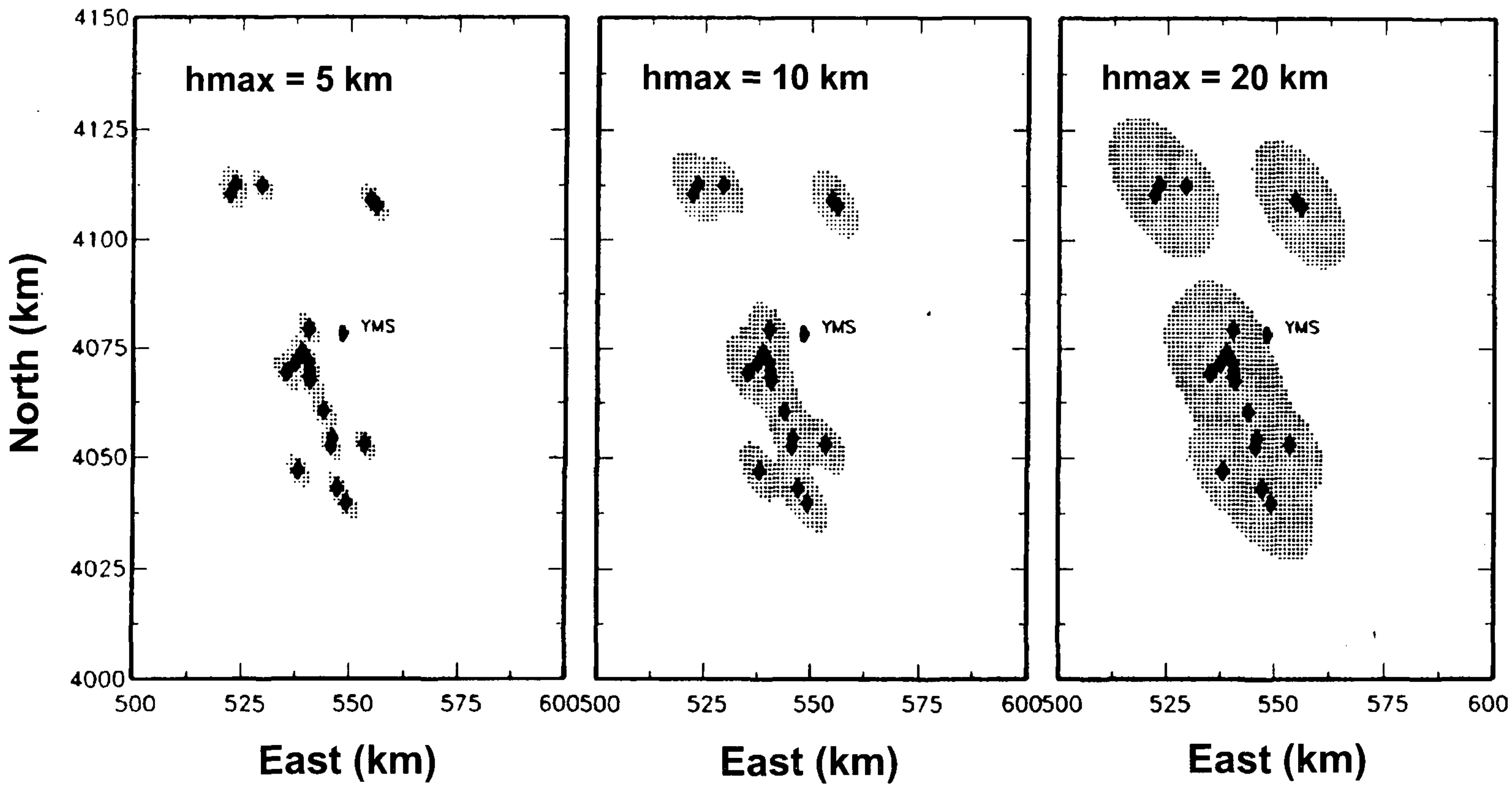


Figure 2.3 Kernel density estimates of the spatial distribution of future volcanic events. Stippled areas show the 95 percent density region computed using smoothing parameters of 5, 10, and 20 km. The density estimates were computed using the maximum number of events assessed for the post-5 Ma time period. YMS refers to the proposed Yucca Mountain repository site.

Example Sensitivity Analysis PVHA-96

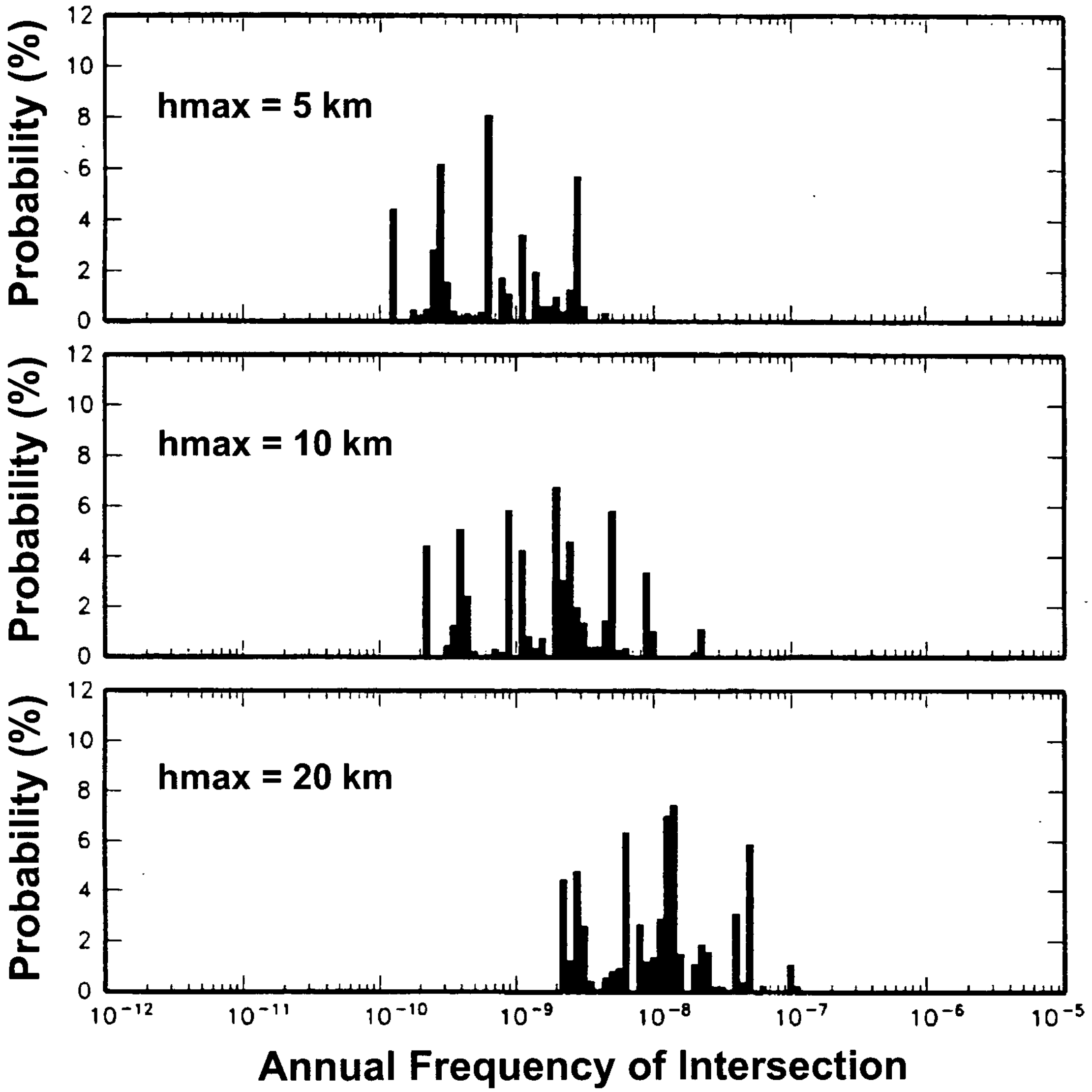
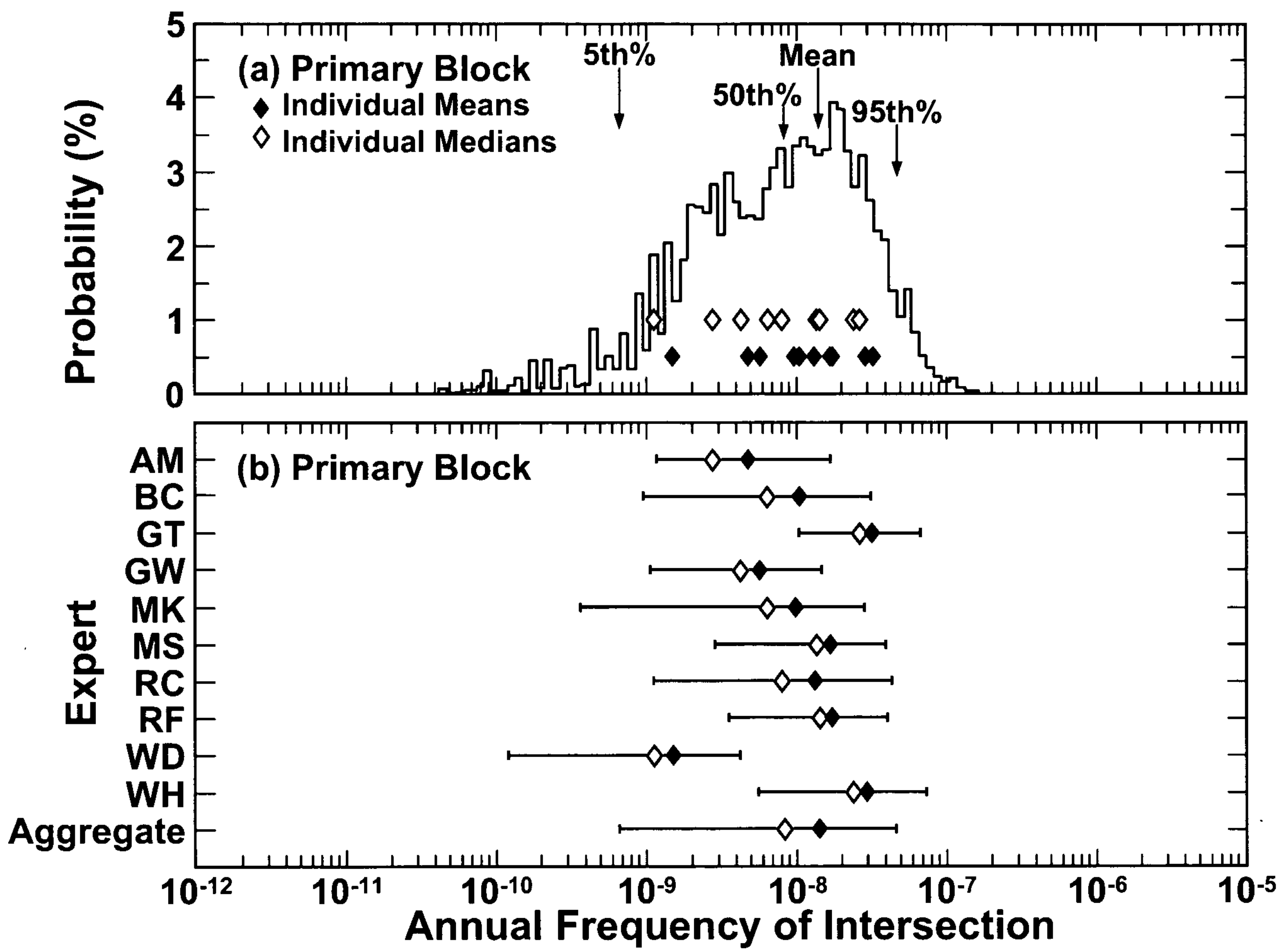


Figure 2.4 Effect of alternative values for the smoothing parameter on the computed distribution for annual frequency of intersecting the repository site. The hazard distributions were computed using the kernel density approach and smoothing parameters of 5, 10, and 20 km.

Annual Frequency of Intersection (PVHA-96)



History Leading to PVHA-U

- Following completion of the PVHA, new aeromagnetic and ground magnetic data became available that suggest the potential for an increased number of buried volcanic centers in Crater Flat (Blakely et al., 2000; O'Leary et al., 2002)
- DOE examined the sensitivity of the frequency of intersection of the repository footprint by a volcanic event, as indicated by the PVHA, to an increase in the number of buried volcanic centers in Crater Flat, as interpreted from the aeromagnetic data

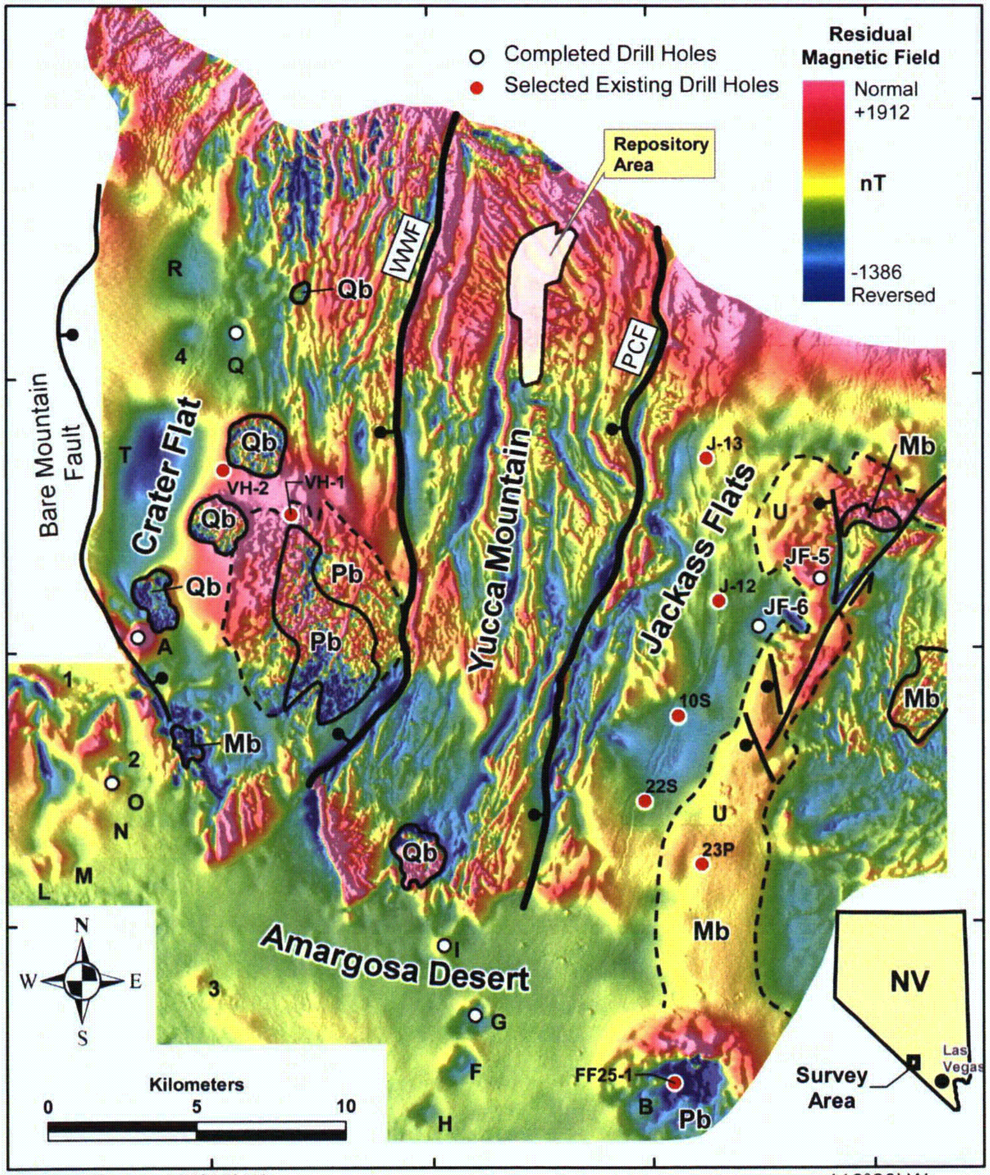
History Leading to PVHA-U (continued)

- Sensitivity study indicated a modest increase in the mean annual frequency of intersection of the repository; transmitted to NRC for review (Ziegler, 2002)
- The NRC staff concluded that the information DOE submitted did not provide an adequate technical basis to evaluate the likely impacts of the new aeromagnetic and ground magnetic data on the volcanic hazard estimate and that additional information was needed (Schlueter, 2002)
- DOE made a regulatory commitment to complete a program of field studies (aeromagnetic survey, drilling, and sampling), data analysis, and an update to the PVHA (Ziegler, 2003). Final documentation is planned for Fiscal Year 2008 during LA review.

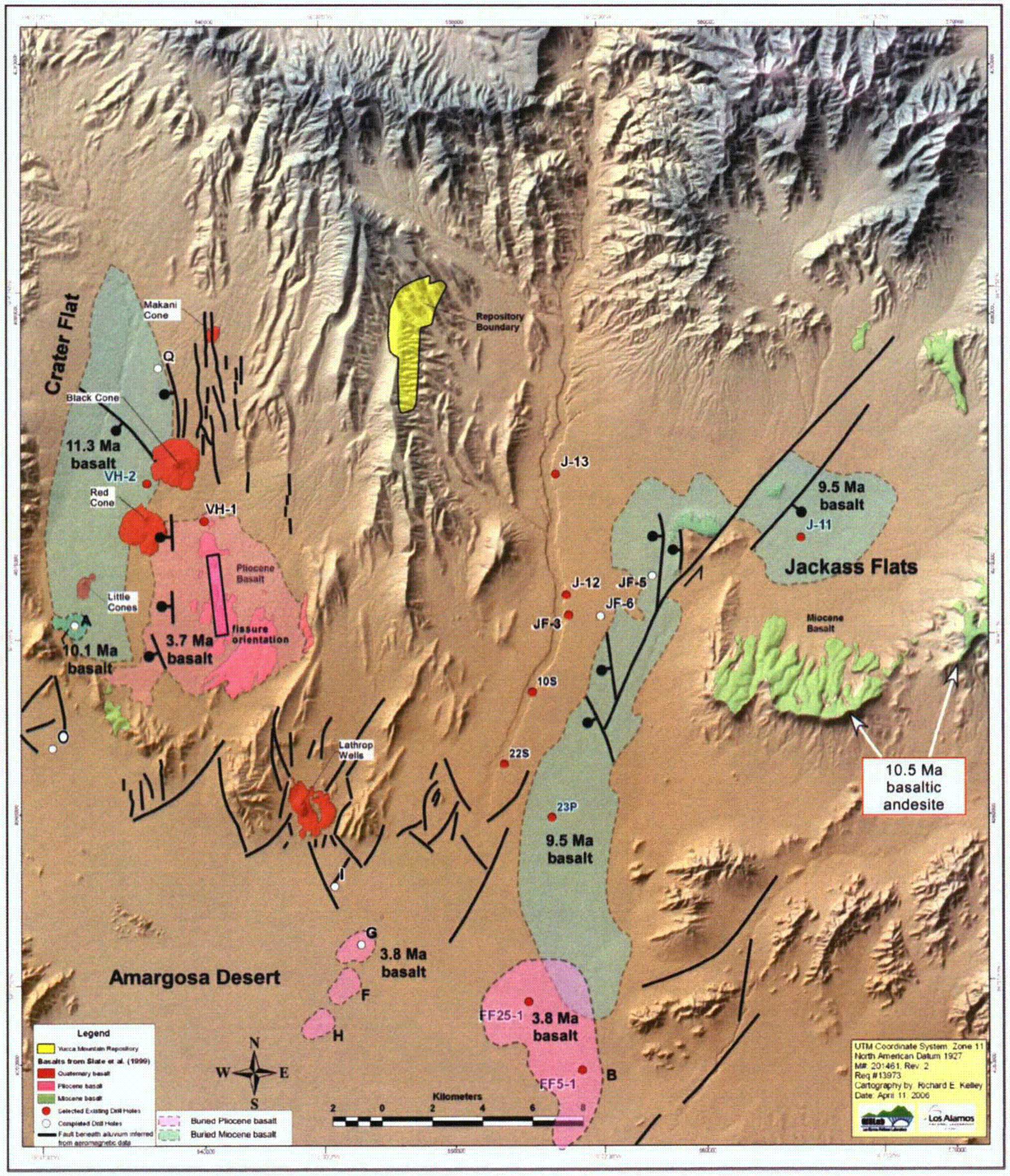
Overview of Aeromagnetic Survey and Drilling Program

- 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



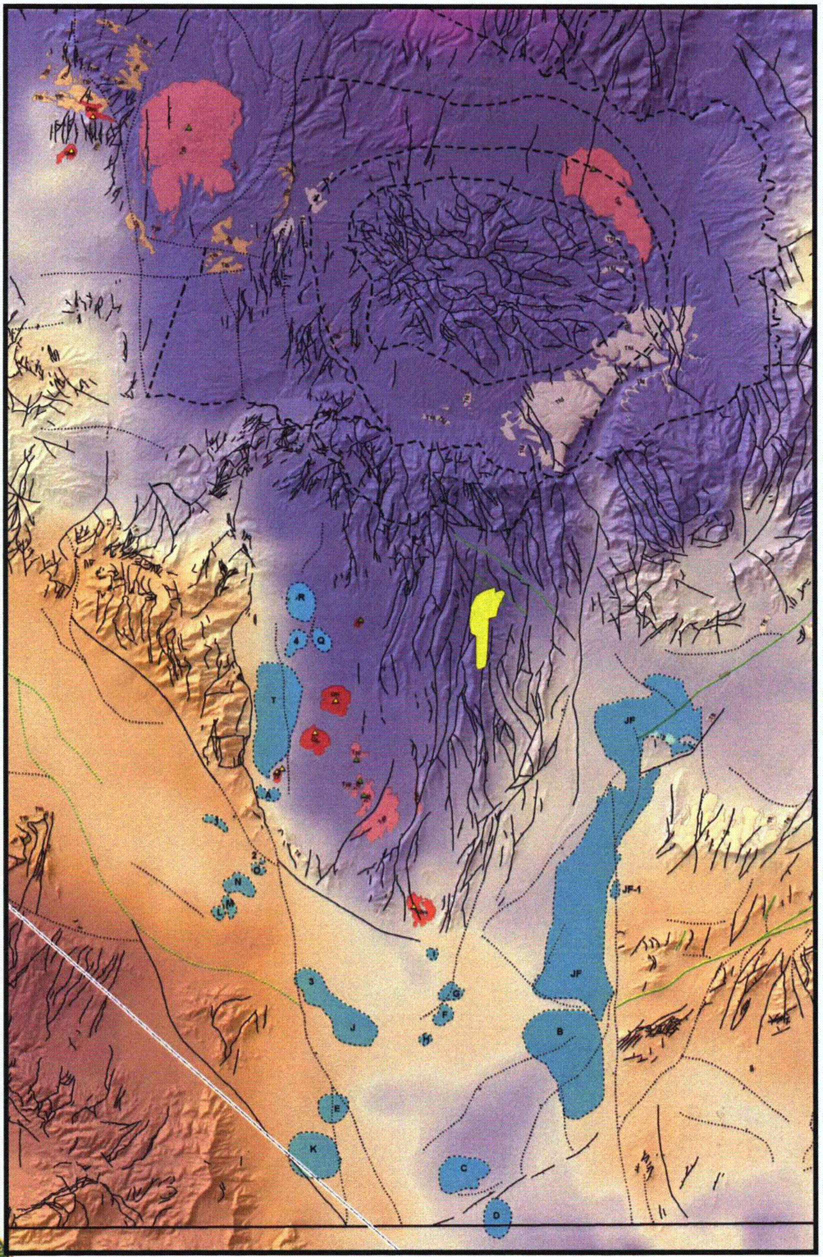
- Four basalts in new drill holes represent four different basalt units erupted between ~11 and 3.8 Ma
- Some anomalies represent faulted tuff blocks
- No post-Miocene basalt in Jackass Flats; extensive buried Miocene basalt
- Several volcanoes fed by feeder dikes captured by NNW-trending faults

Elements of PVHA-Update
Expert Elicitation Process

- Formal structured expert elicitation process (see schedule)
  - Data dissemination
  - Field trip, workshops, expert interactions
  - Individual expert interviews, followed by feedback

Elements of PVHA-Update
Data Dissemination

- Compilation of data and information related to event definition at analog locations
- Field trip to analog locations to allow first-hand review by experts
- Compilation of literature, reports, data
- Development of GIS-based database to allow combinations of layers
- Response to expert requests



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

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 10kyr and 1Myr

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

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 2007
Experts Finalize Elicitation Summaries	June 2007
Final Hazard Calculations and Aggregation of Expert Assessments	June 2007 to January 2008
Report Preparation/Finalization	November 2007 to June 2008

Complete (Planning through Second Round of Elicitation Interviews)

Conclusions

- Methods for conducting formal expert elicitations for probabilistic hazard analyses have evolved over the past 20+ years
- Methodology guidance provides for essential steps that should be followed within NRC regulatory environment
- PVHA-96 and PVHA-U take advantage of the lessons learned
- Each expert elicitation provides an opportunity for refinement

References

- Bernreuter, D.L.; Savy, J.B.; Mensing, R.W.; and Chen, J.C. 1989. *Seismic Hazard Characterization of 69 Nuclear Plant Sites East of the Rocky Mountains.* NUREG/CR-5250. Eight volumes. Washington, D.C.: U.S. Nuclear Regulatory Commission.
- Blakely, R.J.; Langenheim, V.E.; Ponce, D.A.; and Dixon, G.L. 2000. *Aeromagnetic Survey of the Amargosa Desert, Nevada and California: A Tool for Understanding Near-Surface Geology and Hydrology.* Open-File Report 00-188. [Denver, Colorado]: U.S. Geological Survey.
- CRWMS M&O 1996. *Probabilistic Volcanic Hazard Analysis for Yucca Mountain, Nevada.* BA0000000-01717-2200-00082 REV 0. Las Vegas Nevada: CRWMS M&O.
- EPRI (Electric Power Research Institute) 1986. *Methodology.* Volume 1 of *Seismic Hazard Methodology for the Central and Eastern United States.* EPRI NP-4726. Palo Alto, California: Electric Power Research Institute.
- Keeney, R.L. and von Winterfeldt, D. 1991. "Eliciting Probabilities from Experts in Complex Technical Problems." *IEEE Transactions on Engineering Management, 38,* (3), 191-201. [New York, New York: Institute of Electrical and Electronics Engineers].

References (continued)

- Kotra, J.P.; Lee, M.P.; Eisenberg, N.A.; and DeWispelare, A.R. 1996. *Branch Technical Position on the Use of Expert Elicitation in the High-Level Radioactive Waste Program.* NUREG-1563. Washington, D.C.: U.S. Nuclear Regulatory Commission.
- O'Leary, D.W.; Mankinen, E.A.; Blakely, R.J.; Langenheim, V.E.; and Ponce, D.A. 2002. *Aeromagnetic Expression of Buried Basaltic Volcanoes Near Yucca Mountain, Nevada.* Open-File Report 02-020. Denver, Colorado: U.S. Geological Survey.
- PRA Working Group, 1994, A Review of the NRC Staff's Uses of Probabilistic Risk Assessment, U.S. Nuclear Regulatory Commission, NUREG-1489, March 1994
- Senior Seismic Hazard Analysis Committee (SSHAC), Budnitz, R.J.; Apostolakis, G.; Boore, D.M.; Cluff, L.S.; Coppersmith, K.J.; Cornell, C.A.; and Morris, P.A. 1997. *Recommendations for Probabilistic Seismic Hazard Analysis: Guidance on the Uncertainty and Use of Experts.* NUREG/CR-6372. Two volumes. Washington, D.C.: U.S. Nuclear Regulatory Commission.

References (continued)

- Schlueter, J.R. 2002. "Request for Additional Information – Igneous Activity Agreement 1.02." Letter from J.R. Schlueter (NRC) to J.D. Ziegler (DOE), December 19, 2002, with enclosure, "NRC Review of DOE Documents Pertaining to Igneous Activity Key Technical Issue Agreement Item 1.02."
- Slate, J.L.; Berry, M.E.; Rowley, P.D.; Fridrich, C.J.; Morgan, K.S.; Workman, J.B.; Young, O.D.; Dixon, G.L.; Williams, V.S.; McKee, E.H.; Ponce, D.A.; Hildenbrand, T.G.; Swadley, W C; Lundstrom, S.C.; Ekren, E.B.; Warren, R.G.; Cole, J.C.; Fleck, R.J.; Lanphere, M.A.; Sawyer, D.A.; Minor, S.A.; Grunwald, D.J.; Laczniak, R.J.; Menges, C.M.; Yount, J.C.; Jayko, A.S.; Mankinen, E.A.; Davidson, J.G.; Morin, R.L.; and Blakely, R.J. 2000. *Digital Geologic Map of the Nevada Test Site and Vicinity, Nye, Lincoln and Clark Counties, Nevada, and Inyo County, California, Revision 4; Digital Aeromagnetic Map of the Nevada Test Site and Vicinity, Nye, Lincoln, and Clark Counties, Nevada, and Inyo County, California; and Digital Isostatic Gravity Map of the Nevada Test Site and Vicinity, Nye, Lincoln, and Clark Counties, Nevada, and Inyo County, California.* Open-File Report 99-554—A, —B, and —C. Denver, Colorado: U.S. Geological Survey.

References (continued)

- Ziegler, J.D. 2002. "Transmittal of Report Addressing Key Technical Issue (KTI) Agreement Item Igneous Activity (IA) 1.02." Letter from, J.D. Ziegler (DOE) to J.R. Schlueter (NRC), September 26, 2002, Las Vegas, Nevada, U.S. Department of Energy.
- Ziegler, J.D. 2003. "Igneous Activity Agreement (IA) 1.02 Additional Information Needed (AIN-1): U.S. Department of Energy (DOE) Position on Volcanic Hazard at Yucca Mountain, Nevada, and Plans for Confirmatory Studies." Letter from, J.D. Ziegler (DOE) to J.R. Schlueter (NRC), November 11, 2003, Las Vegas, Nevada, U.S. Department of Energy.