

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

**PRESENTATION TO  
THE NUCLEAR WASTE TECHNICAL REVIEW BOARD**

**SUBJECT: OVERVIEW OF PROGRESS**

**PRESENTER: BRUCE M. CROWE**

**PRESENTER'S TITLE  
AND ORGANIZATION: VOLCANOLOGIST  
LOS ALAMOS NATIONAL LABORATORY**

**PRESENTER'S  
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**MARCH 1, 1991**

# VOLCANISM STUDIES YUCCA MOUNTAIN PROJECT

## 1. CONDITIONAL PROBABILITY

$$PR_{DQ} = \{E3 \text{ GIVEN } E2 \text{ GIVEN } E1\}$$

**E1 IS THE RECURRENCE RATE OF VOLCANIC EVENTS**

**E2 IS THE PROBABILITY OF DISRUPTION**

**E3 IS THE PROBABILITY THAT DIRECT RELEASES FROM MAGMATIC DISRUPTION  
OF THE REPOSITORY EXCEED REGULATORY GUIDELINES**

## 2. ALL VOLCANISM WORK IS STRUCTURED TO PROVIDE DATA TO ASSESS THE CONDITIONAL PROBABILITY

-- DATA COLLECTION: STUDY PLAN 8.3.1.8.5.1

-- PROBABILITY CALCULATIONS (E1 AND E2): STUDY PLAN 8.3.1.8.1.1

-- DISRUPTIVE EFFECTS (E3): STUDY PLAN 8.3.1.8.1.2

## 3. INDIVIDUAL PROBABILITY VALUES ARE ESTIMATES. THE SIGNIFICANT CONSTRAINTS ARE THE PROBABILITY BOUNDS.

## 4. 40 CFR PART 191 APPENDIX B "... PERFORMANCE ASSESSMENTS NEED NOT CONSIDER CATEGORIES OF EVENTS OR PROCESSES THAT ARE ESTIMATED TO HAVE LESS THAN ONE CHANCE IN 10,000 OF OCCURRING OVER 10,000 YEARS."

$$10^{-8} \text{ YR}^{-1}$$

# VOLCANISM STUDIES YUCCA MOUNTAIN PROJECT

<u>VOLCANISM TASK</u>	<u>PARTICIPANT</u>	<u>ORGANIZATION</u>
<b>GEOCHRONOLOGY STUDIES</b>		
K-AR	USGS	USGS
U-TH	MIKE MURRELL	LOS ALAMOS
<sup>3</sup> He/ <sup>4</sup> He	JANE POTHS	LOS ALAMOS
TL	STEVE FORMAN	OHIO STATE
GEOMORPHOLOGY	STEVE WELLS	UNM
SOILS STUDIES	LES MCFADDEN	UNM
PALEOMAGNETISM	JOHN GEISSMAN	UNM
<b>FIELD STUDIES</b>		
	BRUCE CROWE	LOS ALAMOS
	FRANK PERRY	UNM
<b>GEOCHEMISTRY OF SCORIA SEQUENCES</b>		
PETROLOGY	FRANK PERRY	UNM
PIXE	PAM ROGERS	LOS ALAMOS
<b>EVOLUTIONARY CYCLES OF VOLCANIC FIELDS</b>		
	FRANK PERRY	UNM
	BRUCE CROWE	LOS ALAMOS
	RICH MORLEY	LOS ALAMOS
<b>PRESENCE OF MAGMA BODIES</b>		
	BRUCE CROWE	LOS ALAMOS
	HOWARD OLIVER	USGS
<b>STRUCTURAL CONTROLS OF VOLCANIC CENTERS</b>		
	BRUCE CROWE	LOS ALAMOS
	RICH MORLEY	LOS ALAMOS
<b>PROBABILITY CALCULATIONS</b>		
	BRUCE CROWE	LOS ALAMOS
	RICHARD BECKMAN	LOS ALAMOS
<b>ADMINISTRATIVE SUPPORT</b>		
	RICH MORLEY	LOS ALAMOS

# VOLCANISM STUDIES YUCCA MOUNTAIN PROJECT

## ACCOMPLISHMENTS

### 1. STUDY PLANS

- TWO COMPLETE AND TO NRC
- INITIAL ACCEPTANCE BY NRC: 8.3.1.8.5.1
- STRATEGY FOR RESOLUTION OF VOLCANISM ISSUE: 8.3.1.8.1.1

### 2. GEOCHRONOLOGY METHODS

- SOLVED ANALYTICAL PROBLEMS; FIRST NUMBERS  
U-TH DISEQUILIBRIUM,  $^3\text{He}/^4\text{He}$
- MAJOR PROGRESS  
TL METHOD
- SOIL AGE ESTIMATES/ $^{14}\text{C}$
- NEW K-AR RESULTS ( $^{40}\text{Ar}/^{39}\text{Ar}$ )
- PALEOMAGNETIC STUDIES (CRATER FLAT, SLEEPING BUTTE)  
(NOT FUNDED BY YMP)

### 3. SLEEPING BUTTE VOLCANIC CENTER

- BOTH CENTERS MAPPED
- REPORT IN PRESS

### 4. GEOCHEMISTRY OF ERUPTIVE SEQUENCES

- UNIQUE CHEMISTRY OF FIELD UNITS
- SEPARATE BATCH MELTS

### 5. WANING VOLCANISM - YM REGION

- MULTIPLE LINES OF EVIDENCE
- ANALOGIES TO MAUNA KEA

### 6. POLYCYCLIC VOLCANISM (MULTIPLE, TIME-SEPARATE VOLCANIC EVENTS)

- ADDITIONAL SUPPORTIVE EVIDENCE

### 7. QA AUDITS

### 7. PROBABILITY ASSESSMENT

- EXAMINATION OF UNCERTAINTY BOUNDS
- BOUNDS ARE ROBUST

# VOLCANISM STUDIES YUCCA MOUNTAIN PROJECT

## PROBLEM AREAS

### 1. QUATERNARY CHRONOLOGY STUDIES

- PROGRESS ENCOURAGING BUT SOMEWHAT SLOW
- SOME DISAGREEMENTS OVER DATA INTERPRETATIONS  
CONCLUSIVE VERSUS PERMISSIVE  
CONSERVATIVE VERSUS CONVENTIONAL
- PERSONNEL CHANGES USGS WORK  
SEE PAPERS IN HANDOUTS

### 2. QUALITY ASSURANCE SOFTWARE

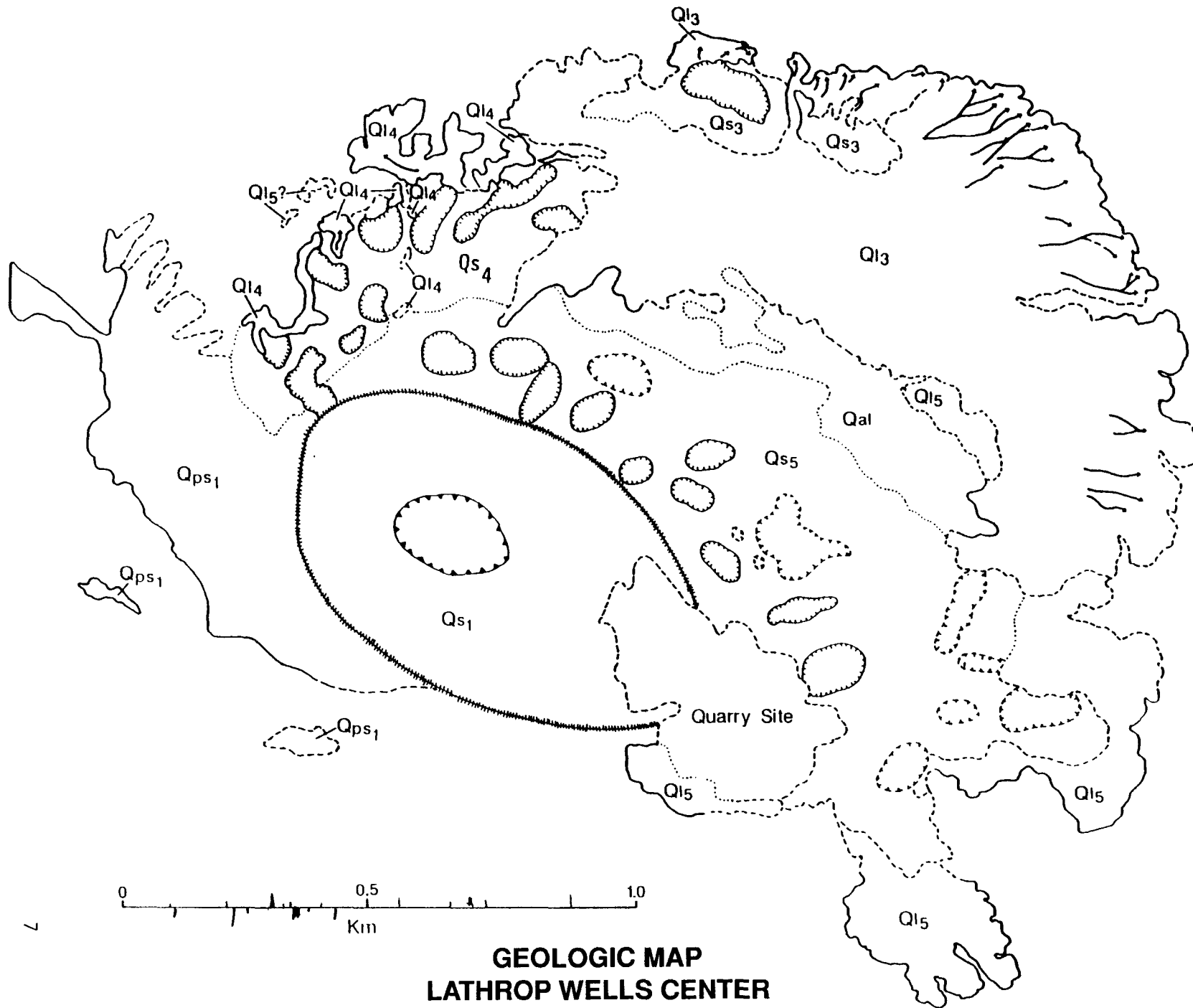
- ANALYTICAL INSTRUMENTATION

### 3. TRENCHING

- RESOLUTION OF CHRONOLOGY DATA AT LATHROP WELLS AND SLEEPING  
BUTTE WILL REQUIRE TRENCHING
- UNABLE TO GAIN ACCESS

BUT: THE TRUCK  
SUCCESS WITH TL AND HELIUM





**GEOLOGIC MAP  
LATHROP WELLS CENTER**

**SOUTH CONE WALL  
LATHROP WELLS CENTER**



**QUARRY SECTION #1  
LATHROP WELLS CENTER**

**QUARRY SECTION #2  
LATHROP WELLS CENTER**

**QUARRY SECTION #3  
LATHROP WELLS CENTER**

**NORTH CONE  
UNCONFORMITY  
LATHROP WELLS CENTER**

**NORTH LAVAS ( $QI_4-QI_3$ )  
LATHROP WELLS CENTER**

**SOUTHWEST SIDE  
LATHROP WELLS**

**VOLCANISM STUDIES  
YUCCA MOUNTAIN PROJECT**

**SUMMARY OF CHRONOLOGY RESULTS**

<u>METHOD</u>	<u>AGE ESTIMATE (KA)</u>	<u>UNIT</u>
-----		
<b>K-AR (CONVENTIONAL)</b>		
<b>USGS (1980)</b>	126 +/- 182	QL3
	485 +/- 261	QL5
-----		
<b>SINNOCK</b>		
<b>LAB A</b>	658 +/- 79	QL5
<b>LAB B</b>	77 +/- 81	QL5
<b>LAB C</b>	568 +/- 93	QL5
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<b>TURRIN ET AL.</b>	214 +/- 170	QL3
	137 +/- 13	QL3
	177 +/- 74	QL5
	176 +/- 60	QL5
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<b>TURRIN ET AL.</b>	113 +/- 10	QL3
<b>(SUMMARY)</b>	116 +/- 13	QL5
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<b>UNLV</b>	67 +/- 30	?
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<sup>40</sup> Ar/ <sup>39</sup> Ar	171 +/- 87	QL3
<b>TURRIN/CHAMPION</b>	183 +/- 21	QL3
	129 +/- 77	QL5
	149 +/- 49	QL5
-----		
<b>U-Th DISEQUILIBRIUM</b>	>120	QL4
<b>MURRELL</b>		
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**SUMMARY:** WIDE RANGE OF RESULTS (NEGATIVE AGES TO > 500 KA)  
 REPRODUCIBLE "MEAN" VALUES  
 POSSIBLE CONFIRMATION FROM U-Th AND SOIL/TEPHRA  
 CORRELATION

**VOLCANISM STUDIES  
YUCCA MOUNTAIN PROJECT  
SUMMARY OF CHRONOLOGY RESULTS**

<u>METHOD</u>	<u>AGE ESTIMATE (KA)</u>	<u>UNIT</u>
<sup>36</sup> CL (PHILLIPS)	90	SURFACE BOMB?
	65	QL5
	45	Qs1
<sup>3</sup> HE/ <sup>4</sup> HE (POTHS)	20 +/- 20-25%	Qs1
	40 +/- 20-25%	QL4
TL (FORMAN)	8.7 +/- 0.7	QUARRY SECTION
	9.9 +/- 0.7	QUARRY SECTION
	8.7 +/- 1.0	QUARRY SECTION
	24.5 +/- 2.5	QL3

**SUMMARY:** GOOD AGREEMENT BETWEEN TL AND HELIUM  
 GOOD AGREEMENT WITH SOILS/GEOMORPHOLOGY  
<sup>36</sup>CL RESULTS HARD TO INTERPRET (NON-YMP DATA)

**CONTINUED CONFIRMATION OF YOUNG  
(LATE PLEISTOCENE OR HOLOCENE)  
VOLCANIC EVENTS**



# VOLCANISM STUDIES YUCCA MOUNTAIN PROJECT

## OTHER CHRONOLOGY RESULTS (ALL IN KA)

### SNAKE RIVER PLAINS

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#### BAKED SEDIMENT UNDER LAVA FLOW

TL AGE: 2.2 +/- 0.4       $^{14}\text{C}$ : 2.2 +/- 0.1

#### BAKED SEDIMENT UNDER LAVA FLOW

TL AGE: 93.8 +/- 12.1      K/Ar: 95 +/- 50

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### CIMA VOLCANIC FIELD

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#### A CONE LAVA FLOW

TL AGE: 7.3 +/- 0.5       $^{40}\text{Ar}/^{39}\text{Ar}$ : 138 +/- 63  
10.2 +/- 0.8      119 +/- 28

RADIOCARBON 14-20  
(VARNISH)

HELIUM 12  
(AUST)

SOIL                      HOLOCENE  
CORRELATION

#### I CONE LAVA FLOW

HELIUM AGE: 20 +/- 20-25% (LANL)  
HELIUM AGE: 19 (AUST)

K-Ar: 100\*

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\*MAY BE SOME CONFUSION IN IDENTIFICATION OF LAVA UNITS. TWO FLOWS CAN BE IDENTIFIED BASED ON SOIL AND GEOMORPHIC CRITERIA. THE HELIUM RESULTS ARE FROM THE YOUNGER FLOW. THE K-AR RESULTS MAY BE FROM BOTH FLOWS.

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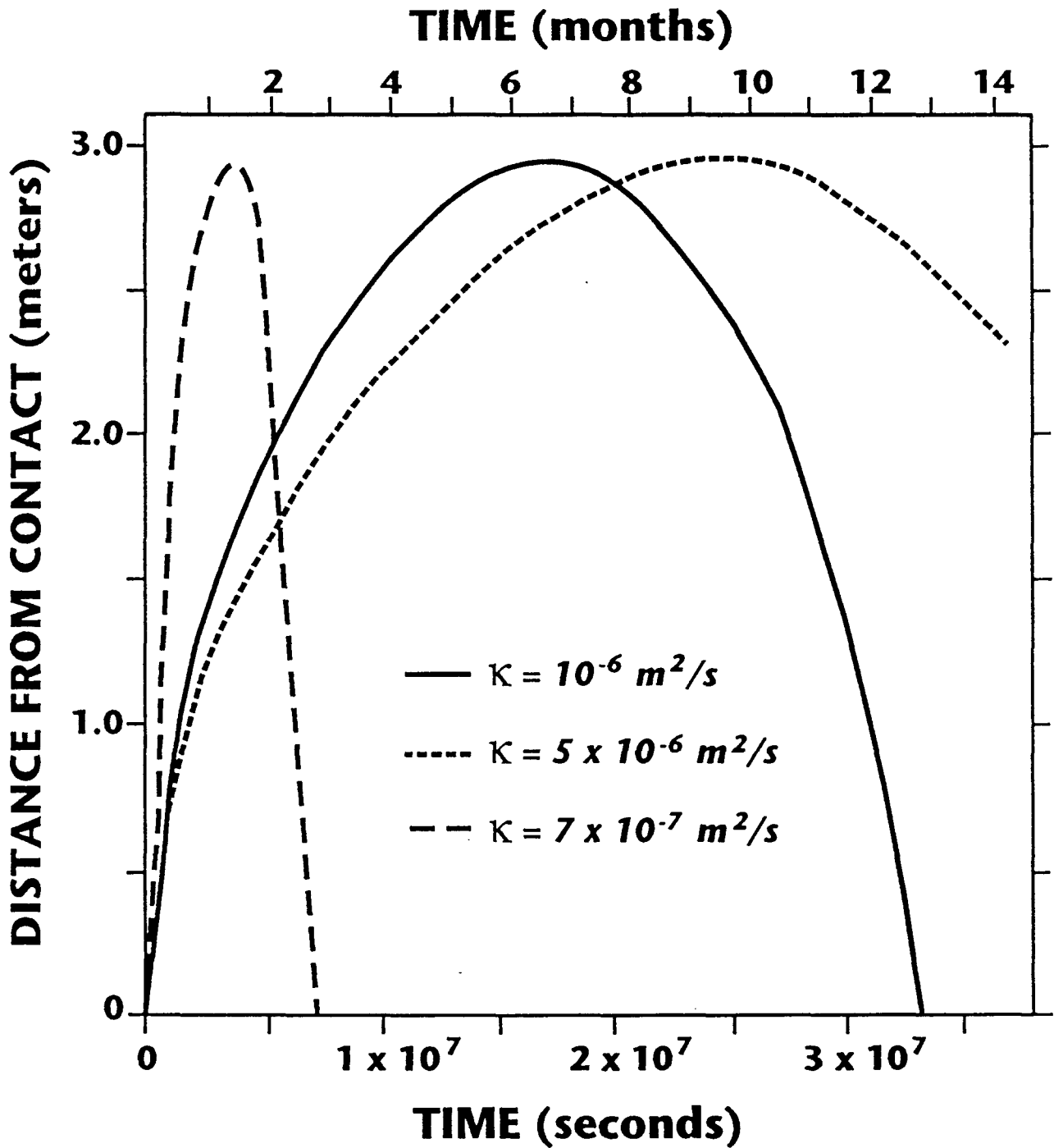
Dear Bruce,

I will be closing shop at Colorado in a few weeks and would like at this time to summarize TL age estimates for sites on Crater Flats, NV, the Cima Volcanic Field and related sites on the eastern Snake River Plain. So far we have analyzed eight samples from volcanic terrain, all with some level of independent age control. Below is a listing of results by area:

Site	Stratigraphic Context	Field #	Lab #	TL Age Est. (ka)	Known Age (ka)
<b>Eastern Snake River Plain</b>					
Kings Bowl <sup>1</sup>	Baked sediment under lava flow	F90-ID32	ITL-308	2.2 ± 0.4 1.8 ± 0.3	2.2 ± 0.1 ( <sup>14</sup> C)
RWMC <sup>1</sup>	Baked sediment under lava flow	F90-ID20	ITL-305	93.8 ± 12.1	95 ± 50 (K/Ar)
<b>Cima Volcanic Field, CA</b>					
A Cone	Surface Av Horizon	F89-LA8	ITL-Y2	0.5 ± 0.2	< 2ka (Les's soil knowledge)
A Cone	Baked soil under Black Tank lava flow Wash	F89-LA9	ITL-Y3	7.3 ± 0.5 10.2 ± 0.8	138 ± 63 (Ar/Ar) <sup>2</sup> 14-20 (Dorn <sup>14</sup> C) 10-30 ( <sup>36</sup> Cl)
<b>Lathrop Wells, NV</b>					
Quarry	Buried Soil 1 Av	F89-LA3	ITL-Y1	8.9 ± 0.7 9.9 ± 0.7 8.7 ± 1.0	<25 ka (Les's soil knowledge)
Quarry <sup>1</sup>	Buried Soil 2 Av	F89-LA4	ITL-Y6	3.7 ± 0.4	" "
Quarry	Buried Soil 4 Av	F89-LA6	ITL-Y4	3.7 ± 0.4 4.5 ± 0.4	" "
QL3 Exp. <sup>1</sup>	Baked sediment under lava flow	F89-LA1	ITL-Y5	24.5 ± 2.5	171 ± 87 (Ar/Ar) <sup>2</sup>

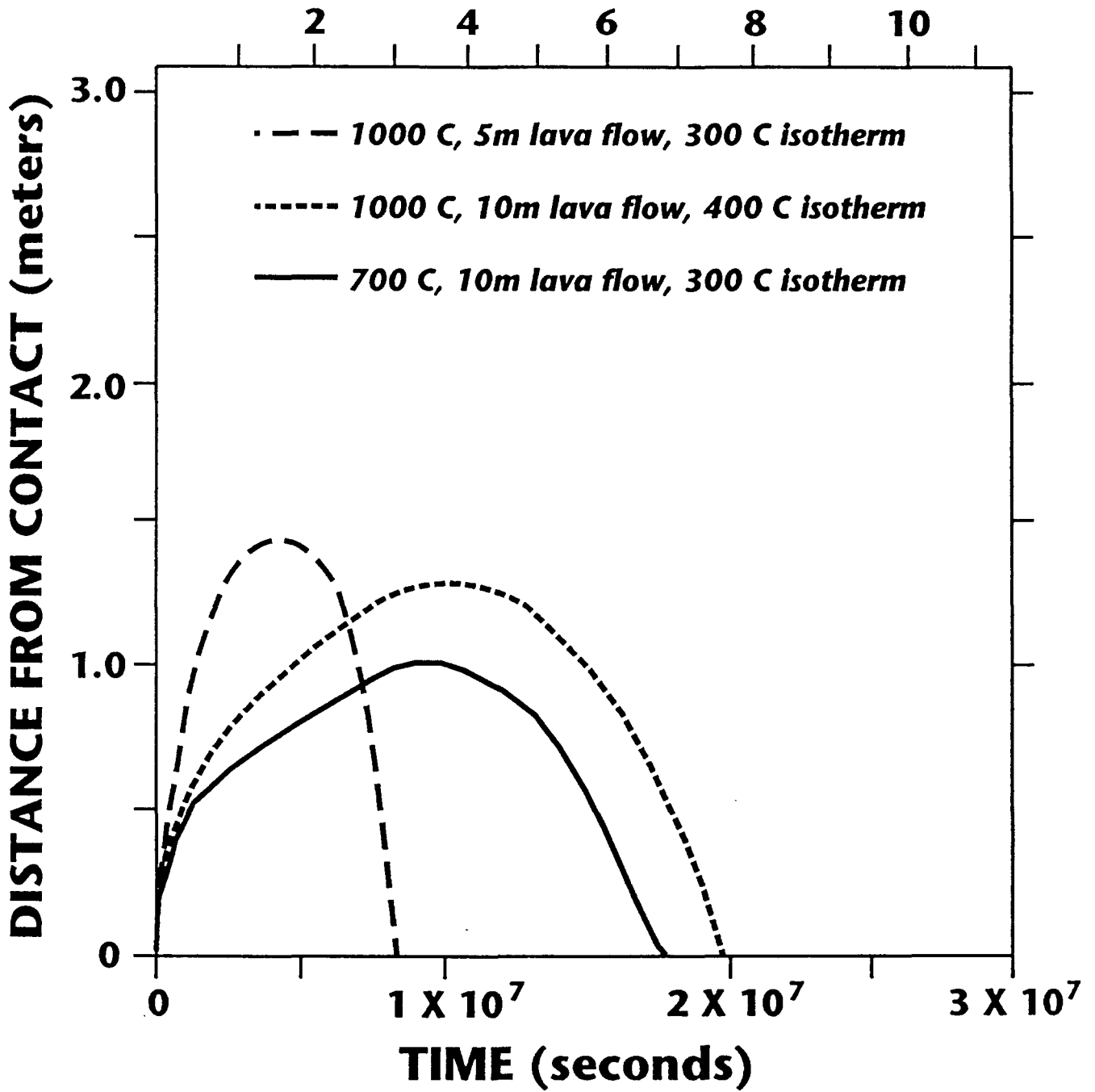
1 K values for these sediments have been estimated. Ages may change by ± 10% with final K analysis.  
 2 <sup>40</sup>Ar/<sup>39</sup>Ar age from Turrin and Champion, unpublished data. Errors calculated by the arithmetic mean are shown, which is similar to error calculations for the K/Ar age from the Snake River Plain and for TL age estimates. This is a conservative approach to error evaluation and should be used during the preliminary phase of data interpretation.

# TL TEMPERATURE CALCULATIONS



# TL TEMPERATURE CALCULATIONS

## TIME (months)



# VOLCANISM STUDIES YUCCA MOUNTAIN PROJECT

## CHRONOLOGY MODELS: LATHROP WELLS CENTER

MODEL I: SIMPLE MONOGENETIC CENTER. ALL UNITS GREATER THAN 100 KA

PRO: K-AR (CONVENTIONAL AND  $^{40}\text{Ar}/^{39}\text{Ar}$ ), U-TH  
DISEQUILIBRIUM, TEPHRA CORRELATION

NEUTRAL: PALEOMAGNETIC,  $^{36}\text{Cl}$ ?

CON: GEOMORPHOLOGY, SOILS, TL,  $^3\text{He}/^4\text{He}$ , STRATIGRAPHY,  
GEOCHEMISTRY, TEPHRA FALL DEPOSITS WITH INTERBEDDED SOILS

### STRENGTHS:

MONOGENETIC CLASSIFICATION IS THE STANDARD INTERPRETATION OF SMALL VOLUME STROMBOLIAN CENTERS. LACK OF CONVERGENCE OF CHRONOLOGY METHODS MAY REFLECT DEVELOPMENTAL STAGE OF THE TECHNIQUES. SIMPLIFIES CHRONOLOGY STUDIES. LEADS TO A MORE FAVORABLE INTERPRETATION, FOR MOST MODELS, OF THE IMPACT OF VOLCANISM ON THE YUCCA MOUNTAIN SITE (YOUNGEST VOLCANIC EVENT IS > 100 KA).

### WEAKNESSES:

IGNORES A MAJOR GROUP OF DATA SUPPORTING A YOUNG (<< 100 KA) AGE OF SOME EVENTS. REQUIRES SPECIAL (AND UNSPECIFIED) EXPLANATIONS FOR THE LACK OF SOIL DEVELOPMENT, LACK OF GEOMORPHIC DEGRADATION AND QUARRY SOILS SECTION WITH TEPHRA-FALL DEPOSITS (TL DATES). TEPHRA CORRELATION HAS NOT BEEN TESTED OR PROVEN. COULD LEAD TO A FALSE POSITIVE CONCLUSION FOR VOLCANIC HAZARDS (CENTER IS OLD WHEN IT IS YOUNG).

### SIGNIFICANT AREAS OF DISAGREEMENT:

1. PROOF OF PRINCIPAL: VARIANCE WEIGHTING METHOD FOR AVERAGING K-AR AGE ESTIMATES (NO DISAGREEMENT IN DATA SET BUT IN THE INTERPRETATION OF THE DATA SET).
2. ASSIGNMENT OF MAP UNITS (MINOR: SHOULD BE EASILY RESOLVED WITH TRENCHING).

# **VOLCANISM STUDIES YUCCA MOUNTAIN PROJECT**

## **CHRONOLOGY MODELS: LATHROP WELLS CENTER (CONT)**

**MODEL II: POLYCYCLIC CENTER. SOME UNITS > 100 KA AND SOME < 50 KA**

### **STRENGTHS:**

**COMPROMISE INTERPRETATION. COULD PROVIDE AN EXPLANATION FOR THE POLARITY OF CHRONOLOGY RESULTS. SOME SUPPORT PROVIDED BY THE STRATIGRAPHY, GEOCHEMISTRY AND GEOMORPHOLOGY STUDIES. NO SIGNIFICANT IMPACT ON VOLCANIC HAZARDS.**

### **WEAKNESSES:**

**HAVE NOT FOUND TWO DISTINCT GROUPS OF SOILS. GEOMORPHIC DIFFERENCES BETWEEN UNITS MAY BE MINOR. REQUIRES AN UNCONVENTIONAL INTERPRETATION OF BASALT CENTERS. AGE GAP BETWEEN EVENTS IS LARGE.**

### **SIGNIFICANT AREAS OF DISAGREEMENT:**

**NONE (BUT STAY TUNED)**

# VOLCANISM STUDIES YUCCA MOUNTAIN PROJECT

## CHRONOLOGY MODELS: (CONTINUED)

MODEL III: POLYCYCLIC CENTER BUT ALL UNITS ARE YOUNG (<50) KA.  
K-AR AND U-TH RESULTS DO NOT PROVIDE A CRYSTALLIZATION AGE.

PRO: GEOMORPHOLOGY, SOILS, TL,  $^3\text{He}/^4\text{He}$ , STRATIGRAPHY,  
GEOCHEMISTRY, PALEOMAGNETIC, TEPHRA-FALL UNITS BETWEEN  
SOILS

NEUTRAL:  $^{36}\text{Cl}$ ?

CON: K-AR, U-TH, TEPHRA CORRELATION

## STRENGTHS:

CONSISTENCY OF TL,  $^3\text{He}/^4\text{He}$ , SOILS, GEOMORPHIC AND GEOCHEMISTRY RESULTS. EVIDENCE IS ACCUMULATING THAT THE K-AR METHOD MAY NOT BE RELIABLE FOR ESTABLISHING THE AGE OF BASALTIC ROCKS < 200 KA, PARTICULARLY FOR WHOLE ROCK AGE DETERMINATIONS. U-TH RESULTS MAY REFLECT TWO-STAGE ASCENT HISTORY OF BASALT (MIXED PHENOCRYSTS). IDENTIFIES A POTENTIALLY SENSITIVE AREA OF VOLCANIC HAZARD ASSESSMENT.

## WEAKNESSES:

UNCONVENTIONAL INTERPRETATION OF BASALT CENTERS. CONVERGENCE OF RESULTS FROM K-AR, U-TH AND TEPHRA CORRELATION. K-AR IS THE STANDARD CHRONOLOGY METHOD. ALTERNATIVE U-TH DISEQUILIBRIUM MODELS ARE SPECULATIVE AND NEED TO BE TESTED. NEED MORE TRENCHING TO FURTHER TEST CHRONOLOGY MODEL.

## SIGNIFICANT AREAS OF DISAGREEMENT: (USGS NOT STATE OR NRC)

1. TL RESULTS, SOIL AND GEOMORPHOLOGY CORRELATIONS
2. TEPHRA FALL DEPOSITS (PRIMARY VERSUS REWORKED)
3. POLYCYCLIC VOLCANISM

# **VOLCANISM STUDIES YUCCA MOUNTAIN PROJECT**

**LATHROP WELLS CHRONOLOGY MODELS: ARE THEY IMPORTANT?**

**FOR MOST ASSESSMENTS: NOT SENSITIVE**

**-- EVENT COUNTS: NO**

**-- VOLUME/TIME PLOTS: GENERALLY NOT, BUT DEPENDS ON AGE AND  
VOLUME OF UNITS (WORK STILL IN PROGRESS)**

**POLYCYCLIC MODEL: MAY BE IMPORTANT**

**LEADS TO TWO PROBABILITY MODELS FOR A FUTURE VOLCANIC EVENT**

- 1. RECURRENCE OF AN ERUPTION AT AN EXISTING CENTER  
NO EFFECT ON YUCCA MOUNTAIN**
- 2. FORMATION OF A NEW VOLCANIC CENTER  
POTENTIAL EFFECTS ON YUCCA MOUNTAIN**

**CONTINUE TO WORK TO TEST MODEL OF POLYCYCLIC EVENTS**

**IF NO -- SIMPLIFIES VOLCANIC RISK ASSESSMENT**

**IF YES -- IMPORTANCE OF TESTING ALTERNATIVE MODELS**

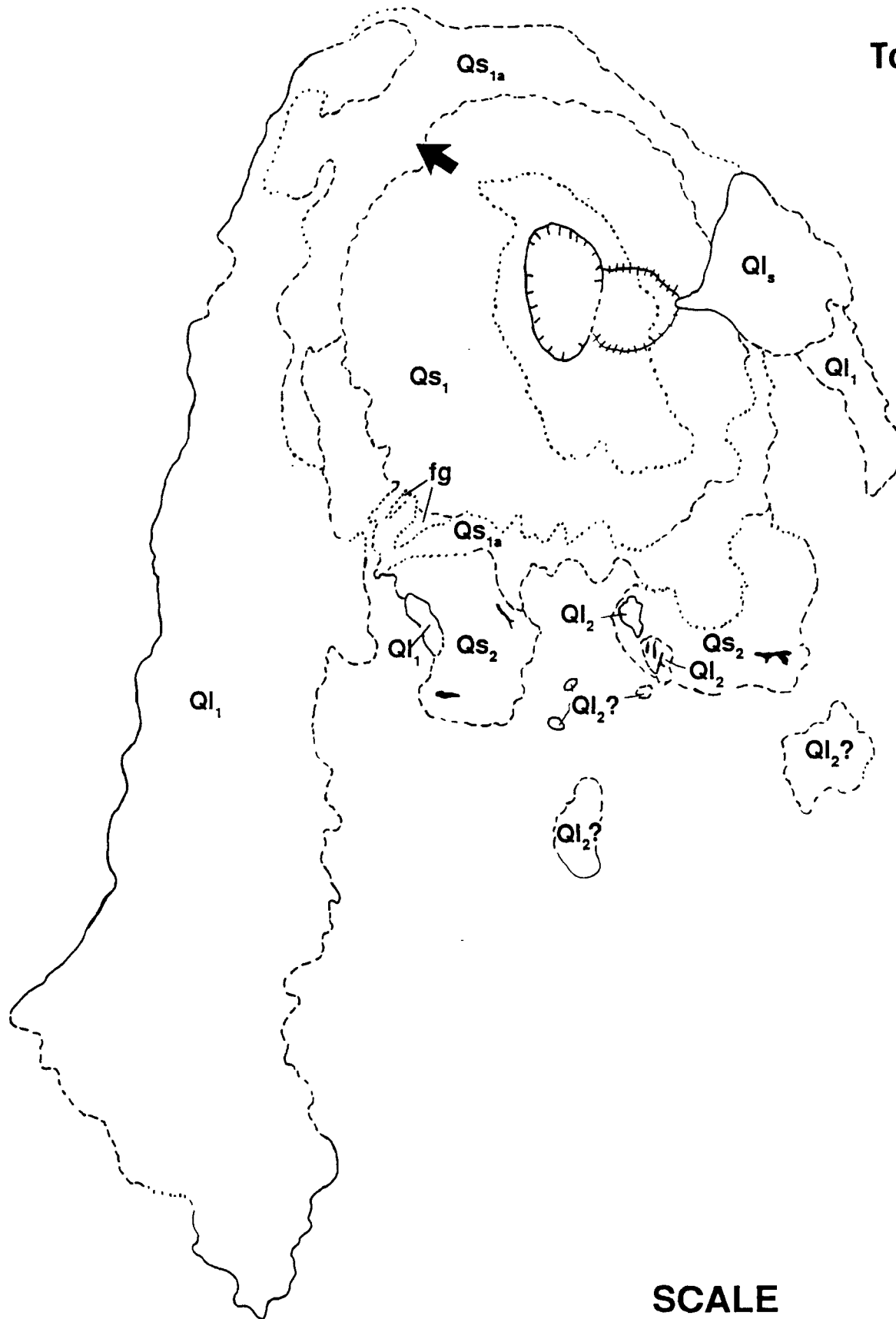
**RECURRENCE RATES**

**CONTROLLING MECHANISMS**



# LITTLE BLACK PEAK CONE GEOLOGIC MAP

To SCALE



SCALE  
1:4975





15

**'A' CONE  
EAST WALL**





90 5 29



# **VOLCANISM STUDIES YUCCA MOUNTAIN PROJECT**

## **PALEOMAGNETIC STUDIES (D. CHAMPION, USGS)**

### **SLEEPING BUTTE**

**1.2 MA CRATER FLAT**

**3.7 MA CRATER FLAT**

-- "GROUPED" FIELD MAGNETIC DIRECTIONS

## **ERUPTION MODEL**

-- CLUSTERED VOLCANIC EVENTS

-- ANALOGIES TO CLUSTERED SEISMICITY

## **UNKNOWNNS**

-- SECULAR VARIATION

-- POLYCYCLIC CONCEPTS

**HIDDEN CONE: POLYCYCLIC**

**1.2 MA: UNKNOWN**

**3.7 MA: UNKNOWN**



# **VOLCANISM STUDIES YUCCA MOUNTAIN PROJECT**

## **SUMMARY OF PROGRESS**

### **1. CHRONOLOGY STUDIES STILL IN PROGRESS**

- SOME DATA PUZZLING**
- INCONSISTENCIES ARE PERHAPS EXPECTED**
- ENCOURAGED BY PROGRESS**
- SCIENTIFIC SPINOFFS**

**SYSTEMATIC ERROR TERM: K-Ar  
GEOMORPHIC/SOIL PROCESSES**

### **2. POLYCYCLIC ERUPTIVE MODEL**

- CONTINUES TO BE SUPPORTED FOR SOME BUT NOT ALL CENTERS**
- IMPORTANT IN DEFINING FUTURE VOLCANIC SCENARIOS**

### **3. CLUSTER MODEL**

- EPISODIC EVENTS**
- EVENT = CONE CLUSTER**
- LATHROP WELLS: FAILED CLUSTER?**
- CHRONOLOGY RESOLUTION OLDER CENTERS**