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Yucca Mt.

UNITED STATES
NUCLEAR REGULATORY COMMISSSION
WASHINGTON, D.C. 20555

OFFICE OF THE
EXECUTIVE DIRECTOR
FOR OPERATIONS

July 25, 1989

TO: M. Federline, OCM/KC
M. Lopez-Otin, OCM/TR
J. Scarborough, OCM/KR
J. Gray, OCM/JC

FROM: James L. Blaha, AO/OEDO

SUBJECT: BACKGROUND INFORMATION

Enclosed is background information related to the potential for volcanism at Yucca Mountain. This has also been sent to the PDR and DOE.

James L. Blaha, AO/OEDO

Enclosure:
As stated

cc: SECY
V. Stello
J. Taylor
H. Thompson

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UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

JUL 17 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:

Enclosed is additional background material (Enclosure 1) related to my July 11, 1989 letter (Enclosure 2) regarding topics to be discussed during the forthcoming tectonics meetings. This material is being provided to you and other interested parties so that you can see how we are addressing specific concerns and opinions expressed by one of our technical staff members. It should be noted the NRC staff considers that it is premature to make definitive judgments about site suitability given the currently available information. However, the technical concerns noted in Enclosure 1 were considered during development of the NRC staff comments on DOE's Site Characterization Plan and were incorporated as appropriate in the material provided to you by my letter dated July 11, 1989.

Accordingly, our forthcoming technical meeting should continue to focus on technical concerns such as those included in my July 11, 1989 letter and how these concerns can be addressed promptly.

Sincerely,

R E Browning for

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

Enclosures:
1. P. Justus note to J. Trapp dated July 14, 1989
2. Linehan to Stein Letter dated July 11, 1989

cc: R. Loux, State of Nevada
M. Baughman, Lincoln County, NV
S. Bradhurst, Nye County, NV
D. Bechtel, Clark County, NV
C. Gertz, DOE/Nevada

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July 14, 1989

NOTE TO: John Trapp
Senior Geologist

FROM: Philip Justus
Geology-Geophysics Section Leader

SUBJECT: PROBABILITY OF VOLCANISM AT YUCCA MOUNTAIN

This is in response to your note dated 22 June 1989 (enclosed) on the subject "Probability of Volcanism at Yucca Mountain" sent to myself and others. It is my understanding, based on our discussions on this subject, that you are satisfied your concerns are addressed in the staff's and Director's proposed comments on DOE's Site Characterization Plan (i.e., NRC's Site Characterization Analysis (SCA), discussed below).

Further, I want to point out that there are ongoing actions that should ensure prompt consideration of your concerns as they are reflected in the SCA. Also, the technical points in your note were transmitted to DOE and other parties and are due to be considered in meetings now being scheduled.

Also, as we discussed, with regard to the personal opinions that you have expressed, because you "...feel we [NRC] need to assure that the [DOE] program of investigation will concentrate on those things which can attempt to help resolve some of the technical concerns I have expressed," I consider that you have not pre-judged the site's suitability and that you properly recognize that the burden of establishing with reasonable assurance that the licensing requirements will be met falls on DOE. These are two prerequisites for the conduct of objective, impartial technical reviews by regulatory scientists. At any time you consider that your ability to remain an objective reviewer may be in question please let me know.

Specifically, the NRC actions already taken and currently underway that we discussed include:

(1) The field trip held May 1 through 5, 1989 referenced in your note, where you and other staff observed volcanic areas currently under study by DOE and the State of Nevada.
(2) Draft Site Characterization Analysis (SCA) has been prepared and is currently being reviewed by the Commission for transmittal to DOE.
(3) Technical meetings with DOE to pursue, in depth, how NRC tectonics concerns can be addressed and resolved are being scheduled. In this regard, we transmitted to DOE and other parties the technical points raised in your note (letter from J. J. Linehan to R. Stein dated July 11, 1989).
(4) Coordinated and integrated 'staff positions' on tectonics, including volcanism, for the tectonics meeting

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discussed in the Linehan to Stein letter are being developed. Your concerns will be addressed at the tectonics meetings; and

(5) Once the technical meetings have been conducted and DOE's responses to your and other staff concerns are reviewed, the open items will be tracked and evaluated on schedules warranted by their relative significance. Resolution of items will be duly documented.

(6) Interactions with the ACNW will be held at appropriate times.

Additional discussion on the above items follows. The joint NRC/DOE/State of Nevada field trip to various volcanic fields in the vicinity of YMP held in May that you and other NRC staff attended afforded an opportunity to make direct up-to-date observations of aspects of volcanism to be used to help formulate the staff's independent review capability. The trip report that you and the other participants are finalizing will express such observations.

The proposed SCA Point Papers, SCA summaries and SCA transmittal letter emphasize the need for DOE to address early in site characterization all of the potentially significant tectonic issues raised by NRC, including the ones you have raised concerning probability of volcanism.

Preparation for a tectonics meeting (or family of meetings) are underway. The draft proposed agenda for the meeting that you helped to develop, was transmitted to DOE and the State of Nevada with little modification on July 7th. Specific technical points you raised in your note and which were transmitted to DOE in the Linehan to Stein letter dated July 11th, form the basis for discussion at the proposed tectonics meeting of the SCA concern about the need for DOE to conduct early and iterative performance assessments to evaluate the impact of such potentially adverse conditions as volcanism on the waste isolation capability of the repository.

In preparation for NRC's presentation of its concerns at the forthcoming tectonics meetings, the Geology-Geophysics Section will be developing coordinated and integrated 'staff positions' on the various agenda items. The technical points that you raised in your note have merit and will be further developed to the point where they can form a 'staff position." As you are well aware, staff positions will be subjected to our internal quality assurance (IQA) process prior to discussion at public meetings. This IQA will involve development of a technical consensus among the staff with appropriate consideration of all appropriate technical disciplines and supervisor/management concurrence and approval of the 'positions' for presentation.

I intend for you to participate in the tectonics meetings. In this manner, you will get to convey directly to your technical counterparts in DOE what your concerns are regarding probability of volcanism at YMP.

Additional opportunities to provide guidance to DOE regarding volcanism (and other tectonic matters) will arise after meetings are conducted and DOE's written responses are reviewed. DOE clearly has the responsibility of gathering data about the site sufficient to perform assessments of the suitability of the site for a repository as soon as practicable. Thus, the technical points you and others raised that bear on performance assessment, such as establishment of boundary conditions and alternative tectonic models must be addressed by DOE. You and others will have an opportunity, through the study plan review process, to focus DOE's attention on the attainment of critical information needed to resolve significant tectonics issues. Also, the Center is actively seeking consultants who are experts in aspects of volcanism (and other areas of tectonics) where necessary to assist or enhance our staff reviews of DOE's data and assessment methods, models and codes.

In summary, any attempt to bring into early focus important issues such as you have done by your preliminary analysis is in the best interest of the national program.

Enclosure:
As stated

cc: R. Bernero
G. Arlotto
R. Browning
J. Youngblood
R. Ballard
J. Linehan

ENCLOSURE

NOTE TO: R. Bernero
G. Arlotto
R. Browning
B.J. Youngblood
R. Ballard
J. Linehan
P. Justus

FROM: J. Trapp 22 Dec 89

SUBJECT: Probability of Volcanism at Yucca Mountain

INTRODUCTION.
From May 1 through May 5th, 1989, C. Abrams, K. Mcconnell, and I attended a volcanics field trip during which we had the opportunity to view may of the areas where both the State of Nevada and DOE workers are studying volcanic features. Following that trip I expressed my opinion that the information I had seen suggested to me that the Yucca Mountain site would have a very hard time passing a licensing hearing, strictly on the volcanics issue. The following is to present some of my reasoning, along with background information supporting that reasoning. I also need to express several cautions for the reader. Some of the basic information which I have used is published, but much is in draft stages or based on field observations. More important, however, is the fact that in order to present my concerns I have had to generate various probabilities. While these numbers are mathematically correct, I consider them geologic valid only to the extent that I feel they do reflect the relative range in uncertainty in our present understanding of the mechanism of volcanism in the Basin and Range.

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 times 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,

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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 he used to obtain his calculations is representative of the area in which volcanics can occur in the future.

While the concept of structural control has been recognized, during the field trip I was impressed by the very sharp limits of the various fields, such as the eastern and western limits of the Reveille Range. Upon return I reexamined some of the base data to attempt to determine if any area around the site demonstrated evidence which could be used to define the structural limits for the zone of volcanic activity for the Crater Flat-Lathrop Wells field. The only data set which appear to be of enough detail and of large enough aerial extent to provide information on this area was the aeromagnetic data presented by Kane and Bracken, 1983. Examination of this information 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. This 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 question is, therefore, are these numbers representative of the potential possibility of 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. Some of the work being done by the LANL personnel is suggesting that, from geochemical data, a case can be made that the basaltic volcanism is in a waning stage. There is

work being done by UNLV, through the State however, which suggests that there may be cycles as postulated by LANL, but that these are only cycles within cycles. In other words, there may be a stage which goes from nepheline to hypersthene, but then it reverts to the nepheline stage again. If, as is being suggested by the LANL personnel, the Lunar Crater area is an extension of the Reveille Range area, this would suggest that the States postulation is correct. 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. 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.

RATE OF MAGMA PRODUCTION TO DETERMINE PROBABILITY.
Several of the previous probability calculations have been based on the rate of magma production. Depending on the assumptions, this information has 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.

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.
One of the purposes of the field trip was to examine the evidence of possible multiple eruptions for the various cones, and the preliminary evidence appears indisputable that Quaternary basaltic volcanism in the general area of the Basin and Range around the site 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 SCF 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 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.

One of the main differences between the calculations presented in this note and previous calculations is my attempt to better factor geologic controls into the

probability calculations. While the aeromagnetic signature of the YMVZ is suggestive that such a feature may be valid, it would require much more detailed work along with a much better understanding of the overall process 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 causes the variation in numbers is the attempt to evaluate the position of the site area within the entire volcanic cycle. The data for the entire Western United States suggests that volcanic activity, in general, 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.

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. I do consider that this chart represents the problems which would confront the licensing board if this site were to undergo licensing today.

IMPLICATIONS AND OPINIONS.

If there were to be a serious discussion on the merits of either continuing on with site characterization, or dropping the site, the argument would have to be based on (1) the possibility that additional work could improve our knowledge, and decrease uncertainty, to the point that a logical conclusion on the probability and consequence of volcanism could be made at licensing and (2) the possibility that this conclusion would result in a favorable finding for the site.

It is at this point that my biases strongly come into play. (1) I do not think that we will be able to advance technical knowledge to the point that it will be possible to significantly improve our substantive knowledge of the mechanism responsible for volcanism in the area of the Yucca Mountain site, and (2) I do not think the Yucca Mountain site itself can be shown to be favorable in a licensing arena. I, therefore, am of the opinion that this is not the site at which we should be trying to license the first High-Level radioactive waste repository.

While the absolute requirement for geologic stability was removed from the final 10 CFR 60, I am of the opinion that the siting of a repository in the area of Quaternary volcanic activity violates the intent of the rule as I do not believe that it is possible to make projections which can be supported with any relative degree of confidence.

It was the apparent intent of both 10 CFR 60 and 40 CFR 191 is to consider potential effects after the "10,000 year limit", and the present working draft of the EPA standard requires consideration for 100,000 years. In addition, there are no time limits stated on the applicability of 10 CFR 113(a)(ii)(B). Consideration of the long geologic record of volcanism in the general area of Yucca Mountain, and projecting these forward past 10,000 years, must be considered during licensing and makes the site even more unattractive.

WHERE TO NOW?

While I personally believe that the Yucca Mountain site should be dropped from consideration for a nuclear waste repository, I don't expect that this note or any follow up would cause the program to turn around, therefore, I feel we need 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. Along with the fact that I consider volcanism a potential show stopper, there will be delays in sinking the shaft and there will also be delays due to the fact that the experimental drilling techniques can not be even evaluated until DOE can obtain water rights. During this period 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. Much of what I am suggesting is present within the SCP, however, the work that I am suggesting would require more detail and coverage of a larger area, along with readjusting of schedules. Even if I am shown to be 100 percent wrong, the information obtained would be extremely valuable in evaluating the entire tectonic framework for Yucca Mountain.

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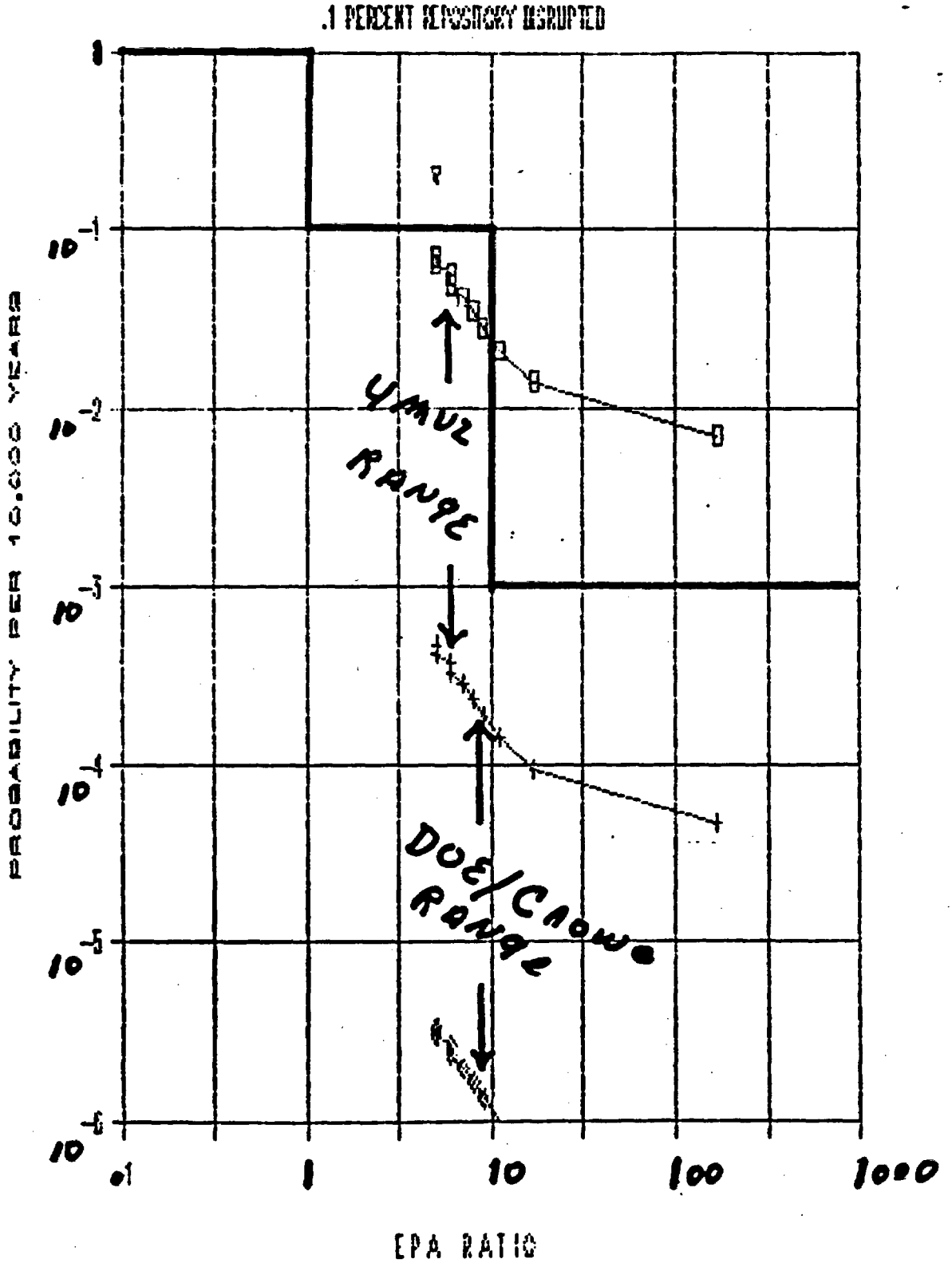
Attachments: as stated

cc: C. Abrams
K. McConnell
K. Stablein
S. Coplan

COMPARISON OF VOLCANIC SCENARIOS



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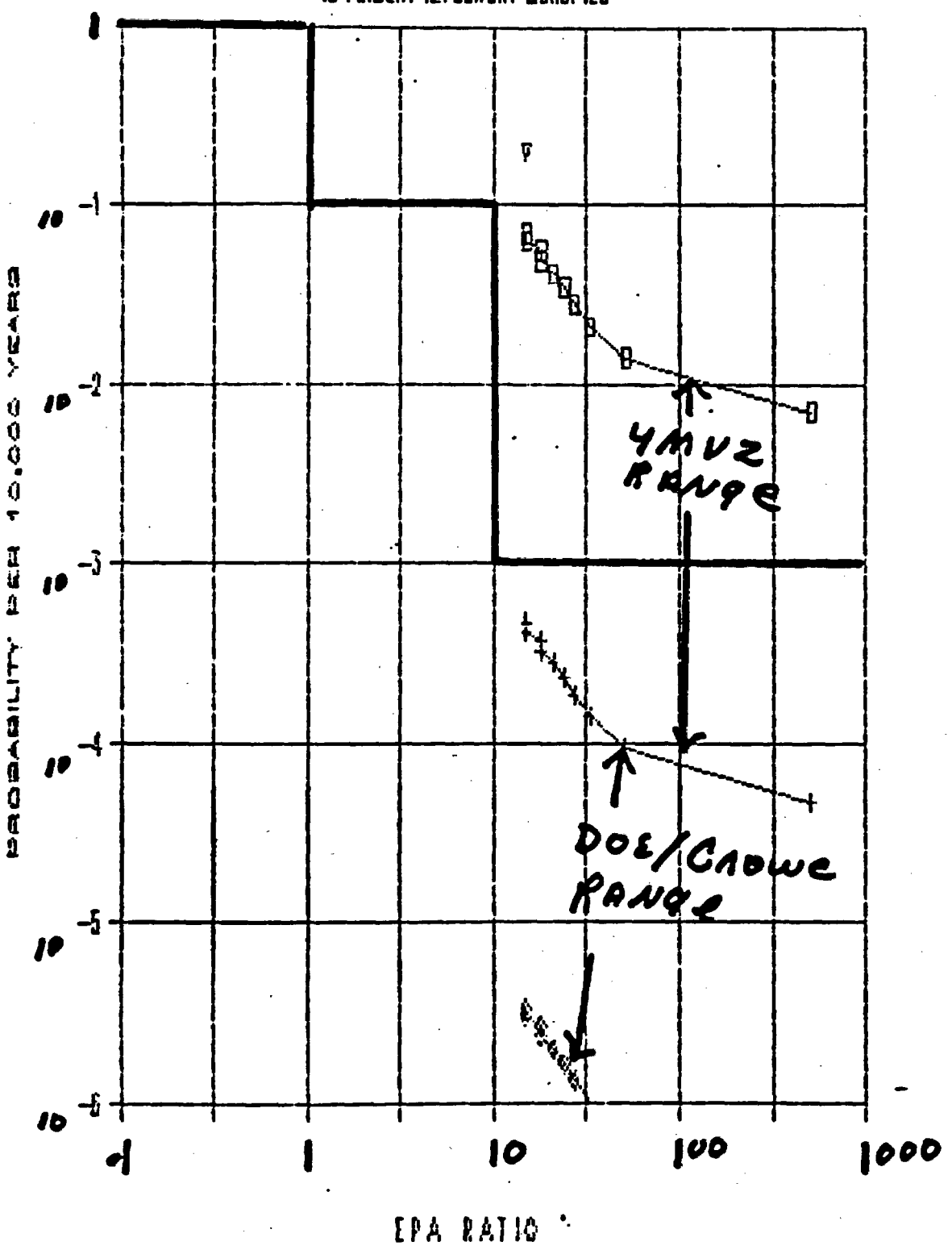

Enclosure 2

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

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,

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
D. Bechtel, Clark County, NV
C. Gertz, DOE-Nevada

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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 may 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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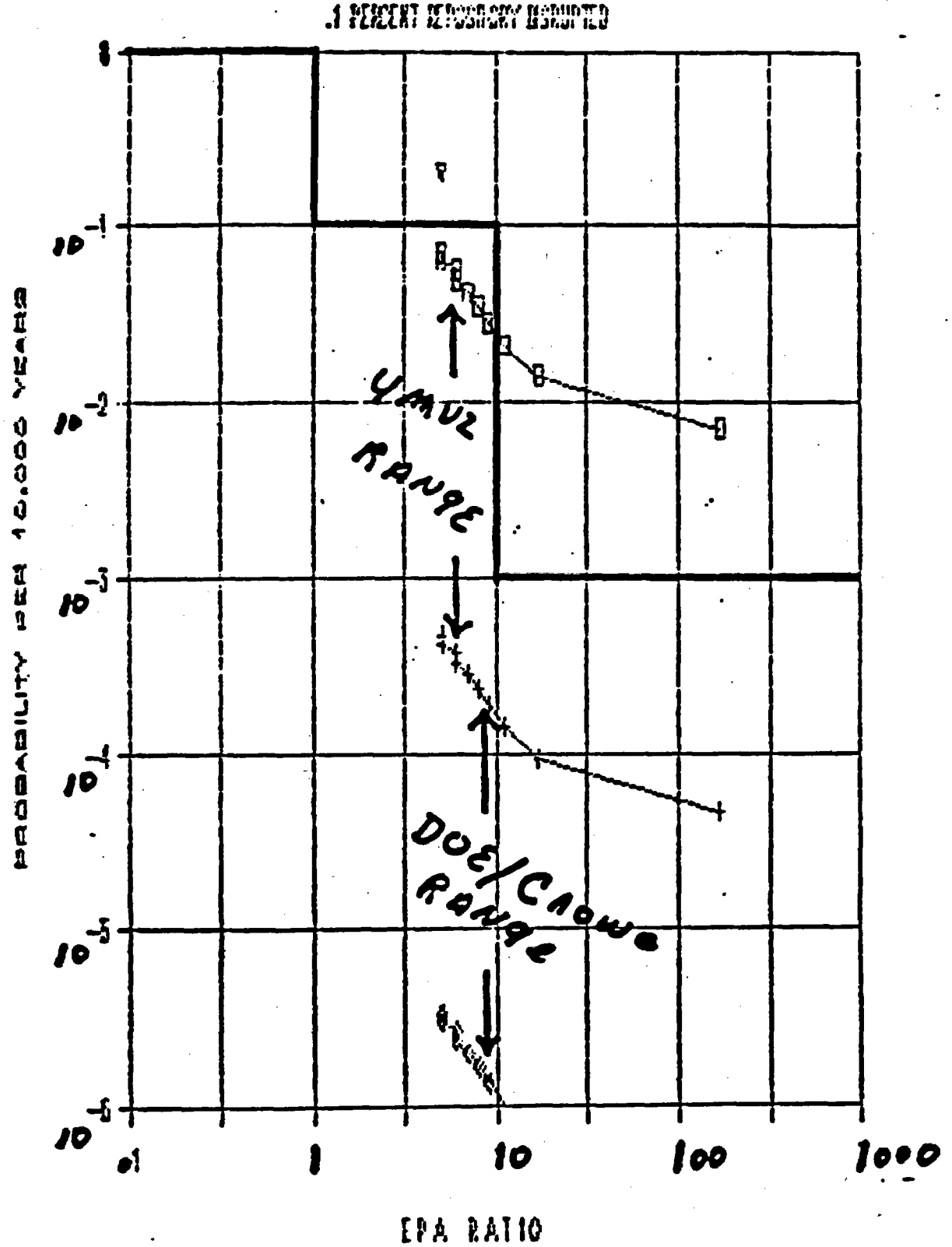

COMPARISON OF VOLCANIC SCENARIOS

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