RISK ASSESSMENT FOR THE YUCCA MOUNTAIN HIGH-LEVEL NUCLEAR WASTE REPOSITORY SITE: ESTIMATION OF VOLCANIC DISRUPTION

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GOALS

To estimate

1. **the recurrence rate**

2. **the probability of volcanic disruption of the repository during the next 10,000 years**

DATA

1. **Define a single event**
2. **Measure each event**
3. **Count them all**

→ **generate a TIME SERIES**

A main cone is the final stage of a single eruption, and a single eruption could have several small vents to accompany the main cone

(Crowe et al. 1983)

Preliminary Data Set

3.7, 3.7, 3.7, 3.7, 2.8, <u>1. 2, 1. 2, 1. 2, 1. 2, 1. 2, 0. 28, 0. 28, 0. 01</u>

(B) Quaternary

(A) Post-6 Ma

MODEL

MODELING THE VOLCANISM -

RECURRENCE RATE ESTIMATION

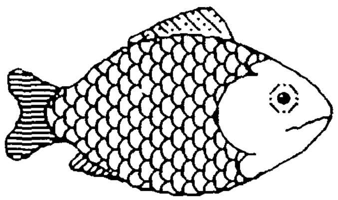
Need a model that captures the basic elements of the study:

1. Time trend

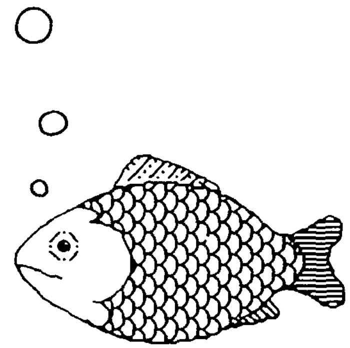
2. Predictability

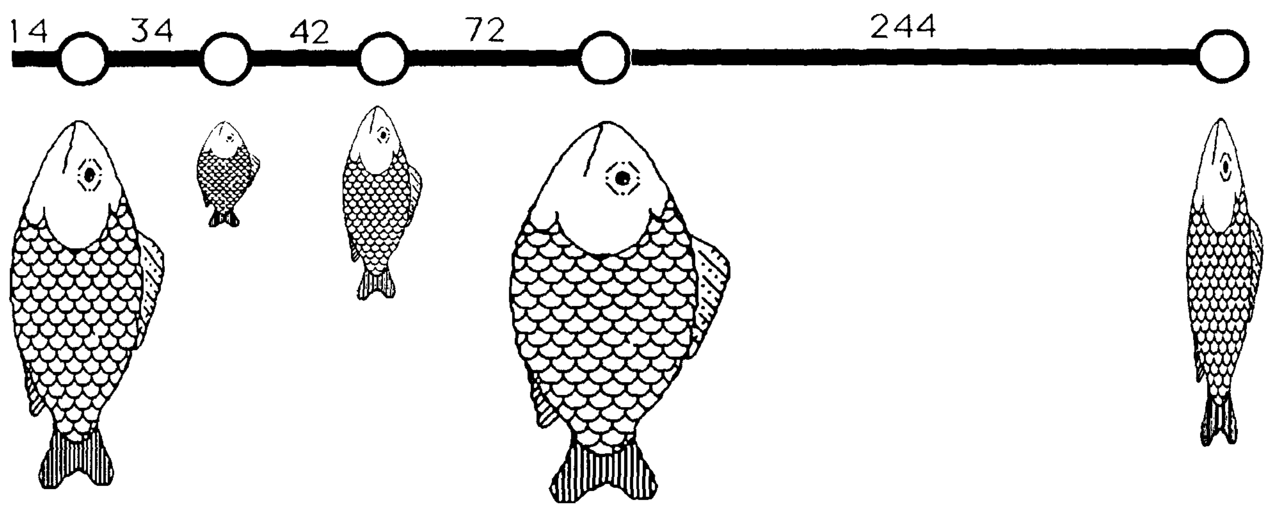
3. Robust to other model assumptions

4. Mathematical simplicity



And you should have seen
the one that got away!





1. **GENERALIZE a constant λ with $\lambda(t)$, a function of time**

2. **Model X(t) = number of events in [0,t]**

   X(t) follows a nonhomogeneous Poisson process (NHPP) with parameter $\mu(t)$

$$\mu(t) = \int_0^t \lambda(s)\, ds$$

(Parzen, 1962, p. 138)

- **Choice of** $\lambda(t) = (\beta/\theta)\,(t/\theta)^{\beta-1}$
- **yields** $\mu(t) = (t/\theta)^{\beta}$
- **implies a Weibull** $(\theta\ ,\ \beta)$

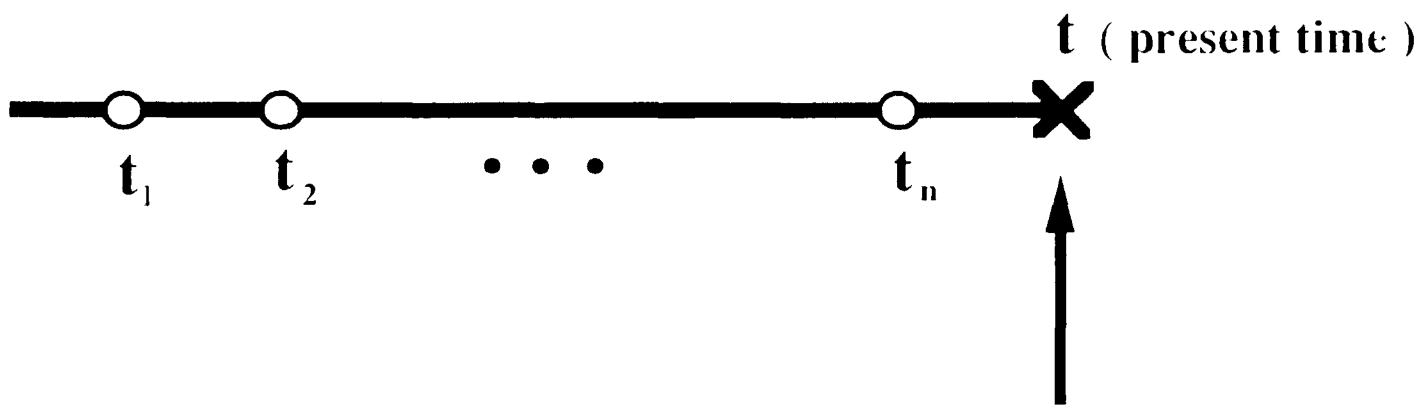
$$\beta \begin{cases} > 1 \text{ increasing} \\ = 1 \text{ simple Poisson} \\ < 1 \text{ decreasing} \end{cases}$$

Let $t_1, t_2, ..., t_n$ be the first n successive times of events in [0,t]: $t_1 < t_2 < ... < t_n$

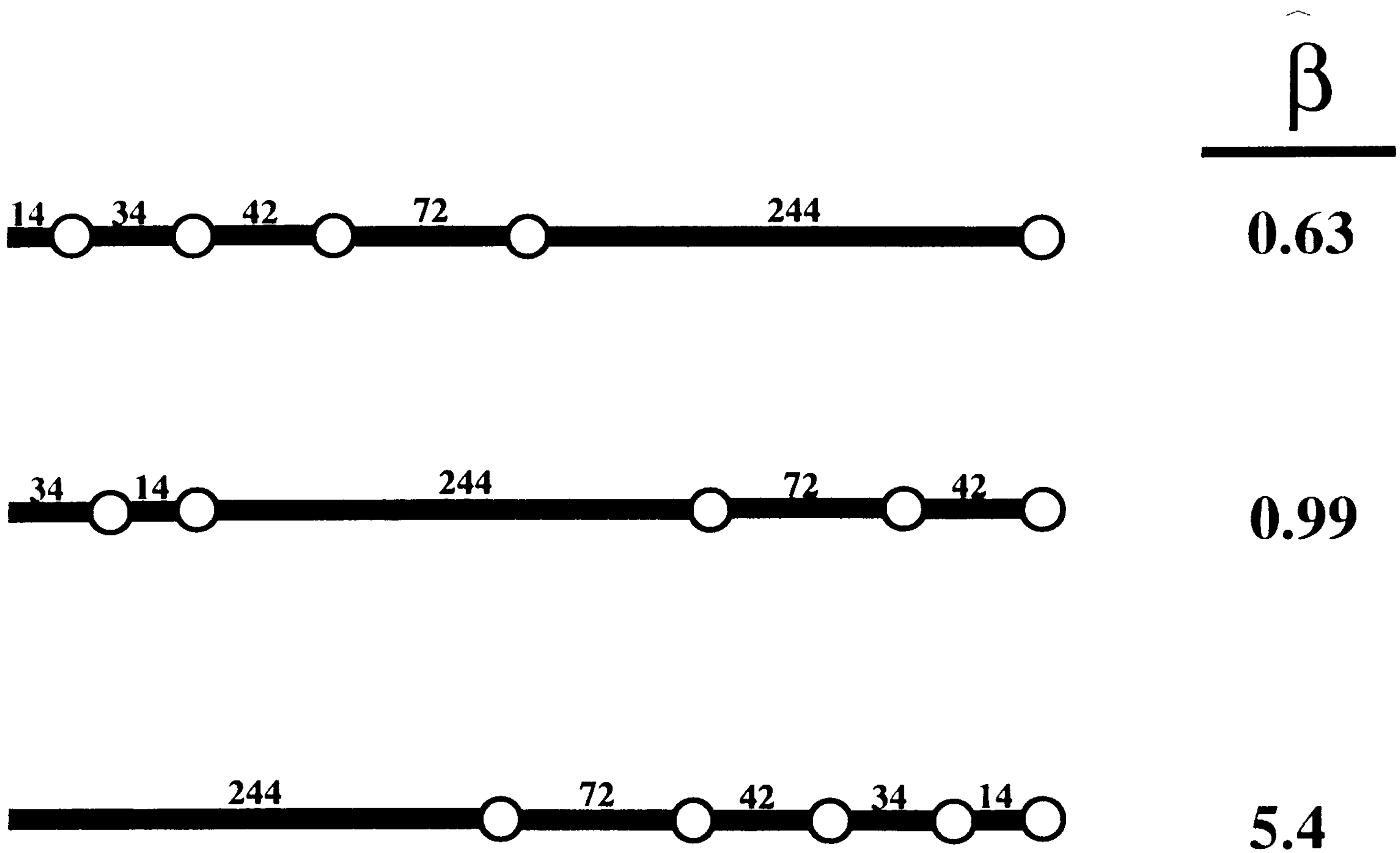
- $\hat{\beta} = n / \sum_{i=1}^{n} \ln(t/t_i)$
- $\hat{\theta} = t/n^{1/\hat{\beta}}$
- $\hat{\lambda} = (\hat{\beta}/\hat{\theta})\,(t/\hat{\theta})^{\hat{\beta}-1}$

(Crow 1974, 1982)

Instantaneous Recurrence Rate



$$\hat{\lambda}(t) = (\hat{\beta}/\hat{\Theta})(t/\hat{\Theta})^{\hat{\beta} - 1}$$



$\hat{\beta}$
14 34 42 72 244
0.63
34 14 244 72 42
0.99
244 72 42 34 14
5.4

Preliminary Data Set

3.7, 3.7, 3.7, 3.7, 2.8, <u>1. 2, 1. 2, 1. 2, 1. 2, 1. 2, 0. 28, 0. 28, 0. 01</u>

(B) Quaternary

(A) Post-6 Ma

(A)

- $\widehat{\beta}$ **= 2.29 (one-sided p-value $\doteq$ 0.005)**
- $\widehat{\lambda}$ **= $5\text{x}10^{-6}$ /yr**

(B)

- $\widehat{\beta}$ **= 1.09 (one-sided p-value $\doteq$ 0.45)**
- $\widehat{\lambda}$ **= 5. $5\text{x}10^{-6}$ /yr**

$$\hat{\lambda} = 5.5 \times 10^{-6}/yr$$

- **The estimated instantaneous recurrrence rate**

- **It represents the instantaneous eruptive status of the volcanism at the end of the observation time t (present)**

Interval estimate of $\lambda(t)$

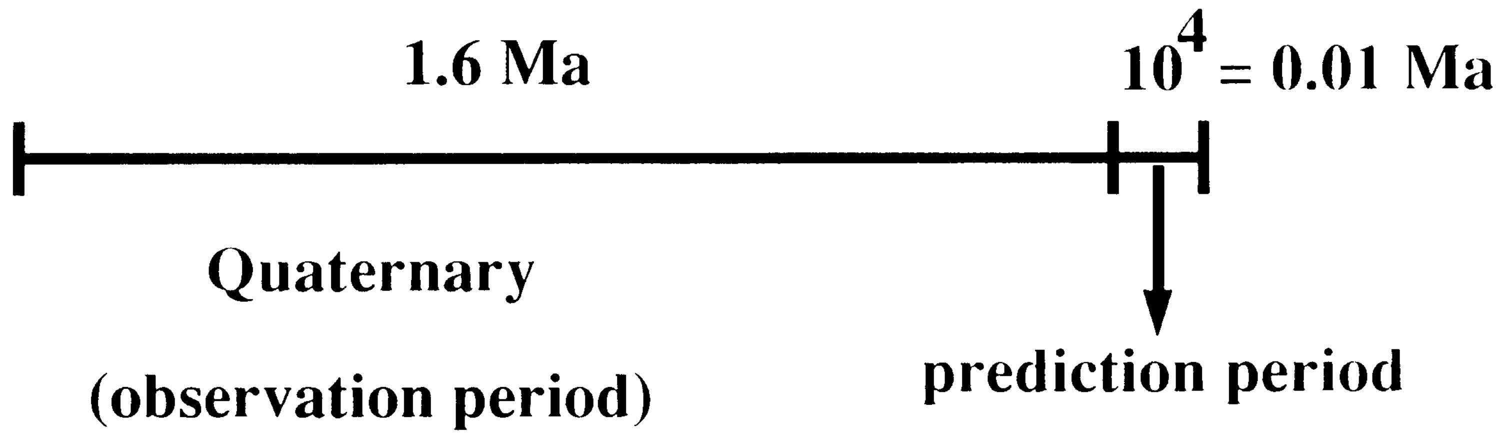
A 90% confidence interval for $\lambda(t)$ is

$(\hat{\lambda}_1 , \hat{\lambda}_2) = (1.85 \times 10^{-6} , 1.26 \times 10^{-5})$, which

is more informative than $\hat{\lambda} = 5.5 \times 10^{-6}$ / yr

PREDICTING

FUTURE ERUPTIONS



1. **The projected time frame is about 0.6% of the OP**
2. **It is only 5% of the average repose time**

⇓

Suggests switching from a NHPP to a predictive HPP model

MODELING

THE VOLCANIC DISRUPTION

Define

Risk = The probability of at least one disruptive event during the next t_0 years.

$X(t_0)$ = The number of occurrences of such a disruptive event in $[0, t_0]$.

REMARKS

1. In this study, we restrict the risk to bull's-eyed volcanic events which result in the formation of volcanic cones and site disruption.

2. In so doing we neglect the potential impact of all other types of events such as a series of dikes, plugs, and sills, etc.

(What goes on under the surface?)

p = The probability that any single eruption is disruptive

(not every eruption would result in disruption of the repository)

$$\text{Risk} = 1 - \int_p \exp\{-\lambda(t) p t_0\}\, \pi(p)\, dp$$

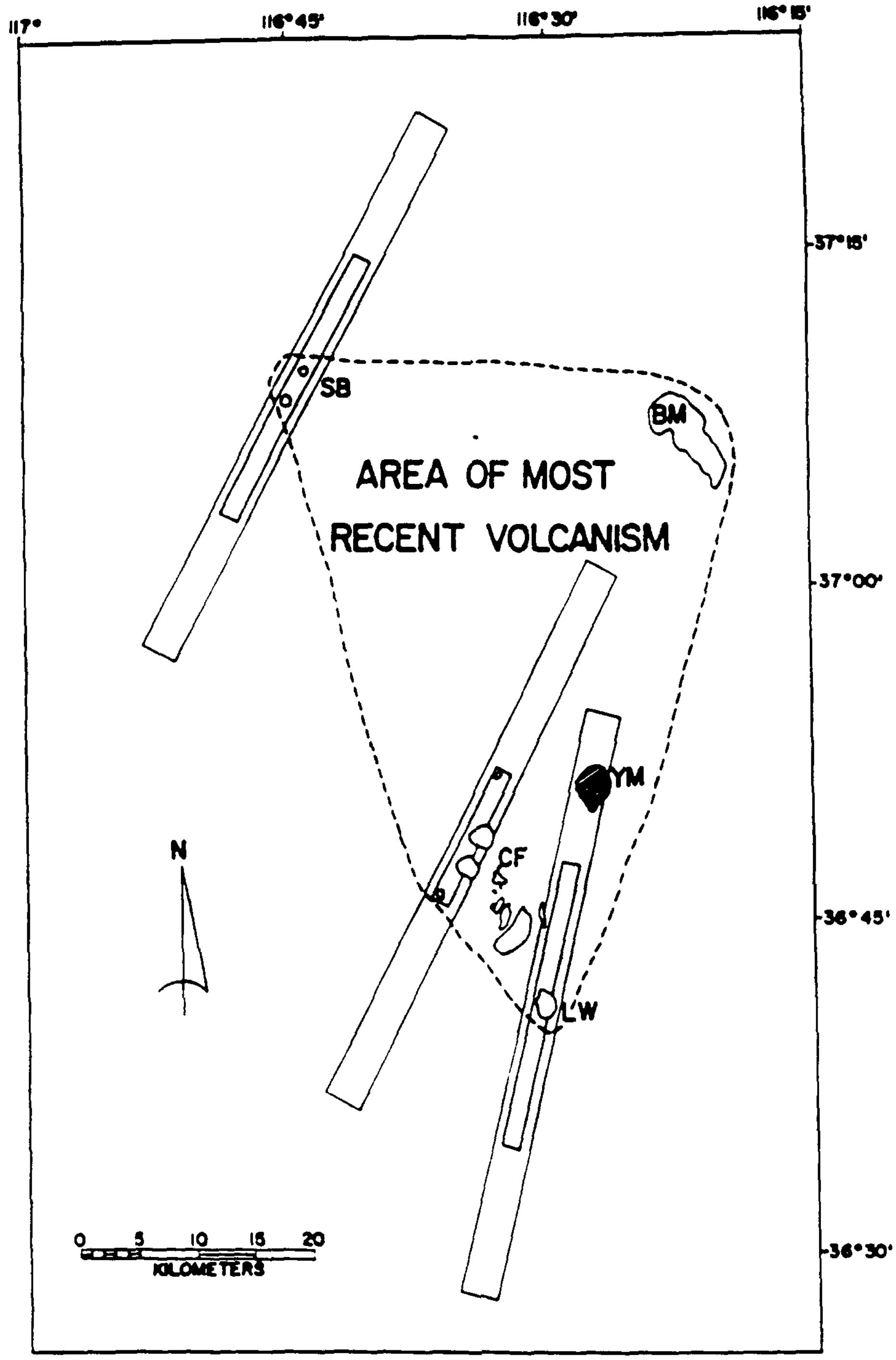
The technical machinery (Bayesian approach) involved in the risk calculation would support much more informative answers if the prior distribution $\pi(p)$ is adequately chosen.

Determination of the Prior

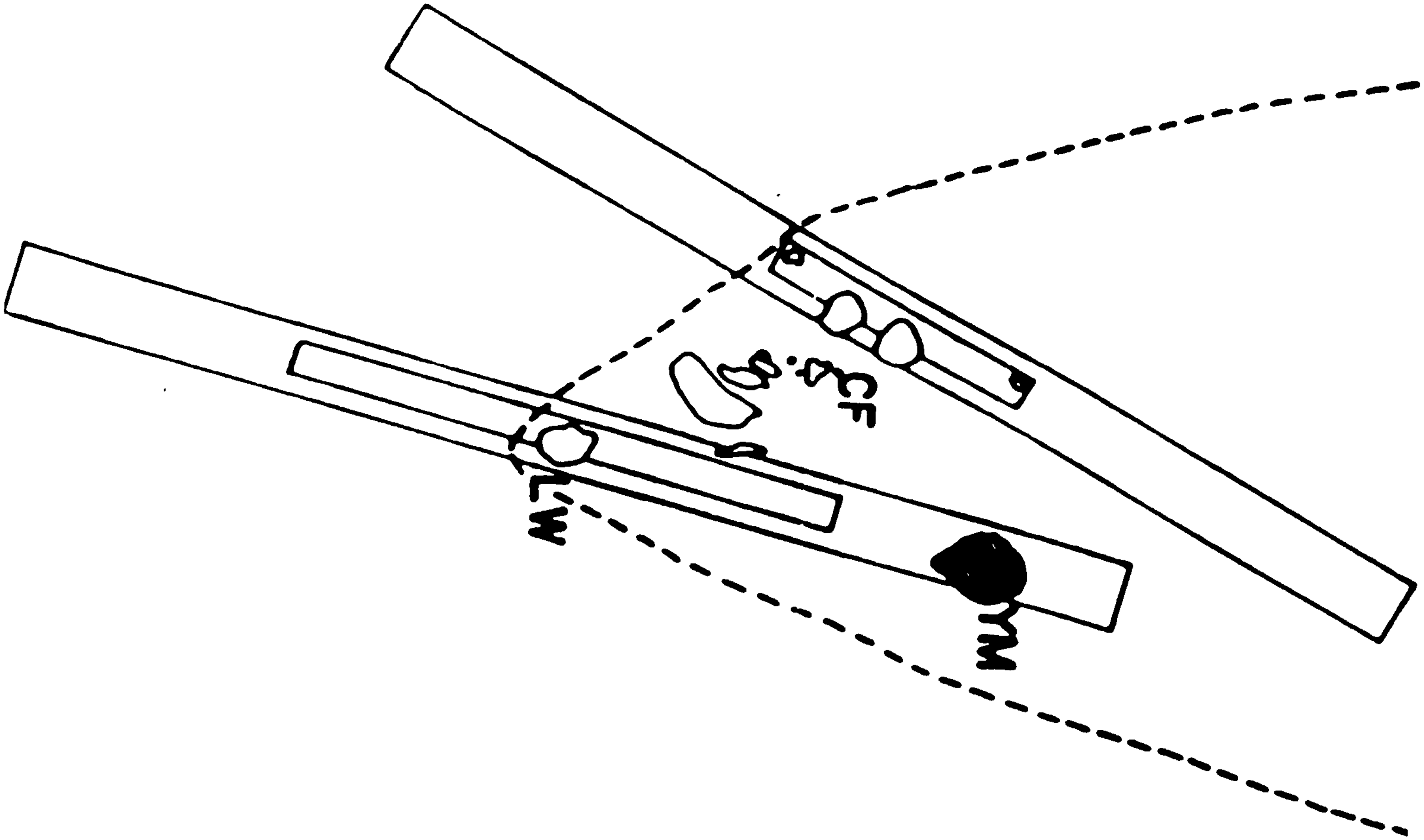
- The permissible range of p is $0 < p < 1$.

- Without use of expert opinions regarding the geological factors at NTS, a natural choice for $\pi(p)$ is a noninformative prior

- For instance, Uniform (0,1) assumes an average of 50% "direct hit" , which is unrealistically conservative (overestimation)



Map outlining the AMRV (dashed line) and high-risk zones (rectangles) in the Yucca Mountain (YM) area that include Lathrop Wells (LW), Sleeping Butte cones (SB), Buckboard Mesa center (BM), volcanic centers within Crater Flat (CF). (Source: Smith et al., 1990a, fig. 7)


CF
LW
YM

We have

1. $A = 75\ km^2$ (= half of the rectangle)

2. $a = 8\ km^2$ (area of the repository, Crowe et al, 1982)

3. $\pi(p) \sim U(0, 8/75)$, which assumes 8/75 as the upper limit for p

RESULT

A 90% confidence interval for the probability of site disruption for an isolation time of 10^4 years is

$$\left(1.0 \times 10^{-3}\ ,\ 6.7 \times 10^{-3}\right)$$