JUL 11 1989

Mr. Ralph Stein, Associate Director
Office of Systems Integration and Regulations
Office of Civilian Radioactive Waste Management
U. S. Department of Energy, RW-24
Washington, D. C. 20545

Dear Mr. Stein:

Last week at the NRC-DOE meeting in Las Vegas on the exploratory shaft facility (ESF) design control process, I discussed the need for an NRC-DOE tectonics meeting in the near future and handed out a draft agenda for the meeting. One topic that needs to be discussed at that meeting is the need for early and iterative performance assessments to evaluate the impact of potentially adverse tectonic conditions (e.g., volcanism, faulting, seismicity) on the waste isolation capability of the repository. As a simple example, an early partial and preliminary performance assessment of the probability of volcanism at Yucca Mountain done by an NRC staff member is enclosed. This assessment is not an NRC position, but merely an example of the type of assessments that will be discussed at the tectonics meeting and that need to be performed by DOE during site characterization.

King Stablein (FTS 492-0446) of my staff is arranging for a conference call later this week involving NRC, DOE, and the State of Nevada to schedule the tectonics meeting and to develop the agenda for it.

Sincerely,

/S/

John J. Linehan, Director
Repository Licensing and Quality
Assurance Project Directorate
Division of High-Level Waste Management

Enclosure: As stated

cc: R. Loux, State of Nevada
M. Baughman, Lincoln County, NV
S. Bradhurst, Nye County, NV
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1/1

102
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PROBABILITY OF VOLCANISM AT YUCCA MOUNTAIN

INTRODUCTION.

This evaluation provides alternative sample calculations for probability and consequence for basaltic volcanism at Yucca Mountain. These calculations are based on a combination of published data, draft data and field observations and should be considered preliminary and for illustrative purposes only. Their purpose is to demonstrate that with the present data base there are serious concerns which need to be resolved prior to being able to license a repository at the Yucca Mountain site.

UNDERLYING REGULATIONS.

The regulation which is of primary concern when discussing volcanism, and its effect on licensing of the Yucca Mountain site, is 40 CFR 191 as it will be implemented in 10 CFR 60.112. This regulation sets numerical limits on release associated with probability. In simplest terms the probability that the repository will not release more than a specified cumulative amount of radiation to the accessible environment must not be exceeded more than 1 time in 10 in 10,000 years, and the probability that ten times this amount will not be released must not exceed 1 chance in 1000 in 10,000 years.

In addition to the EPA standard, volcanism, and its effects, must be considered in relationship to the engineered barrier system. In this case we are concerned only with the "anticipated processes and events", however, the new data on volcanism will require a reevaluation to determine what processes and events fall under this category.

While the regulatory requirements tend to focus all work on a 10,000 year time frame, it was not the intent of either 40 CFR 191 or 10 CFR 60 to ignore time frames past this point. This is perhaps most explicitly stated in the statement of considerations for 40 CFR 191 where it is pointed out that 10,000 years was selected because longer time periods would have involved more uncertainty calculations. The wording further states " There was no intention to indicate that times beyond 10,000 years were unimportant..." In addition, the working draft of the revised standard has specific requirements for a 100,000 year time frame.

Another concept intended by 10 CFR 60 was that a site should exhibit geologic stability. While the exact requirement was present in the proposed rule and then removed from the final rule, the statement of considerations for final rule 10 CFR 60 states that one of the reasons for the concept was to assure that the processes be such that long term changes could be projected with relatively high confidence. This concept was then applied by identifying as potentially adverse conditions those things which stand in the way of such interpretations and projections. Quaternary igneous activity is listed as one of these conditions.

AREA TO USE FOR VOLCANIC PROBABILITY CALCULATIONS

Most of the work related to volcanic probability calculations for Yucca Mountain has been done by Crowe. He has used two basic types of calculations to obtain these numbers, one based on the number of volcanic cones present in an area, and one based on rate of release of magma. The various calculations

Crowe has performed have incorporated different sizes circles and ellipsis in an attempt to address structural control, however, I know of no case where structural control was directly incorporated through geophysical or geologic data. One of the important underlying assumptions which must be evaluated, therefore, is the question of whether or not the area which Crowe used to obtain his calculations is representative of the area in which volcanics can occur in the future.

I presently know of only one data set which can provide an insight into the underlying structure in the area of Yucca Mountain which has enough detail and is of a large enough aerial extent to provide a useful analysis. This is the aeromagnetic data presented by Kane and Bracken, 1983. Examination of this data shows that all Quaternary volcanic activity within the immediate vicinity of the site lies within a zone which has an aeromagnetic signature which is different from the surrounding area. The west, south, and east boundaries are quite clear. These roughly correspond to the boundary of the northeast trending volcanic cones in Crater Flat, the Lathrop Wells cone and the dividing line between Busted Butte-Jackass Flat. The northern boundary is not as clear due to the effects from Timber Mt etc, but there is a strong northwest lineation, or discontinuity, noted by Kane and Bracken. This northwest lineation is the boundary for a series of north to northeast trending lineations which cross the site area and because this signature is characteristic of the area in which Quaternary basaltic volcanism associated with Crater Flat-Lathrop Wells has occurred, I have chosen the northwest lineation for the northern boundary of this zone. The area enclosed by this zone is about 420 square KM. If this area, which I will be referring to this as the Yucca Mountain Volcanic Zone (YMVZ), is compared to that used by Crowe et al., 1982, it is shown to be much smaller, (Crowes areas ranged from 2437 to 69466 square KM), and contains fewer Quaternary cones as it does not include places such as Sleeping Butte and Buckboard Mesa.

If we compare the YMVZ with the NTS region as a whole, Crowe et al., 1982, has calculated the rate of volcanic magma production for the NTS region (which includes the area I am referring to as YMVZ) as somewhere between 3 to 8 X 10E-11 KM3/KM2/year. If the cone volume within the YMVZ is considered as representative of the total volume of magma produced within the YMVZ during the last 1.5 million years, this volume can be obtained from Crowe, et al., 1982, and Crowe, 1983, et al., as approximately 1.9 X 10E8 cubic meters. The calculated rate of magma production for the YMVZ is, therefore, approximately 3 X 10E-10 KM3/KM2/Year. As this value is approximately an order of magnitude greater than the values published by Crowe, it suggests that the YMVZ is a more active volcanic region then the NTS region as a whole, and that calculations of the probability of future eruptions at the Yucca Mountain site which lump the YMVZ into the entire region, such as those done by Crowe, may underestimate the probability of site disruption.

RATES OF VOLCANIC ACTIVITY WITHIN YMVZ BASED ON CONE COUNT.

As stated previously, the volcanic probability calculations have been based on two different types of calculations, one based on cone count, and one based on trying to determine trends in rates of magma production.

The various geologic maps of the area show that there are surface exposures for 5 Quaternary cones within the YMVZ. Various age dating techniques have been used, and the oldest date which has been proposed for any of these cones is on the order of 1.5 million years. If it is assumed that this is representative of rates of future cone formation, the rate of new cone formation within this zone becomes one cone formation per 300,000 years or one chance in 30 of a cone formation within the YMVZ during the next 10,000 years.

If cone count is used to calculate probability that a new volcanic event will occur within the zone and disrupt the site, the probability of it occurring within the repository is based on a ratio of the area of the site to the total area in which volcanism could occur. From Chapter 6 of the SCP it can be determined that the area of the site is 1420 acres plus or minus 210, or for round figures about 6 square kilometers. The probability obtained for cone formation using this method is 420/6 or about 1 in 70 times 1 in 30, or about 1 in 2100, a probability of 4.7 X 10E-4 in 10,000 years.

COMPARISON WITH PREVIOUS NUMBERS.

If the basic assumption that the area of concern for volcanism at the Yucca Mountain site can be delineated by the aeromagnetic data is generally correct, the value obtain corresponds to the upper bound value reported by Crowe et al., 1982. Crowe, et al., reported values which ranged from approximately 4.7 X 10E-4 to 5.1 X 10E-5 per 10,000 years.

If the above numbers were used to determine compliance with 40 CFR 191, as implemented by 60.112, it would appear that the site could be shown to be acceptable. The are, however, obvious problems surrounding the small sample size in making the various projections, and therefore the uncertainty associated with the projections. More important, however, is the question of the applicability of using the cone count type of approach in determining the potential of future volcanic activity at the site.

EFFECT OF CONSIDERATION OF VOLCANIC CYCLES

One of the factors which has to be considered in evaluating the potential for future volcanism at the Yucca Mountain Site is the question of where the Yucca Mountain area is in the general stage of volcanic evolution. There are some investigations conducted by LANL which suggest that, from geochemical data, basaltic volcanism is in a waning stage. This conflicts, however, with preliminary investigations conducted by UNLV, through the State, which suggests that the nepheline - hypersthene cycles may not be representative of waning volcanism, but only a stage in the overall cycle. This information is, therefore, inconclusive at the present time.

If we expand our information base beyond the Basin and Range, there is data from the Western United States which suggests that volcanic activity has been increasing during the last 5 million years. For example, to quote Smith and Luedke, 1984, "Figure 4.11 shows that the average rate had accelerated from 1 vent per 1000 years to about 1 vent per 100 years by 100,000 yr ago. The numbers for vents less than 10,000 yr old may be too small to be significant, but they too are minimum numbers, and the average rate of vent formation may exceed 1 vent per 100 yr today. The average rate is probably not meaningful in a real sense because of the episodic nature of activity in most loci. However, it may be a real indicator of increasing volcanic activity over the last 5 m.y. and specifically over the last 100,000 yr. It is possible that averaging over the 1- to 5- m.y. time period obscures episodic peaks in volcanism with durations of 100,000 yr to 1 m.y."

If the above information is taken at face value, it would suggest that although there is conflicting interpretations of the geologic evidence in the site region, all volcanic probability calculations which are averaged over more than the last 100,000 years may be low, possibly as much as a factor of 10. The cone count method of Crowe, and the recalculations presented in this paper using the same basic methodology, may seriously underestimate the potential of volcanism to effect the Yucca Mountain site.

RATE OF MAGMA PRODUCTION TO DETERMINE PROBABILITY.

Several of the previous probability calculations have been based on the rate of magma production. Depending on underlying assumptions, these type of calculations have been used to suggest either an increasing or decreasing rate of magma production hence either an increasing or decreasing probability of disrupting the repository. The numbers generated, however, were also based on the assumption that the area used was representative of the total region, hence the overall probability.

If we examine the information for the YMVZ, Crowe et al., 1982, has calculated the volumes of magma for the Crater Flat cones and the Lathrop Wells cone as 1.3 X 10E8 and 5.7 X 10E7 cubic meters respectively. If we assume that the sum of this volume is representative of the magma production rate for the last 1.5 million years for the YMVZ, this rate comes to approximately 127 cubic meters per year. If the Lathrop wells cone is considered to be representative of the last 100,000 years, the rate for the last 100,000 years comes to 570 cubic meters per year. If Lathrop Wells is considered to be representative of the last 300,000 years, this number becomes 190 cubic meters per year. In other words, there is a suggestion that the rate of volcanic activity increased in the YMVZ during the last 1.5 million years which is supportive of the interpretation presented in Smith and Luedke.

If this information is used to attempt to determine probability of disruption of the site, we first need to evaluate the amount of magma needed for each volcanic event. Consideration of minimum cone size and multiple eruptive sequences would suggest that on the order of 10E6 to 10E7 cubic meters of magma is needed per eruption. For example, in Crater Flat Little Cone No.2 has a calculated magma volume of only 7.8 X 10E5. (See Crowe et al., 1983) If the Lathrop Wells age data is correct, assuming that the rate of magma production in the YMVZ for the last 100,000 years is on the order of 500 cubic meters per year appears reasonable. Based on this assumption, the time interval between eruptions would be on the order of 2000 to 20,000 years. If this is directly converted into probabilities, and if the next occurrence is taken as a random event in both space and time within YMVZ, the probability of intersecting the repository would range from on the order of 7 X 10E-2 to 7 X 10E-3.

COMPARISON WITH PREVIOUS NUMBERS.

The probability numbers calculated by Crowe et al., 1982, for disruption of the repository using regression analysis of magma production rates ranged from 3.7 X 10E-4 to 3.3 X 10E-6 per 10,000 years. Because Crowe obtained his values through averaging over a much longer time frame than the last 100,000 years, because there are suggestions that the area around the site has a much higher volcanic activity rate than the area used by Crowe, and because there are suggestions that the the Western United States, including the area around the site is in a stage of increased volcanic activity, the numbers which were generated by Crowe, could be highly in in error.

EFFECT OF MULTIPLE ERUPTIONS ON CONE COUNT PROBABILITY.

The recent information within the Basin and Range, especially that being generated by LANL, appears to provide indisputable evidence that Quaternary basaltic volcanism within the Basin and Range is representative of complex multiple eruptive sequences. This contrasts with previous theory and calculations which assumed (either implicitly or explicitly) that the cones were the result of basically one eruptive event. At the present time there is not enough information to determine how many sequences each cone represents. For illustrative purposes, however, I will assume that each cone represents 5 eruptions. Based on this assumption, the probability of eruption during the next 10,000 years, within whatever zone is being considered as representative of the site area, would be five times more probable then cone counts alone would suggest. The probability of an eruption within the YMVZ would not be the 1 in 30 as the above calculations suggested, but would be on the order of one in six. The probability of volcanism occurring at the site is a function of the probability of this event occurring either randomly, or occurring at the location of one of the pre existing cones, such as Lathrop Wells. The probability of occurring at the site in 10,000 years would, therefore, become something between 4.7 X 10E-4 to 2.4 X 10E-3. It can logically be argued that the value of 2.4 X 10E-3 is misleading because was obtained by counting multiple eruptions at a single site. Unless, however, the mechanism responsible for migration of eruptions from one area to another is understood, this value does point out that that use of cone counts to obtain probability of disruption of the site may be misleadingly low.

EFFECT OF SIZE OF SITE AREA.

The above calculations assume that the site would only be effected if the volcanic event occurred totally within the repository boundary. I think it is instructive to examine what happens to these numbers if some zone of influence is placed around the site.

The normal area of a cone in the YMVZ is approximately 1 square KM, therefore, it would make sense to use an area of 1 KM around the site to define an area of influence. The area of the site would expand from approximately 6 KM to approximately 17 KM. The resultant probability of disruption of the site would, therefore, have to be multiplied by three if such a zone of influence were used for the YMVZ. Crowe, et all., 1982, used a site area of 8 square KM, therefore, his numbers would have to be multiplied by 2 to consider a zone of influence. While we can assume various dike or plug sizes, orientations, etc, the exact size of the zone of influence is presently unknown. At present, what these numbers do show is an additional reason why all the previous probability calculations should be considered as unconservative.

CONSEQUENCE OF ERUPTIONS.

Most of the work on consequence of eruptions has been based on assumed dike width, length, geometric arrangement of canisters and the like. Previous calculations which have used this methodology have shown an extreme wide range in potential consequence. See, for example, Link et al., 1982. Aside from the fact the method of calculation using dike characteristics has extreme uncertainties, this method relies on surface characteristics of the volcanic phenomena, when the concern is with the characteristics of the volcanic source zone which would disrupt the repository level.

Within Section 8.3.1.8 of the SCP the DOE has set a goal for volcanic disruption as being less then .1 percent of the repository. Assuming a repository of 1420 acres, this comes to disruption of something less then 1.5 acres. I know of very little information of size of vents or plugs in the exact NTS region, however, Smith, et al., 1988, has provided sketch maps of two plugs in the general Fortification Hills area. The smaller plug has an area of approximately 1.5 acres, while the larger plug has an area of over 4 acres. If these values are representative of the site region it would suggest that the present goal for volcanic consequences may be non conservative. If the statements in 10 CFR 60.122(a)(2)(ii) are taken at face value, (the assumptions used should not underestimate the effects), then the possibility of disruption of more than .1 percent of the repository, either assuming a plug or dike over 1.4 acres in dimension, must be considered in the decision making process.

An additional effect which must be considered is the possibility of hydrovolcanic activity. There are many examples of hydrovolcanic activity (highly explosive) in the general region, and the evidence suggests that volcanic eruption cycle in such places as Lathrop Wells went through a hydrovolcanic stage. In addition, calculations performed by Crowe et al., 1986, suggest that the geologic conditions in the area of Yucca Mountain are such that hydrovolcanic activity is possible at the Yucca Mountain Site. Because of the depth of the water table at Yucca Mountain, he suggests that such hydrovolcanic activity may require a triggering mechanism, such as an earthquake. In the tectonic setting of Yucca Mountain, it would appear that such a triggering mechanism may be readily available. This, therefore, becomes another piece of evidence which suggests the various calculations concerning volcanism within the site region may have been unconservative.

CONCLUSION

The above discussion was meant to strongly suggest that the various probabilities (and consequences) which have been used for volcanic disruption of a repository a Yucca Mountain may be in error by several orders of magnitude.

The most basic questions which must be resolved to rationally assess volcanism revolve around the understanding what has controlled the location of previous volcanic events, and the relationship of this controlling "structure" with the location of potential future events. The aeromagnetic signature of the YMVZ is suggestive that such a feature <u>may</u> be valid., (either as a causative or resultant feature) To determine if it is valid would require much more detailed work along with a much better understanding of the overall process of volcanism to confirm its existence. However, without much more detailed work and a much better understanding of the volcanic process, the existence of the YMVZ would appear to be viable alternative hypothesis.

Another factor which must be resolved in evaluating the validity of the various probability numbers is the relationship of volcanism within the areas of the site to the overall volcanic cycle. While some work has been attempted within the general area of the site, the results are presently inconclusive and debatable. The data for the entire Western United States, however, suggests that volcanic activity has increase during the Quaternary. The comparison of volcanic activity at Lathrop Wells during the last 100,000 to 300,000 years with the activity within the entire Lathrop Wells-Crater Flat area during the last 1.5 million years is suggestive that volcanic activity in the site region has also increased during this period. As all calculations which have been used in the decision making process, to date, were based on averages over the Quaternary or longer, the probability values -- and hence the decision making process -- may be seriously in error.

The combination of recent information confirming the fact that basaltic volcanic activity in the Basin and Range is reflective of multiple eruptive stages, the strong suggestion that the activity at such places as Lathrop Wells is much more recent then previously thought, and consideration of a zone of influence around the site, all further suggest that the probability numbers which have been used in the decision making process concerning the acceptability of the Yucca Mountain site were unconservative.

The potential for hydrovolcanic activity and consideration of mapped plug size both suggest that consequence analysis based on dike width and the like, as has been used in all previous analysis, could be non conservative. This can be supported by simple calculations which assume a dike traversing the repository along one continuous room. Assumptions which total the number of canisters which could be effected and assume straight transposition of this material to the surface could result in much higher numbers that these cases are assuming.

To allow a comparison of the various scenarios discussed in this note I am attaching two drawings showing the interpreted range in effects as would be expressed on a CCDF chart. The fact that this is being expressed as lines, rather then points, is to take into consideration radioactive decay. I have used .1 and .3 percent disruption of the repository for the base cases as these values approximately correspond to the measured sizes of the two plugs. The probability values presented do not consider the potential effects of multiple eruptions or increasing the zone of influence around the site, therefore, I consider the numbers as unconservative. The consequence values also do not cover the full range -- I could come up with more or less in many ways -- but are probably reasonable approximations of expected values.

IMPLICATIONS.

There is a large amount of uncertainty regarding many technical issues at the Yucca Mountain site, and one which has some of the largest uncertainty is volcanism. Site characterization must therefore assure that the additional work has a good possibility of improving our knowledge, and decrease uncertainty, to the point that a logical conclusion on the probability and consequence of volcanism can be made at licensing. We need, therefore, to assure that the program of investigation will concentrate on those things which can attempt to help resolve some of the technical concerns I have expressed. This is in agreement with statements made during several of the recent meetings involving the NRC, the ACNW, and the DOE to the effect that the program emphasis should be on those investigations which, if proven true, could show the site to be unsuitable for licensing.

It would be useful to perform geophysical testing of a regional scale to evaluate the potential of structural control of volcanism within the area which I have referred to as the YMVZ. This could include COCORP type (along with intermediate and shallow) geophysical lines, further analysis, (possibly reflying) of the aeromagnetic information, detailed gravity surveys and the like. Work being conducted by Las Alamos and the state should continue, possible at an accelerated rate, and integration of this information with USGS structural data is needed. There also should be the consideration of aeromagnetic work (and the like) in such areas as the Cima and Lunar Crater fields so analogs could be compared. If this work is conducted now, in a logical order, once drilling and other site intrusive work can began it would be able to focus on problem areas in addition to the areas already laid out in the SCP.

Much of what is being suggested is present within the SCP, however, the work being suggested would require more detail and coverage of a larger area.

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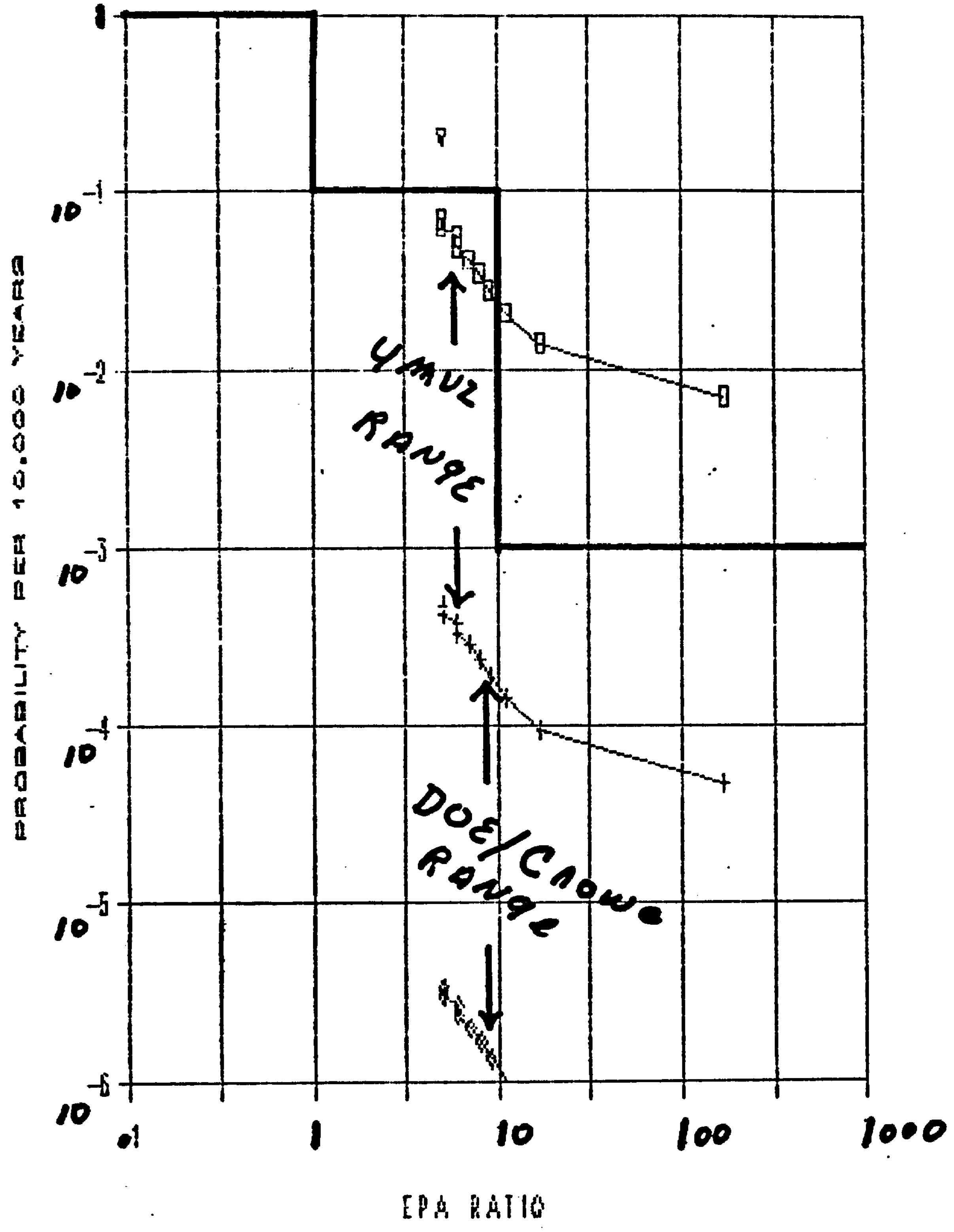
COMPARISON OF VOLCANIC SCENARIOS

.1 PERCENT REPOSITORY DISRUPTED



COMPARISON OF VOLCANIC SCENARIOS

.3 PERCENT REPOSITORY DISRUPTED