Testing Claims about Volcanic Disruption of a Potential Repository at Yucca Mountain

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WORKSHOP 2: ALTERNATIVE MODELS FOR THE PROBABILISTIC VOLCANIC HAZARD ANALYSIS UPDATE

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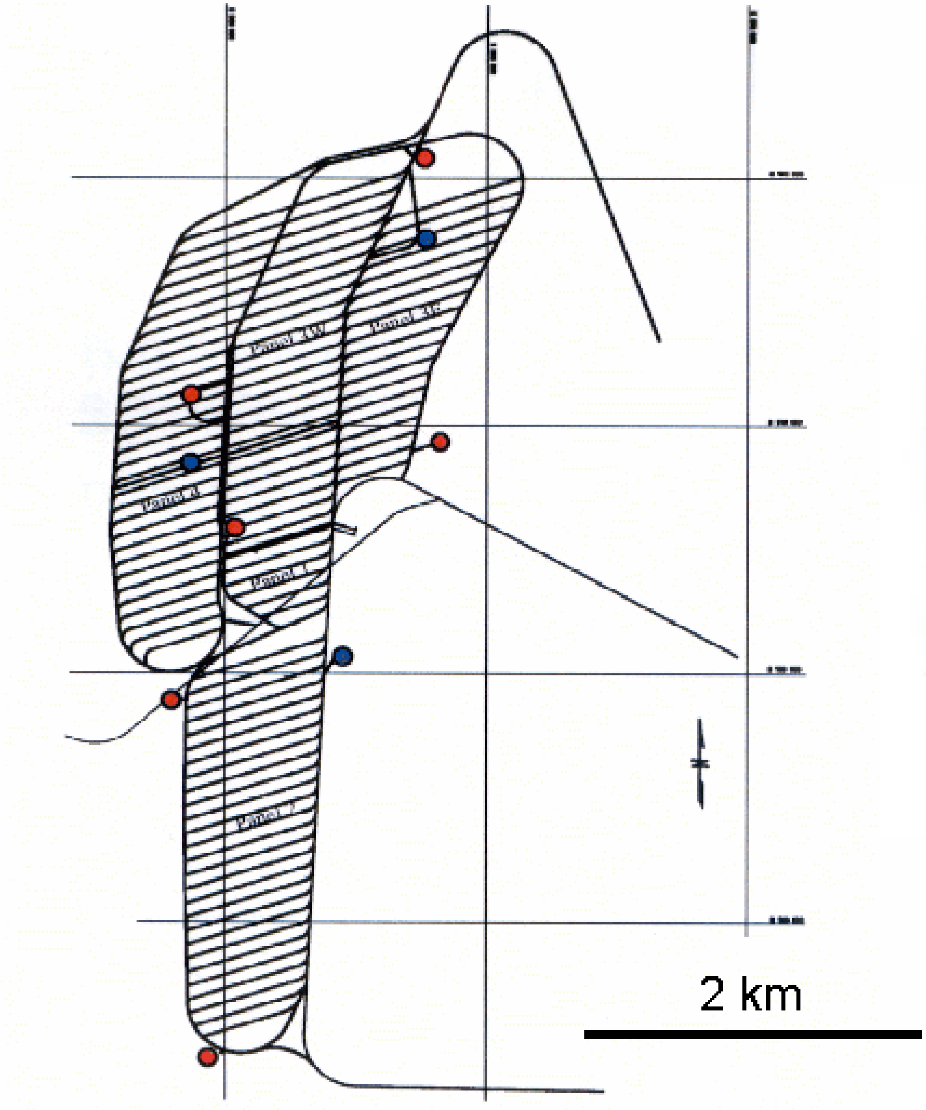
OUTLINE

- **Statement of issue**
- **Brief summary of regional volcanism**
- **Previous estimates of the probability of volcanism intersecting a repository**
- **Our results based on statistical and PVHA analyses**
- **Comparison to other volcanic fields**
- **Conclusions and recommendations**

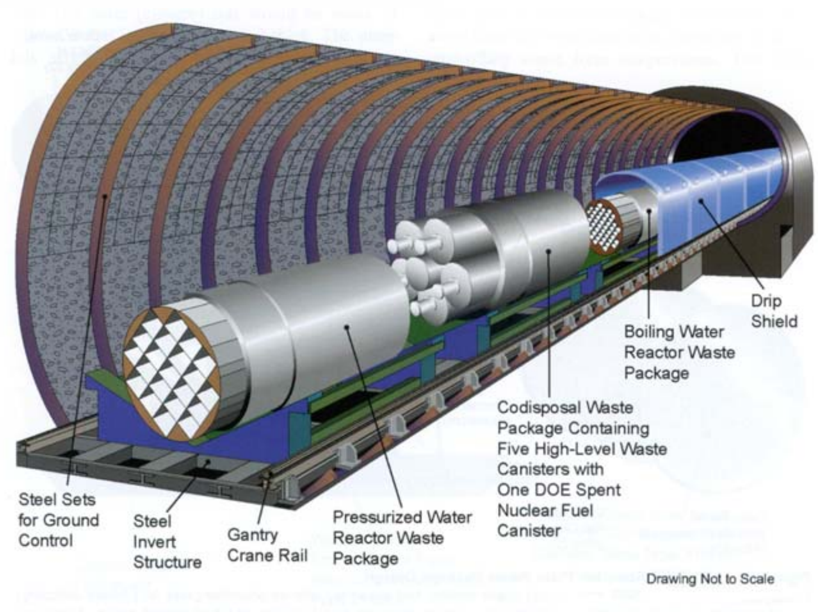
Regional studies suggest the probability of future volcanism is sufficiently high that NRC has required DOE to evaluate consequences of possible dike intersection.

Currently proposed footprint (~6.9 km²)



(Credit: U. S. DOE)

Waste emplacement drift



Schematic Illustration of the Emplacement Drift with Cutaway Views of Different Waste Packages

(Credit: U. S. DOE)

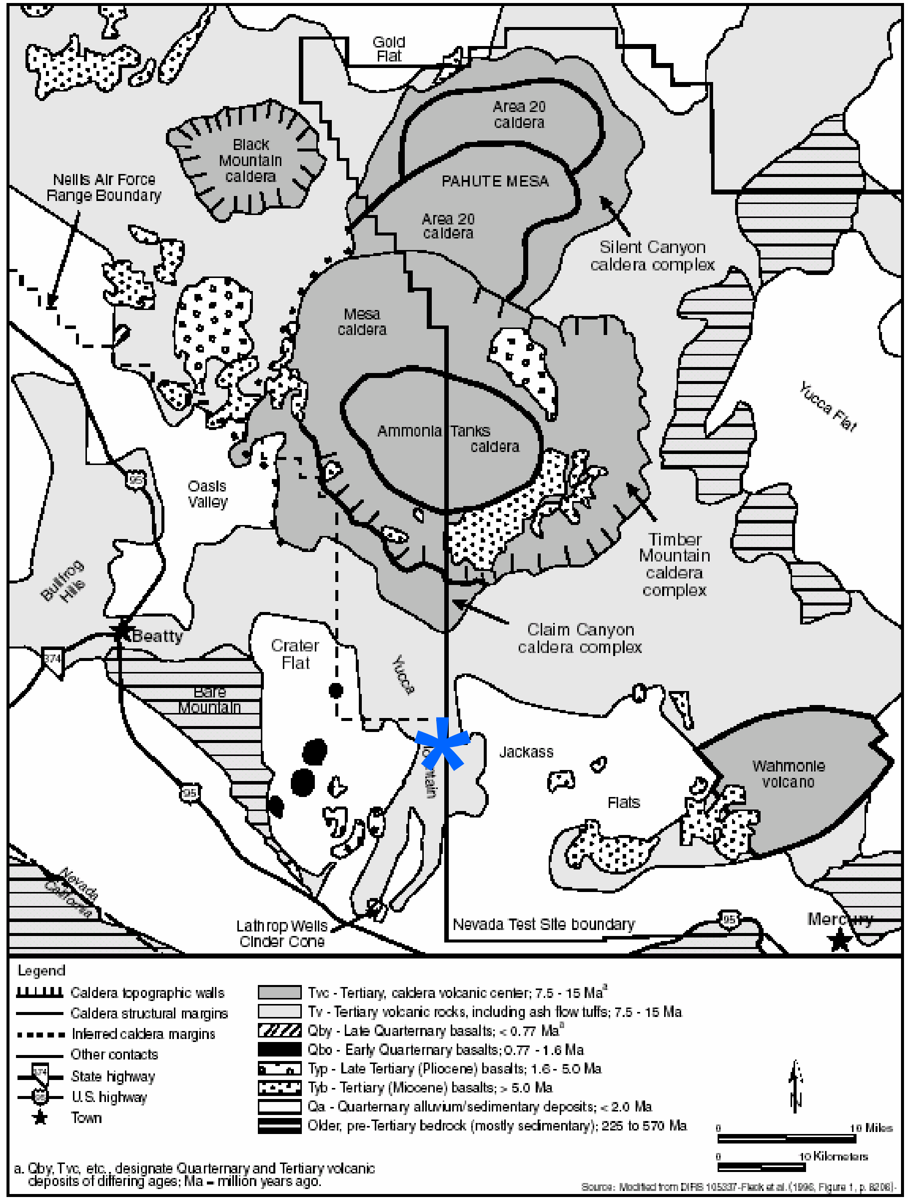
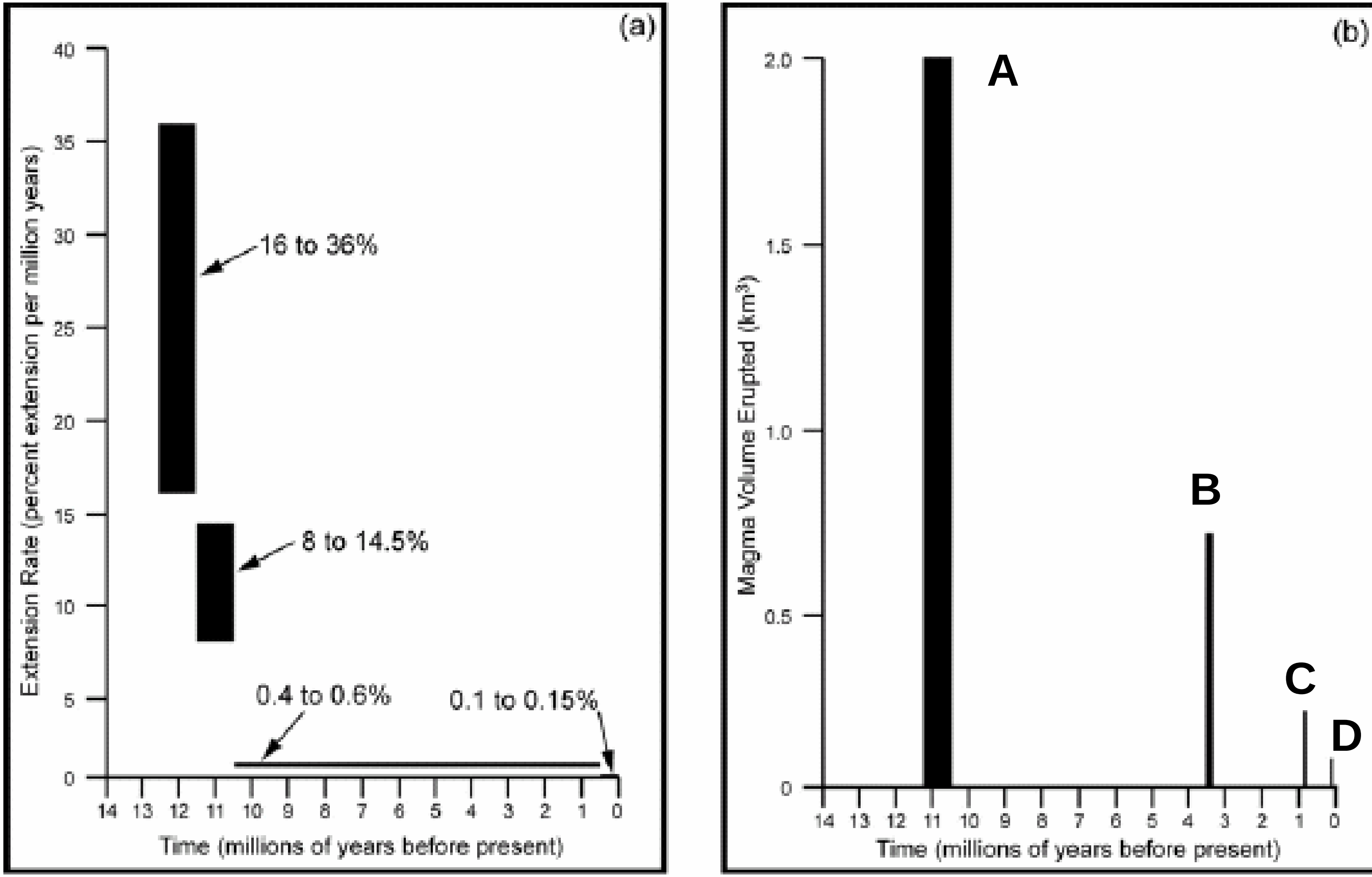


Figure 3-5. Simplified geologic map showing calderas of the southwest Nevada volcanic field in the Yucca Mountain vicinity.

(Credit: U.S. DOE, Office of Civilian Radioactive Waste Management, FEIS)



Estimated extension rates and magma volumes erupted in Crater Flat as a function of time (GSA Special Paper 333, Fridrich et al., 1999).

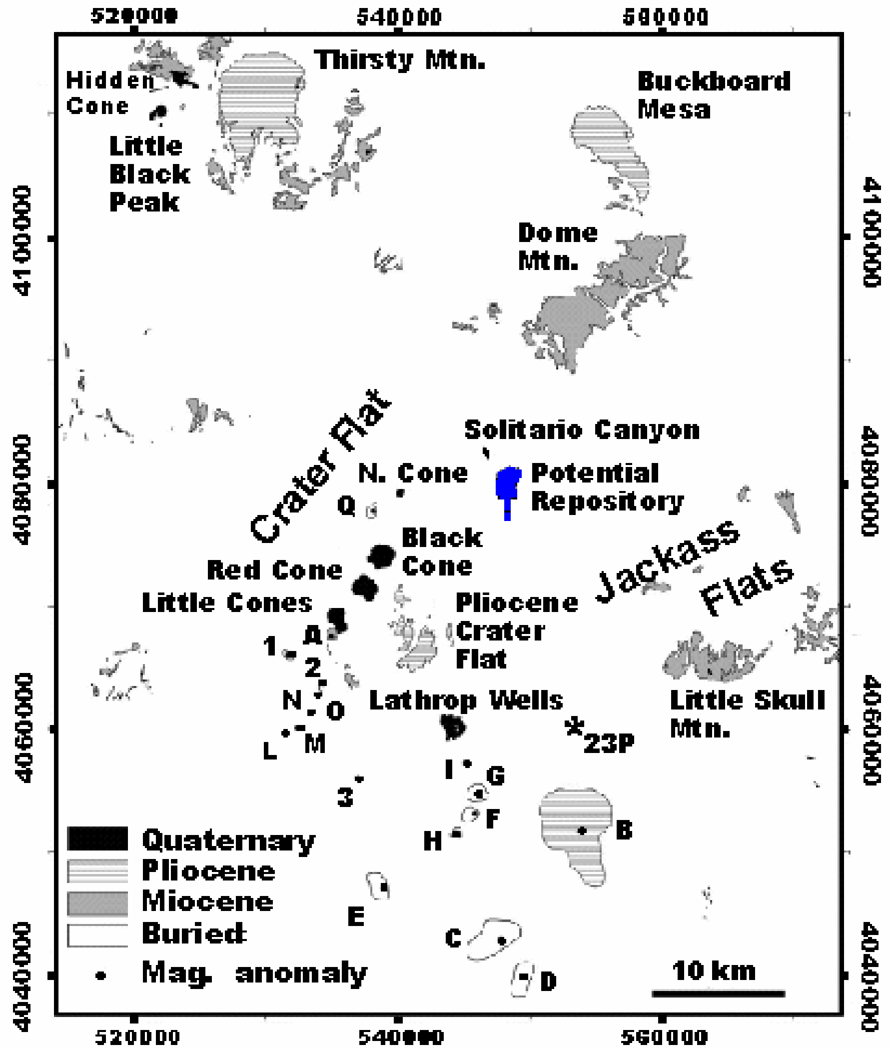
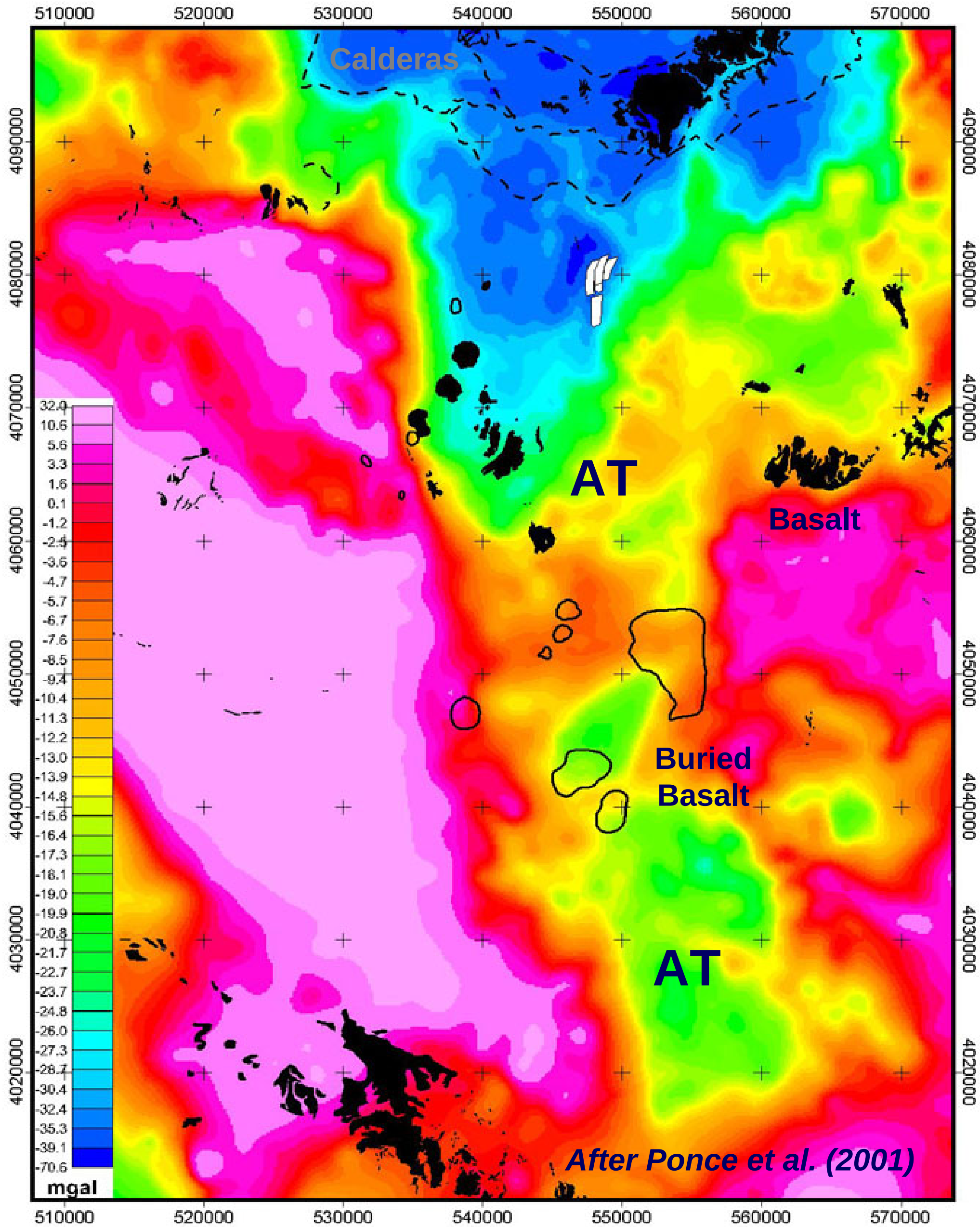


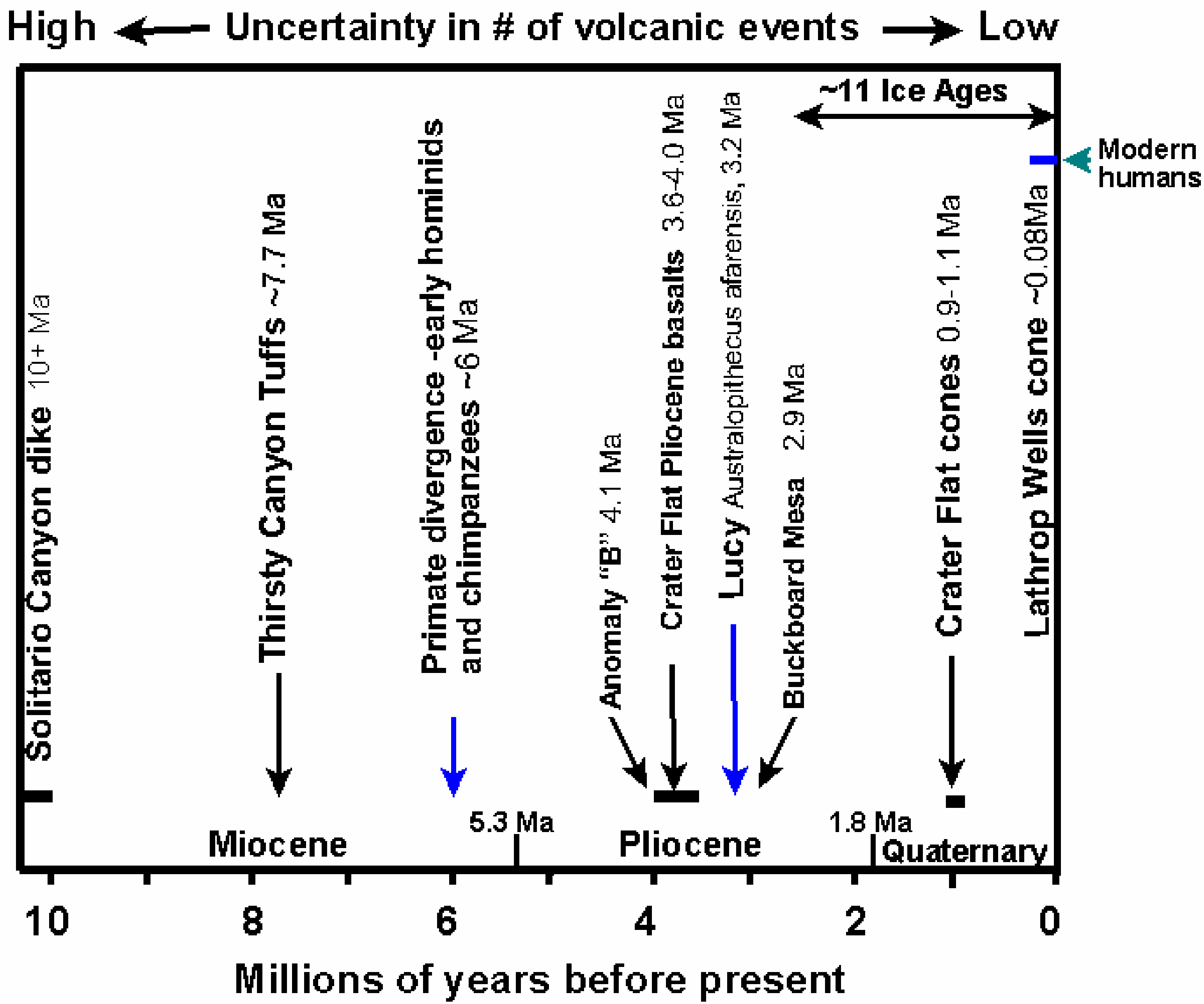
Figure 1. Locations of basaltic volcanos in the Yucca Mountain Region. Letters and numbers are magnetic anomalies of high to moderate confidence that represent possible buried basalts. Drilling at “B”, “D”, and well 23P has detected basalts. Map coordinates in UTM Zone 11 Meters, North American Datum 1927 (after Connor et al., 2002).

(after Connor et al., 2002, CNWRA rpt.)



Credit:
CNWRA

(credit CNWRA)


High
Uncertainty in # of volcanic events
Low
~11 Ice Ages
Modern humans
Solitario Canyon dike 10+ Ma
Thirsty Canyon Tuffs ~7.7 Ma
Primate divergence -early hominids and chimpanzees ~6 Ma
Anomaly "B" 4.1 Ma
Crater Flat Pliocene basalts 3.6-4.0 Ma
Lucy Australopithecus afarensis, 3.2 Ma
Buckboard Mesa 2.9 Ma
Crater Flat cones 0.9-1.1 Ma
Lathrop Wells cone ~0.08Ma
5.3 Ma
1.8 Ma
Miocene
Pliocene
Quaternary
10
8
6
4
2
0
Millions of years before present

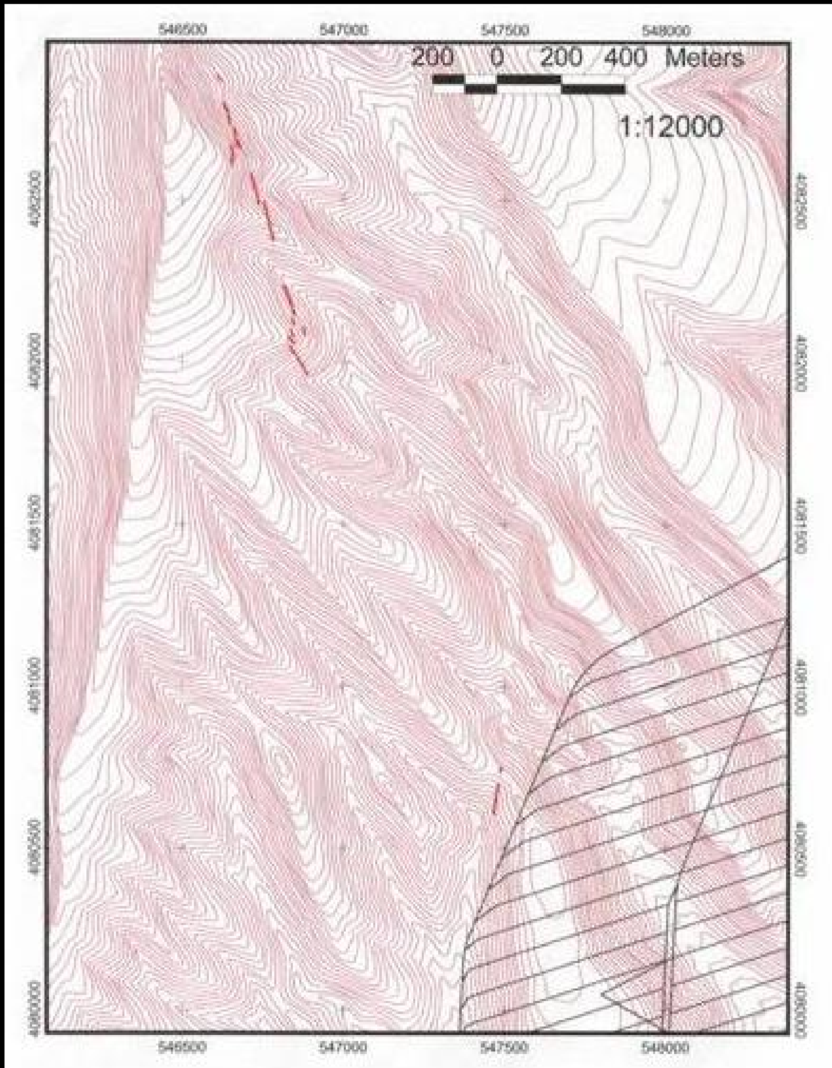
Estimates of volcanic disruption of a potential repository at Yucca Mountain

- 1×10^{-10}/yr - 1×10^{-8}/yr (Crowe et al., 1982)
- 1×10^{-8}/yr - 3×10^{-8}/yr (Connor & Hill, 1995)
- 5.4×10^{-10}/yr – 4.9×10^{-8}/yr (Geomatrix, 1996)
- 1.4×10^{-7}/yr - 3.0×10^{-6}/yr (Ho & Smith, 1997)
- 1.1×10^{-8}/yr - 3.1×10^{-7}/yr (Ho & Smith, 1998)
- 1×10^{-8}/yr - 1×10^{-7}/yr (Connor et al., 2000)
- Up to 10^{-6}/yr (Hill & Stamatakos, 2002)
- 5.6×10^{-10}/yr - 4.3×10^{-8}/yr (DOE, 2003)

IMPLIED ACTIVITY OVER TIME

Assuming a constant penetration rate (λ), the # of penetrating dikes over time T has a Poisson distribution with mean = λT. The probability of at least one penetration = 1 - exp($-\lambda T$). For $\lambda = 2 \times 10^{-7}$/yr, the expected # of penetrating dikes in 13 Myr is 2.6 and the probability of at least one penetration is 0.93. For $\lambda = 1 \times 10^{-6}$/yr, the expected # of dikes is 13 and the probability of at least one penetration is 0.999998.

Because no penetrating dikes have been found in the footprint of the potential repository, these results are inconsistent with the exploration evidence.



(After Day et al., 1998)

Miocene dike (10-11.7 Myr) in Solitario Canyon

Intrusion Frequency Bound Based on Non-Detection of Dikes in Repository Footprint

Age of surface rocks is 12.7 Myr (Tiva Canyon caprock)

One dike of Miocene age was a “near miss” but not a hit, so the observed frequency of dike intersection is zero

Use confidence limit for expectation of a Poisson variable

Poisson value for 95% upper confidence limit is 3.0 (given count = 0)

The upper 95% confidence bound on intrusion frequency is 3.0/13 Myr = 2.3×10^{-7}/yr

Assuming 1 undetected dike, upper bound is 4.7/13 Myr = 3.6×10^{-7}/yr

Pliocene vent complex, Crater Flat

Black Cone, Crater Flat

(Pleistocene age, ~1 Ma)

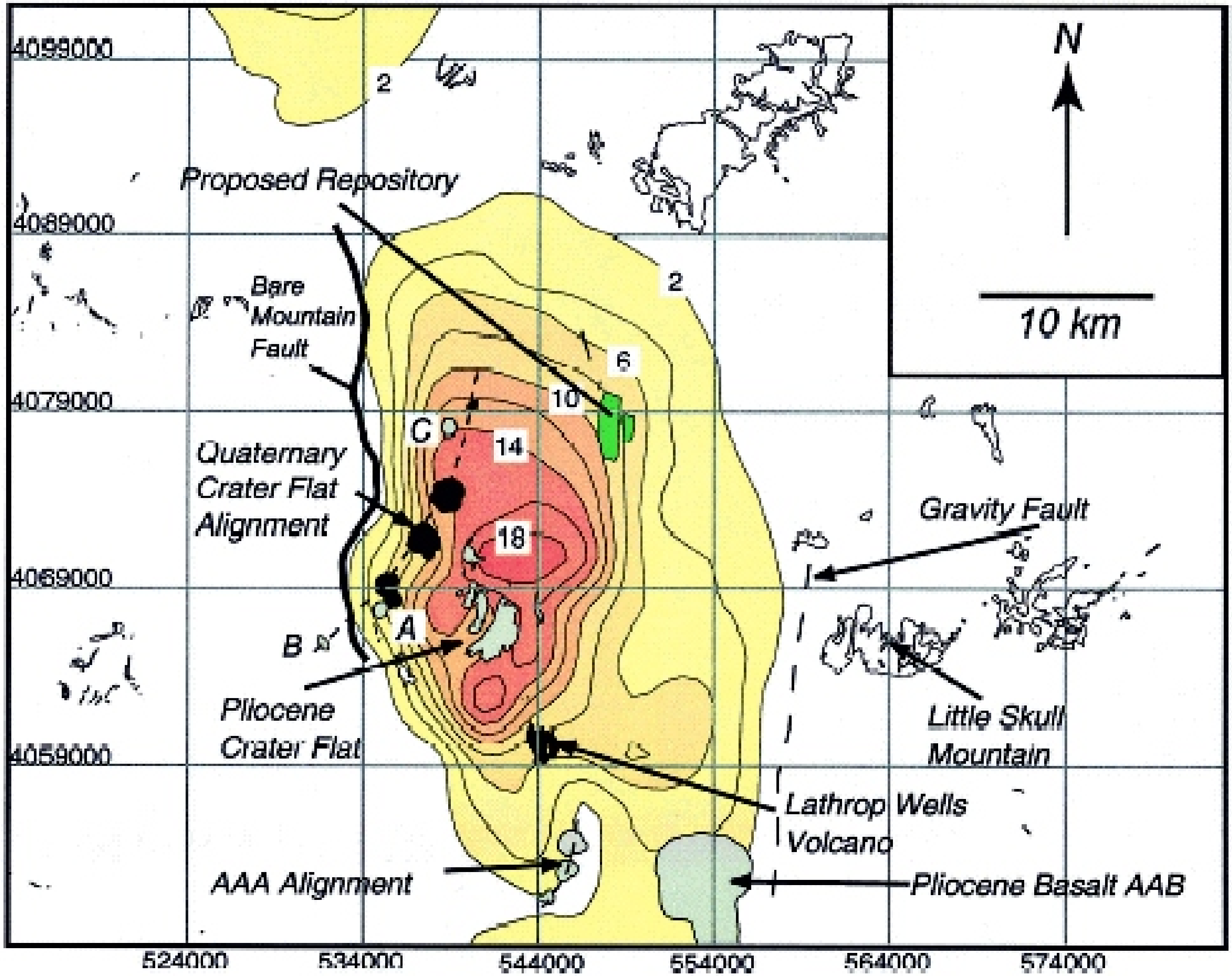


Plate 2. The spatial recurrence rate (volcanic events/km^2) contoured for the YMR, based on the distribution of Quaternary volcanism and its relationship to the BMF (see appendix). The contour interval is 2×10^{-4} volcanic events/km^2.

(From Connor et al., 2000, *JGR*)

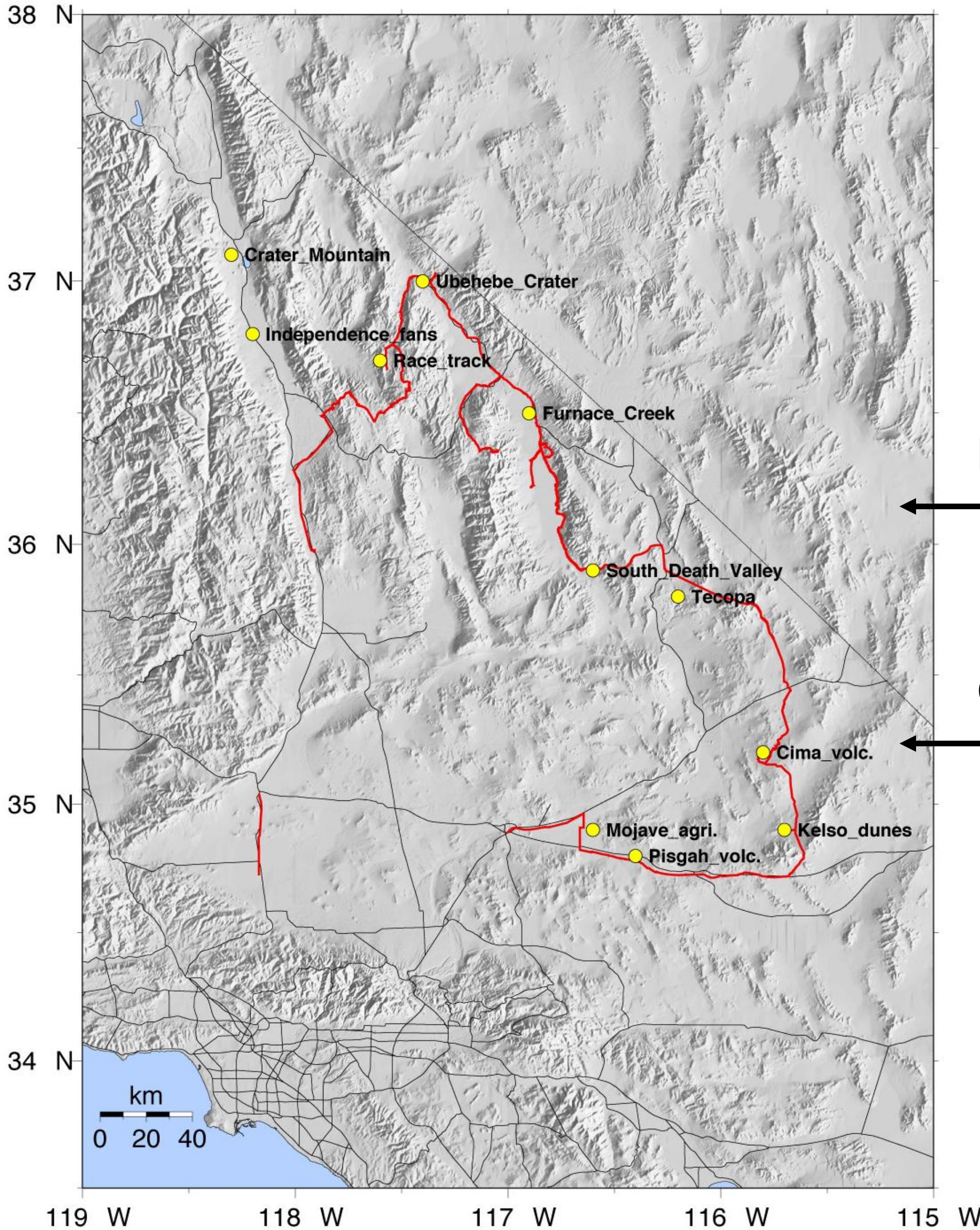
PVHA_YM Data Files	Volcanic events/million yrs in YM region needed to produce repository intersection rates of:		
	10^{-8}/yr	10^{-7}/yr	10^{-6}/yr
All_64events	0.95	9.5	95
CFB_16alignments	0.45	4.5	45
CFB_mio-quat-MAG	0.40	4.0	40
CFB_plio-quat-MAG	0.44	4.4	44
Crater_flat_align_3events	0.63	6.3	63
miocene-quat_47events	0.96	9.6	96
miocene-quat_57events	0.90	9.0	90
pliocene-quat_20events	0.50	5.0	50
pliocene-quat_30events	0.51	5.1	51
quaternary_8events	0.42	4.2	42

(Gaussian model + 100% gravity weighting + 1-5 km dike/event length. Similar results are obtained using an Epanechnikov kernel model. If gravity weighting is eliminated, the numbers of events in the table would DOUBLE.)

Recurrence Intervals

Volcanic Field	Vents/yr
Eifel, Germany	5×10^{-4}
Camargo, Mexico	1×10^{-4}
TransMexican Belt	3×10^{-4}
Springerville, AZ	2×10^{-4}
San Francisco, AZ	1×10^{-4}
Coso, CA	3×10^{-5}
Pancake, NV	1×10^{-5}
Cima, CA	8×10^{-5}
Yucca Mountain, NV	1×10^{-5}

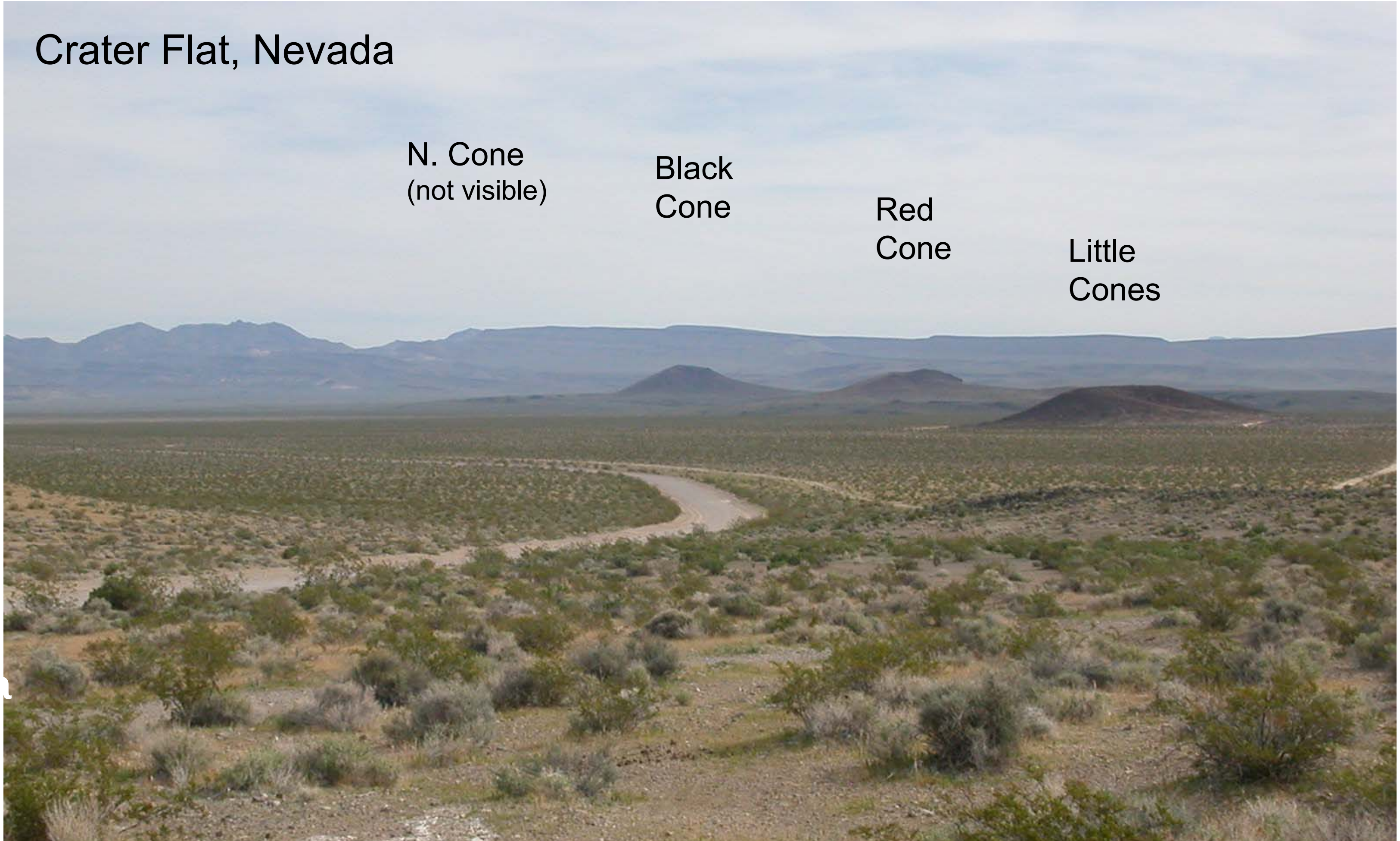
Source: C. Connor at http://www.norvol.hi.is/~thora/summer2003/notes/connor.pdf

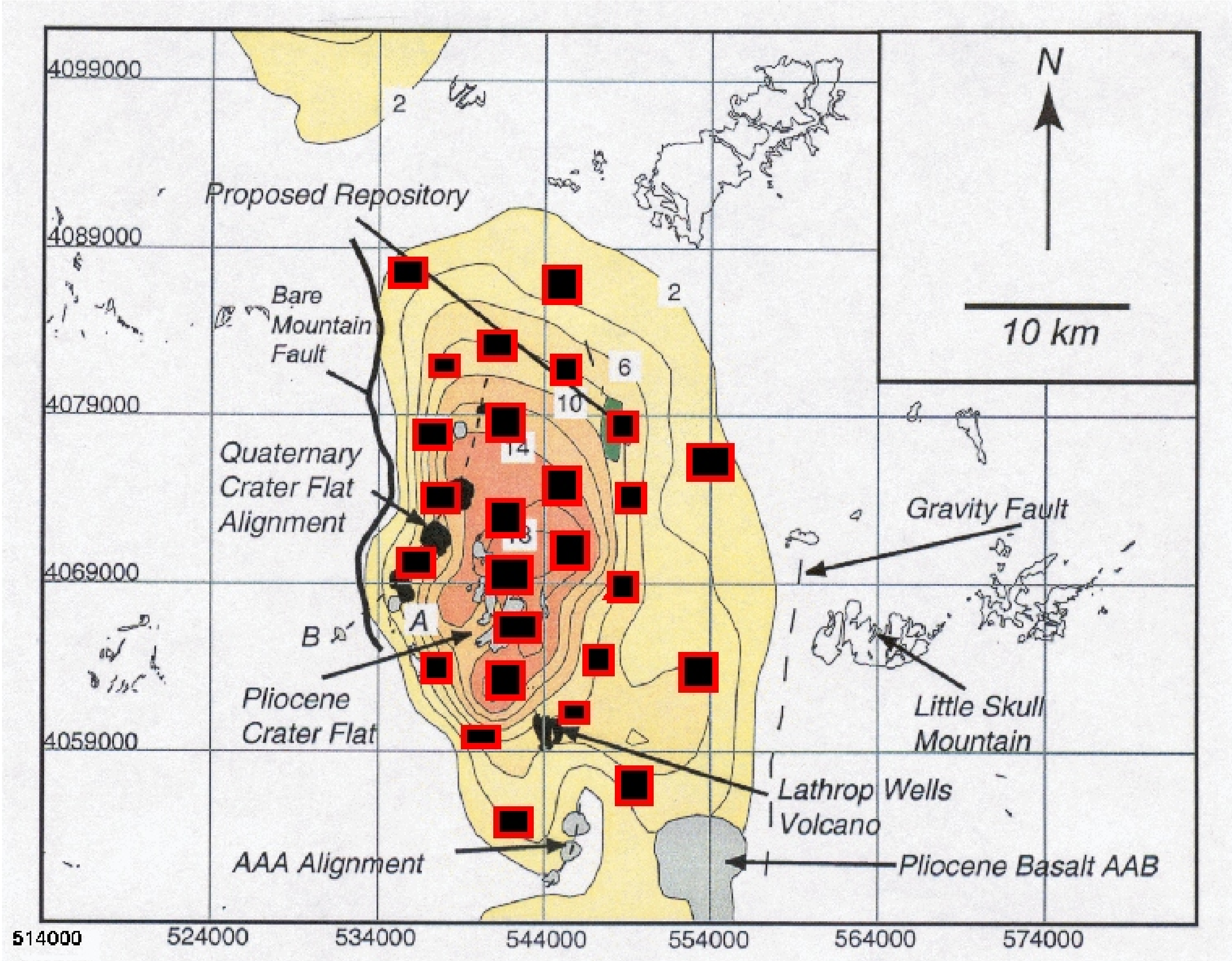


Las Vegas

Cima, CA

Cima, California (~70 vents)





Last million yrs should have looked like this given a penetration rate of 10^{-6}/yr.

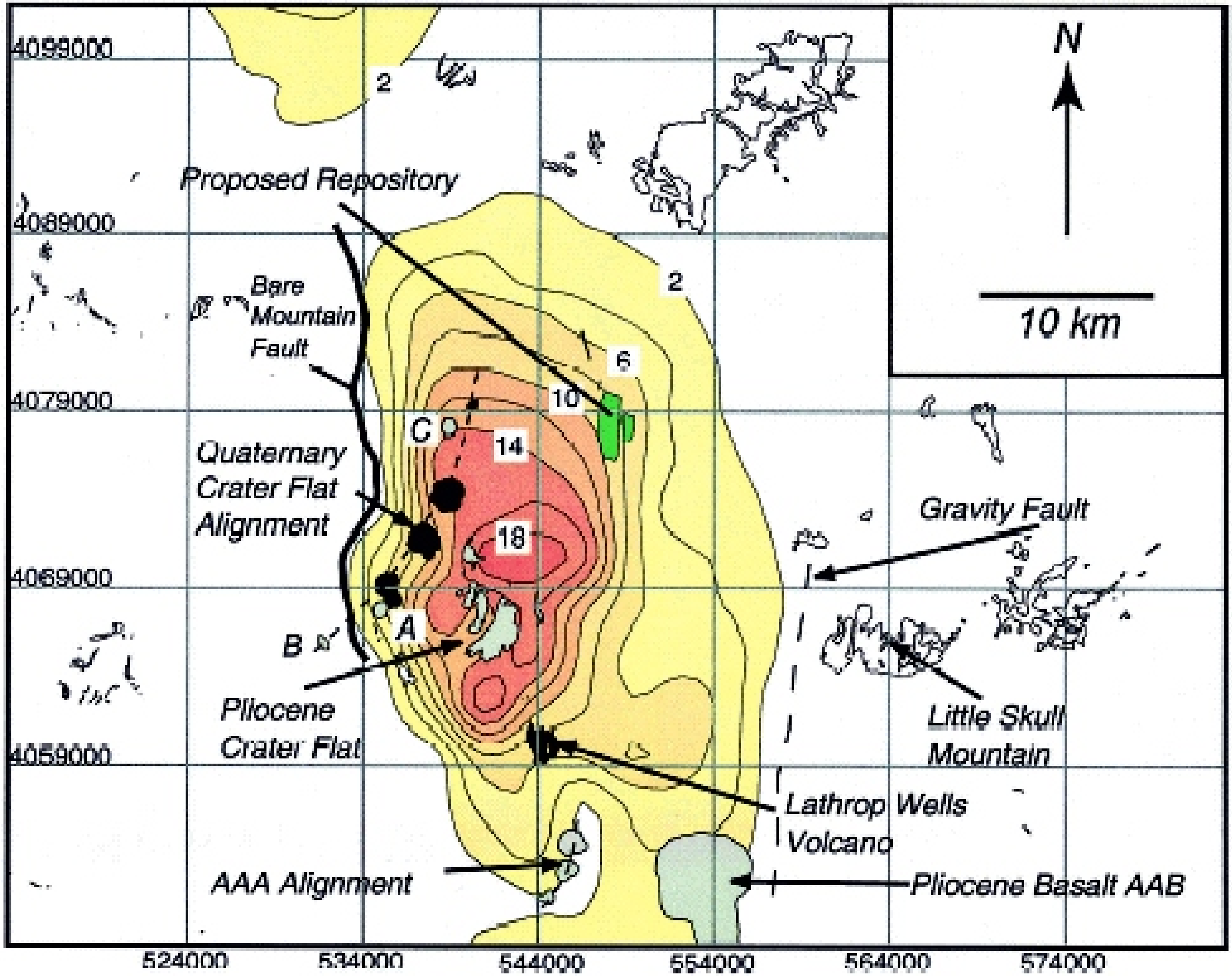


Plate 2. The spatial recurrence rate (volcanic events/km^2) contoured for the YMR, based on the distribution of Quaternary volcanism and its relationship to the BMF (see appendix). The contour interval is 2×10^{-4} volcanic events/km^2.

From Connor et al., 2000, JGR. During the Pleistocene (1.8 Myr), only 8 basaltic events (or fewer) are known to have occurred in the Yucca Mtn. region (6 are visible here).

Rates of basaltic volcanism comparable to those in the Cima, CA volcanic field or on the Colorado Plateau (i.e., 30 volcanoes per million years) have not occurred near Yucca Mountain during the Pliocene-Quaternary (Connor et al., *JGR*, 2000).

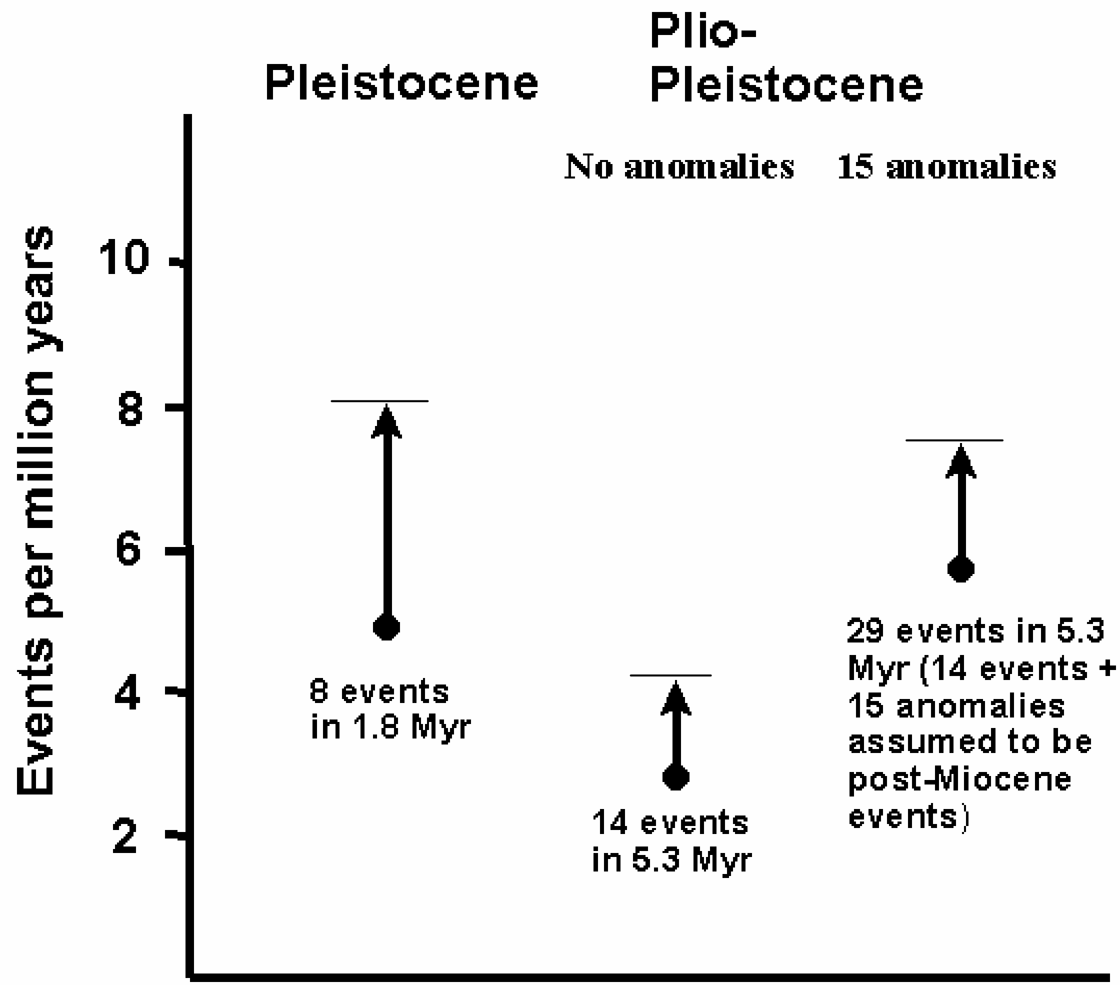
“It is reasonable that the probability estimates we calculate for volcanic eruptions at Yucca Mountain be substantially less than those estimated for these larger, more active volcanic fields” (Connor et al., *JGR*, 2000).

Recommendation

Consider using the Quaternary recurrence rate to estimate the potential frequency of repository intersection. This has 3 advantages:

1. **Compared to Pliocene, the Quaternary better represents the present-day tectonic regime.**
2. **The Quaternary fully captures the most recent volcanism cluster at ~1 Myr. This cluster represents 5 events (or less).**
3. **More reliable recurrence rate. Uncertainty about the number of Quaternary events is reduced compared to Pliocene events. There has been insufficient time to erode or completely bury Pleistocene basalts.**

With respect to decision making, using the Quaternary recurrence rate reduces concerns about older events that may be present but undetected. This approach also reflects the gradual decline in volcanism over time.



Rates of volcanism in Yucca Mt. region with 95% upper confidence bound (based on expectation of a Poisson variable)

Estimate of Repository Intersection Frequency

- Our best estimate uses NRC's PVHA code and data, the Pleistocene recurrence rate (4.4 events/Myr), and zero gravity weighting.
- We estimate an intersection frequency of 5.4×10^{-8}/yr.
- Since the result is based on 8 events, the 95% upper confidence bound (Poisson distribution) is 9.7×10^{-8}/yr.

We also analyzed file ‘‘CFB_plio-quat-Mag’’ which includes 14 Plio-Pleistocene events in Crater Flat (age of one basalt is estimated) and 15 magnetic anomalies that are assumed to be post-Miocene basalts. A recurrence rate of 5.5 x 10^{-6}/yr (29 events in 5.3 Myr) with no PVHA gravity weighting yields a dike penetration frequency of only 5.0 x 10^{-8}/yr.

A Few Thoughts About Event Clustering

Natural processes tend to occur in clusters (earthquakes, volcanism, hurricane landfalls, floods, droughts)

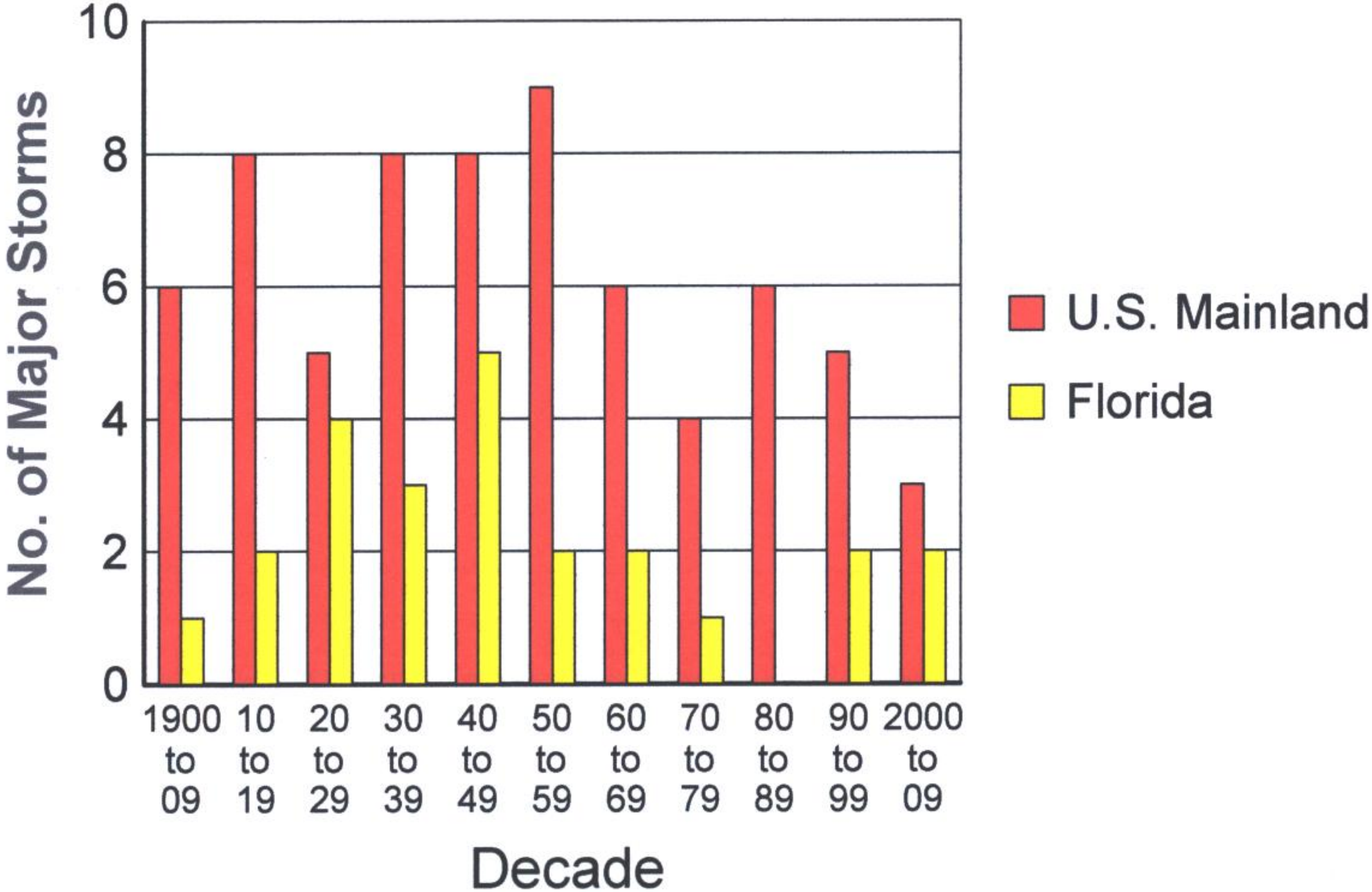
Therefore short-term recurrence rates can change significantly over time

Care is needed in identifying time frames of interest

Event frequencies during clustered activity do not represent long-term expectations

High recurrence rates that represent clusters should only be used if evidence says clustered activity has returned

Major Hurricane Landfalls
(Category 3-5)



Conclusions

Our analysis raises doubts that a repository could be penetrated by a dike once every million yrs (i.e., 10^{-6}/yr). We evaluated four time scales: 13 Myr, 1 Myr, 100 kyr, & present-day.

<u>13 Myr</u>: Non-detection of basalts in the repository foot-print suggests upper-bound penetration rate of 2 x 10^{-7}/yr averaged over 13 Myr. Useful test of model results.

<u>1 Myr</u>: For a penetration rate of 10^{-6}/yr, the NRC PVHA code & data indicate 40-96 volcanic events (80-192 without gravity weighting) would be expected in the region in the past 1 Myr. But only 8 events are known in the last 1.8 Myr.

Conclusions (cont.)

<u>100 kyr</u>: For a penetration rate of 10^{-6}/yr, the PVHA_YM code & data indicate 4 to 9 events would be expected in the last 100,000 yrs. Only 1 is known. Therefore we see no evidence that the Lathrop Wells event (~80kyr) began a new "cluster" of volcanism.

<u>Present day</u>: Previous claims of anomalously high crustal strain in the Yucca Mt. region, a condition that may enhance volcanism, have been contradicted (Savage et al., 2001).

Using a Quaternary recurrence rate of 8 events in 1.8 Myr and the NRC PVHA_YM code, we estimate the frequency of future dike penetration at 5.4 x 10^{-8}/yr. The 95% upper confidence bound is 9.7 × 10^{-8}/yr.

References

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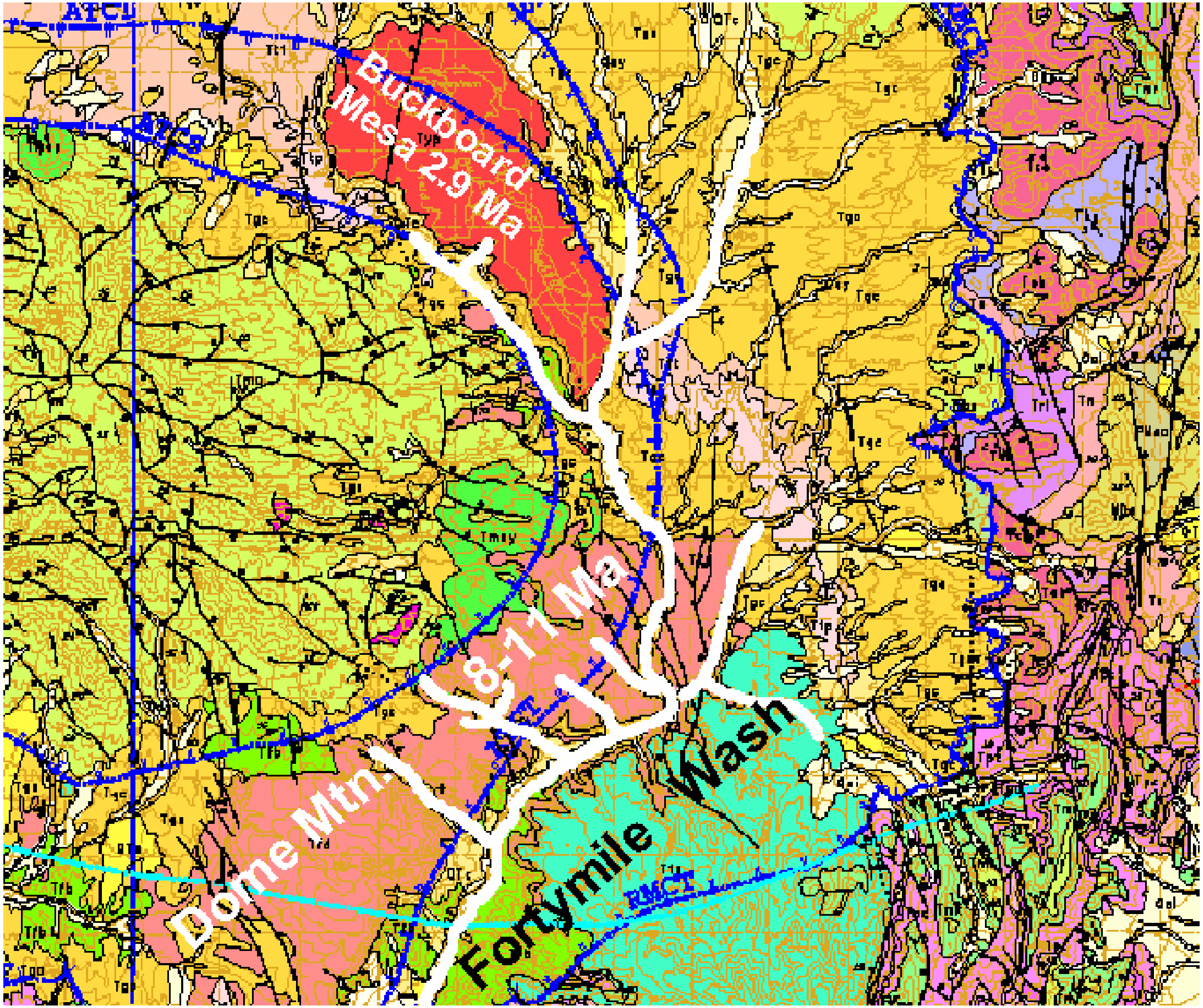

Slate et al. 2000 (USGS OFR 99-554)