



**AGENCY FOR NUCLEAR PROJECTS  
NUCLEAR WASTE PROJECT OFFICE**

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June 2, 1988

Mr. Ronald L. Ballard, Chief  
Technical Review Branch  
Division of High-Level  
Waste Management  
U.S. Nuclear Regulatory Commission  
Washington, DC 20555

Dear Mr. Ballard:

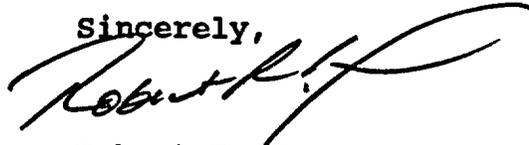
This Office has completed its review of the NRC Draft Generic Technical Position titled "Guidance for Determination of Anticipated Processes and Events and Unanticipated Processes and Events". Our general and specific comments are attached.

In brief, the GTP should specify how anticipated and unanticipated processes and events will be incorporated in the performance assessment and subsequent licensing decision. The NRC should state clearly that a performance assessment incorporating unanticipated processes and events as well as one incorporating anticipated processes and events, must meet the EPA standard (40 CFR Part 191).

The NRC should also return to its original intent in classifying anticipated processes and events as those which are evidenced in the Quaternary period. Additionally, the NRC should consider unanticipated processes and events as those that are reasonable to expect, but may not be associated with the Quaternary period.

This Office would be pleased to meet with the NRC to discuss, clarify, or amplify any of our comments.

Sincerely,

A handwritten signature in black ink, appearing to read "Robert R. Loux", written in a cursive style.

Robert R. Loux  
Executive Director

CAJ:PS/njc

cc: Mr. Paul Prestholt, U.S. Nuclear Regulatory Commission

Attachments

*received  
with letter  
Jul 6/8/88  
102.3*

**STATE OF NEVADA  
COMMENTS**

**ON**

**DRAFT GENERIC TECHNICAL POSITION**

**"GUIDANCE FOR DETERMINATION OF  
ANTICIPATED PROCESSES AND EVENT**

**AND**

**UNANTICIPATED PROCESSES AND EVENTS"**

**June 2, 1988**

## General Comments

1. We view the NRC staff position as generally reasonable in its deterministic approach and, when carefully studied, it gives sufficient guidance as to the intended NRC approach to post-closure site performance assessment from the perspective of "anticipated" and "unanticipated" natural processes and events. We believe that the Quaternary period is a useful time period for determining operating natural processes of "anticipated" and "unanticipated" classification. The criteria adopted by the NRC to differentiate between "anticipated" and "unanticipated" processes and events is not free from possible ambiguities in application, but the intent is clear in the Draft Technical Position.
2. The designation of "anticipated" versus "unanticipated" is important to two general areas of the NRC licensing process. Anticipated processes and events are those that the design of the repository will be based upon. Unanticipated processes and events are not designed for, but must be included in the final performance assessment (i.e. long-term repository modeling) that will be part of demonstrating compliance or non-compliance with the EPA standard. In addition to anticipated and unanticipated, a third category "not sufficiently credible to warrant consideration" is addressed in the GTP. This third type of process or event is not included in the licensing process, even though its occurrence may be possible.

The primary concern regarding the GTP has to do with the incorporation of these two categories or processes and events into the final performance assessments and subsequent licensing decision. How this will be done is not specified in the GTP, yet it is very important in terms of how anticipated and unanticipated processes are distinguished. The GTP suggests on page 3 that two performance assessments will be done:

"In the license application, the applicant must present an evaluation of the performance of the geologic repository for the period after permanent closure, assuming anticipated processes and events, along with a similar evaluation assuming unanticipated processes and events."

On the other hand, Hunter et al. 1986 in a Nuclear Regulatory Commission publication (NUREG-CR/4519)<sup>1</sup> state:

"The EPA assumes that, whenever practicable, DOE or NRC will summarize the results of the performance assessment into a complementary cumulative distribution

function (CCDF) indicating the probability of exceeding various levels of cumulative release. The effects of uncertainties will be incorporated into a single CCDF for each disposal system. If this CCDF meets the requirements of section 191.13 [the EPA standard], the disposal system complies with that section" (emphasis added).

Furthermore, based on the Consultation Draft Site Characterization Plan (CDSCP), DOE appears to be planning on only one performance assessment that combines both anticipated and unanticipated processes into a single CCDF by the use of assigned probabilities (e.g. CDSCP p. 8.3.5.13-5 and p 8.3.5.13-76).

We consider the use of two performance assessments, one of which utilizes anticipated processes and events, and another which evaluates unanticipated processes and events, to be the appropriate approach. Based on the preamble to 10CFR61 (FR Vol. 48 No 120 p. 28200), both performance assessments must show compliance with the EPA standard:

"The license review will thus need to include a determination whether the proposed activities will meet the EPA standard as applied to anticipated processes and events, if any, as have been found to warrant consideration".

The NRC should clearly state in the GTP that separate performance assessments are required, and that they both should demonstrate compliance with the EPA standard. It is of concern that the NRC did not explicitly comment on DOE's plans to generate one CCDF through a single performance assessment as described in the CDSCP (Browning, 1988<sup>2</sup>). It is also of concern that a single CCDF approach is offered in Hunter et al. 1986<sup>1</sup>. We feel that "averaging" anticipated and unanticipated processes together into a single CCDF could inappropriately mask the effects of certain processes.

In the "TECHNICAL POSITION" section of the GTP, the NRC states:

"An "anticipated event" and a natural "unanticipated event" should consider the maximum event which has occurred within the geologic setting during the Quaternary Period. The "anticipated event" should be assumed to occur at the location, or along the controlling geologic structure, where this event occurred during the Quaternary Period. An "unanticipated event" should be transposed within the geologic setting to any credible location at which it

could occur, to determine its effect on waste isolation."

This guidance differs from the preamble to Part 60 (FR Vol. 48 No. 120 p. 28200) which states:

"These [unanticipated processes] include processes and events which are not evidenced during the Quaternary period which, though not evidenced during the Quaternary, are not likely to occur during the relevant time frame."

As can be seen in the above quote, unanticipated events were originally intended to be reasonably possible, although not associated with the Quaternary period. No where in the original rule or preamble is there reference to transposing events or processes within the geologic setting. Many events or processes can impact broad areas, not be related to controlling structures, or otherwise occur throughout a setting. A probable maximum precipitation is an example of such an event. Therefore, the introduction of a location aspect is not particularly useful. In the GTP, the NRC is suggesting events that did not occur during the Quaternary will not be considered anticipated nor unanticipated. The GTP states on page 12:

"Processes and events that have not occurred in the geologic setting during the Quaternary Period would normally not be considered by the staff to be sufficiently credible to warrant consideration."

Again, the GTP guidance is inconsistent with the original intent of Part 60. Based on the above quote and additional discussion on page 12, it appears that NRC is now trying to categorize as unanticipated what was originally intended to be anticipated. We strongly believe the NRC should stick to its original intent of using the Quaternary as representative of anticipated processes.

In regards to unanticipated processes, the GTP limits them to maximum rates in the Quaternary. This also seems contrary to the above quote from Part 60 preamble. The GTP suggests anticipated processes be based on a conservative projection of average rates. Given the amount of uncertainty involved in reading the geologic record, a conservative projection would likely be the same as a maximum rate of the Quaternary period. Therefore, to arrive at an unanticipated process, periods prior to the Quaternary should be utilized as was originally intended in Part 60.

While the GTP considers human-induced processes, such as the greenhouse effect from pollutants, to be unanticipated, it also states:

"Both the "anticipated" and "unanticipated" processes and events must consider the potential modifications of such processes and events caused by past, ongoing or projected human-induced processes and events that will not be under DOE's control"

This area of human-induced processes and events is very unclear in the GTP as can be seen above and on the top of page 16. This needs to be clarified before the merits of this approach can be effectively evaluated.

Under the "DISCUSSION" section of the GTP, the NRC suggested that discriminating between anticipated and unanticipated based on probabilities of occurrence is not possible in a rigorous way. While this may be true, EPA uses a probabilistic approach (i.e. less than 1 in 10,000 chance) in defining events nor sufficiently credible to warrant consideration (Appendix B, EPA Standard). Also, "determining the probabilities of scenarios and of the geologic events and processes that make up scenarios is essential because the Standard is probabilistic" (Hunter et al. 1986)<sup>2</sup>. In other words, while such assigned probabilities of occurrence may not be accurate, they will obviously be necessary to carry out performance assessment. The GTP states assigned probabilities will probably not be necessary to determine compliance with the performance objectives of 60.113. However, there is no apparent basis for this statement in the GTP. Is the NRC suggesting probabilistic approaches to the release limits and ground water travel time requirements are not likely? Codell (1986)<sup>3</sup>, in the Draft GTP on ground water travel time suggests a probabilistic approach may be well-suited for demonstrating compliance with 60.113(a)(2).

In the "EXAMPLE" section of the GTP, the NRC discusses how an anticipated process related to climatic extremes would be evaluated. The GTP is, however, supposed to provide examples on how to designate a process as anticipated, not what to do after it has been designated. In no case should a process be designated anticipated, unanticipated, or not credible, based on their "resultant effect on waste isolation" (page 15). We are concerned that such an approach would lead to anticipated processes being those that only are favorable (or less jeopardizing) to waste isolation. This approach is not suggested in the GTP, however, warning against this would be appropriate on the part of NRC.

3. The position of the NRC appears to be basically sound based on the generally accepted conservative philosophy established not only by the NRC, but also explicitly stated by DOE itself, and, based on the need for conservatism required to analyze high-risk facilities. From a scientific standpoint, this position is supported by the limitations of a purely statistical approach. Even if probability values are expressed in statistically conservative terms by the statisticians, it is impossible to judge whether these values are in fact conservative without an accurate understanding of real geologic values. As related to the geohydrologic concerns, we concur on the whole with the basic position, but we do have reservations about several issues where there may be possible problems.

The positive aspects of the conservative approach adopted here by the NRC cover a number of issues.

The NRC states (p. 9) that the basic rationale governing their position is that the geologic record of the geologic setting for the Quaternary period should provide the basis for determining the classification of events and processes. This rationale is sound based both on the wording of 10 CFR 60 and on the generally understood aspects of Quaternary faulting. State-of-the-art assessments dictate that the potential for surface faulting at the repository site during the 10,000-year post-closure period is going to be based on an analysis of the Quaternary, especially the late Quaternary record, given an understanding of the pre-Quaternary structural-tectonic setting. In other words, the Tertiary and pre-Tertiary histories of the region allow the outline of the basic structural-tectonic framework of the site, but it is the Quaternary record of recency and recurrence of movement that will primarily determine site characteristics.

As a result, some misleading conclusions previously drawn by DOE in the Draft EA and the EA will be appropriately discarded for site characterization purposes. For example, in those documents DOE concluded that based on a comparison of Tertiary and Quaternary faulting rates at Yucca Mountain, the Quaternary rates would be indicative of greatly diminishing fault activity (implying low probability of occurrence).

One potential problem with the stated rationale relates to the use of the term "geologic setting", but this is a problem more or less common to the entire set of HLW geologic criteria. This term, taken directly from 10 CFR

60, defines the geologic setting as the "geologic, hydrologic, and geochemical systems of the region in which a geologic repository operations area is or may be located." Obviously, this definition is extremely general and, although the NRC narrows this definition somewhat (p. 4, footnote 3), it will undoubtedly be open to various interpretations. An example is the question of to what extent are various portions of the Walker Lane included in the geologic setting of Yucca Mountain. So, although the NRC rationale is tight with regard to using specific Quaternary criteria in defining events and processes, it contains previously written language that is rather generalized in terms of what regional events and processes need to be considered.

The NRC position further defines (p. 4) the anticipated and unanticipated events to include the consideration of the maximum event which has occurred during the Quaternary, but also states (p. 6) that the staff will not simply use average or maximum values. Rather, they will consider the natural geologic variability, including spatial and temporal variability and periodicity of events, as well as the evidence from analogues in other geologic settings. Again, this is a reasonable approach indicating that identification of events will include consideration of probabilistic-like elements, rather than restricting it to purely deterministic definitions. It appears to be actually a slight modification of the Appendix A, 10 CFR 100 criteria for fault hazard evaluation. It is also consistent with existing literature (e.g., Wallace, 1978)<sup>4</sup> that describes variations of tectonic activity in the Great Basin.

This position will incorporate the preliminary conclusions being reached in our evaluation of the structural-tectonic similarities between the faulting in the 1932 Cedar Mountain earthquake area and that seen at Yucca Mountain. Using the NRC definitions, a 1932-type event will definitely be categorized at least as an unanticipated event at Yucca Mountain. Depending upon how the geologic setting and other structural-tectonic linkages are defined, a 1932-type event may also be interpreted to be an anticipated event at Yucca Mountain.

The NRC (p. 8-9) rejects the probabilistic approach in identifying and differentiating the two types of processes and events, stating "identification of anticipated and unanticipated processes and events will require considerable judgement and will not be amenable to accurate quantification, by statistical analysis, of their probability of occurrence." They conclude that "while it is recognized that probabilistic risk assessment techniques may be used by the DOE to help define the risk associated with

the various compliance requirements and performance objectives...probabilities will probably not need to be estimated to determine compliance."

This approach has both positive and negative attributes. On the positive side, the NRC is correct in stating that owing to the large uncertainties involved in most recurrence studies, it is difficult to accurately quantify the probability of occurrence. For example, the DOE in the Draft SCP claims (section 8.3.1.7.in particular) that probabilistic methods will be used to evaluate the adequacy of the deterministic final results, and already claims to also know the annual probability for the controlling earthquake on the Paintbrush Canyon fault is less than  $10^{-4}$ . Such a conclusion is not based on the available data, as much as it is based on a probabilistic method that minimizes the use of hard geologic data. The geologic recurrence intervals on the Paintbrush Canyon fault are presently undetermined and could not have been factored in. The NRC definition thus precludes this sort of probabilistic abuse.

On the negative side, the use of a purely deterministic method could pose a danger in incorrectly classifying the potential for post-closure activity. If the NRC intends to use the nuclear reactor criteria as suggested by John Trapp in his 1986 memo "Applicability of Appendix A of 10 CFR 100 to 10 CFR 60 Technical Criteria", some problems may arise with determination of "capable" faults as defined by these criteria. If a capable fault is accepted to be one that has moved once in the last 35,000 years (or more that once in the last 500,000 years), it is possible that given the long geologic recurrence intervals associated with many faults in the Great Basin, some of the faults at and near Yucca Mountain may be incorrectly categorized. If (hypothetically), the Ghost Dance fault was shown to have not moved in the last 40,000 years and there was insufficient information to constrain the fault history over the last 500,000 years, it might not be categorized as a capable fault if a narrow interpretation of the criteria is used. In actuality, the potential for near-future movement may be quite high if the fault has a 40,000 year recurrence interval. The present and future accumulated stress aspects (such as elapsed time) need to be factored in somehow. The NRC does incorporate some probability-like elements (p. 6 and 11) in the sense that considerations are given to geologic variability and periodicity, and this may compensate for the strictly deterministic approach.

In brief the NRC deterministic approach is a practical solution to an engineering problem. From scientific, state-of-the-art basis, it is not entirely adequate for defining the actual potential for tectonic activity, but this is partly ameliorated by the incorporation of geologic

variability and periodicity considerations. There is a need for the NRC to be more specific about what likelihood or probability or random events will be considered for the pre- and post-closure "anticipated" and "unanticipated" events. Some terms, such as "conservatively", are loosely defined and open to a wide range of interpretation. More concrete guidelines, such as using maximum values for conservative purposes, would be desirable for minimizing different interpretations and understandings of quantitative estimates.

4. Several sections of the GTP use nontechnical words which may appear vague to readers unfamiliar with preceding DOE and NRC reports (e.g. "EPA standard" page 3, paragraph 3). We recommend that the GTP be written so that it can be read and evaluated without cross-referencing other NRC or DOE documents; this may require expansion of the GTP glossary to include words such as those found on page 3 (e.g. "gradual", "the period", "EPA standard", "vacated standard", etc.).
5. The technical terminology is for the most part vague, ill defined and ambiguous. Contemporary usage as practiced by the earth science community and the many legal precedent set by the NRC in resolving earth science issues should be followed and used in this GTP.

Specific definitions of what constitutes the "region" around Yucca Mountain needs to be provided. Is this the same as the geologic term "province" as has been used historically in the context of 10 CFR 100, Appendix A? If so are there different boundaries for the geologic province, the seismotectonic province, the hydrologic province, the physiographic province, etc.? What is the NRC present position on the province boundaries? How will a significant event occurring in a neighboring province be handled (e.g. M 8.5 earthquake in Owens Valley)? What will be a mechanism for handling the determination of these boundaries prior to license application when differences in opinion arise?

The NRC needs to take a specific position on when the defacto licensing process is effectively initiated insofar as the GTP is concerned. Certainly the DOE needs to make a preliminary finding on what constitutes "anticipated and unanticipated processes and events" given the available data prior to issuing the statutory SCP. Anything less will make it difficult for the NRC and State to initially determine whether the proposed program will likely provide the data necessary to resolve the most important issues in a reasonable and timely manner. In addition it should be made clear that any preliminary finding by the DOE with tacit concurrence by the NRC and/or the State as to what constitutes point in the processes is subject to change

based on new events can become tomorrows anticipated processes and events (and vice versa) as new and more complete information becomes available. The NRC should also consider establishing a procedure for periodically making such a determination.

6. As the title of the GTP indicates, the style of the position paper is generic although there are three examples near the end of the report, one that pertains to the basalt repository at Hanford, a second one that pertains to the tuff repository at Yucca Mountain, and a third one that deals with climate.

Since Congress has chosen Yucca Mountain to be the first repository, the paper should be rewritten and be more specific to Yucca Mountain. The paper should spell out, based on present information, which events and processes are considered as anticipated and unanticipated. The GTP could also include a section that would indicate how the site characterization process could alter or affect the categorization of events and processes.

#### Specific Comments

##### Page 1. Footnote 1

The basis for equating the terms "undisturbed performance" (EPA) and "anticipated processes and events" (NRC) is not fully understood. Does this footnote imply that anticipated processes and events cannot include those that may or may not disturb performance? This confusion may stem from a lack of understanding of the EPA definition of "undisturbed performance" so it may be appropriate to include this definition in the GTP.

##### Page 1. Footnote 2

Based on footnote #2, it is interesting to note that a 50-70 year long period of construction, waste loading, and maintenance of retrievability is not considered in the performance assessment rule. Repository performance also can be impacted by anticipated and unanticipated natural events and processes during this period. Perhaps repository performance assessment should begin as waste is loaded into the repository.

##### Page 2. 1st paragraph

"The NRC staff recognizes that the first step in developing the scenarios that will need to be addressed, in determining compliance with 10 CFR Part 60, is the identification of a comprehensive set of processes and events that may be important at the site being considered."

It is assumed by this statement that the NRC intends to require that a comprehensive set of processes and events be identified at the time the statutory SCP is issued.

Page 2. 1st paragraph

"This GTP will also discuss "human-induced" processes and events, and to a minor degree will also address the category of "processes and events which are not sufficiently credible to warrant consideration."

This statement needs the support of a better and more specific example than presently found later in the text. These examples would not necessarily need to be specific to the Yucca Mtn region but could provide analogous examples from other regions. A possible candidate example for the "man-induced" processes and events might be a rise in the regional ground-water table or impoundment of a nearby reservoir that induces additional stress release (e.g. Columbia Basin, Lake Mead). A possible candidate example of "not sufficiently credible to warrant consideration" might be a violent eruption of the Lathrop Wells cone in a manner similar to Mt. St. Helens.

Page 3. 2nd and 3rd paragraph

Several potentially vague terms (see general comment 4) should be added to the glossary.

Page 3. 2nd paragraph

"Within §60.113(a)(1), it is specified that the engineered barrier system be designed so that assuming anticipated processes and events: (a)...(b) release of radionuclides from the engineered barrier system will be a gradual process; . . ."

There needs to be a definition of what gradual means. Is it a percentage of total inventory per unit time? Is release tied to one or more specific isotopes? Is any release allowed before 300 years?

Page 3. 3rd paragraph

"Within §60.113(a)(1), it is specified that the engineered barrier system be designed so that assuming anticipated processes and events: (a) containment of high level waste will be substantially complete during the period when radiation and thermal conditions within the engineered barrier system are dominated by fission product decay; . . ."

Given the relative certainty as to the fission product inventories that will be disposed of and their thermal flux it should be possible to specify the "period" of domination or at least provide a minimum time.

Page 3. 3rd paragraph

"In the license application, the applicant must present an evaluation of the performance of the geologic repository for the period after permanent closure, assuming anticipated processes and events, along with a similar evaluation assuming unanticipated processes and events (§60.21(c)(1)(ii)(C))."

It is not clear what constitutes the effective initiation of the license application. The NRC needs to take a specific position on when the defacto licensing process is effectively initiated insofar as the GTP is concerned. Certainly the DOE needs to make a preliminary finding on what constitutes "anticipated and unanticipated processes and events" given the available data prior to issuing the statutory SCP. If the time of "license application" does not occur until after DOE decides that site characterization is complete, substantial delay could result while the question of comprehensiveness of identified anticipated/unanticipated processes and events is resolved. In addition NRC should specify that the issue will be revisited at the time the operation permit is applied for and at the time a permit for closure is applied for and specific performance data is available.

Page 4. 2nd paragraph

The term "maximum event" should be defined. At present it is very speculative to determine the maximum value of such parameters as water table elevation, percolation flux, or fracture flow in the unsaturated zone in tuff.

Page 4. 2nd paragraph

It is indicated that in considering anticipated and unanticipated events the scenario analyzer should consider the maximum event which has occurred within the geologic setting during the Quaternary Period, which the footnote identifies as having began about 1.8 million years ago. Some clarification appears necessary with regards to climate changes for which the following guidance is provided at the bottom of page 15 of the GTP: "While the entire Quaternary Period needs to be evaluated, the late Quaternary record would be the record most relied upon by the staff." For the Yucca Mountain project, the DOE plans to perform studies that should allow forecasting climatic variables for the next 100,000 years. For paleontologic studies, the DOE has set goals for collecting data that emphasizes the past 50,000 yr in great detail, the past 200,000 yr in moderate detail, and the past 1,000,000 yr in some detail<sup>5</sup>. It would appear that the DOE's plans are not compatible with the NRC's position.

Page 4. 2nd paragraph

There appears to be some indecision with respect to the geologic time period which is to be considered. The position paper states on page 4 that the evaluation "should" (not used) "consider the maximum event which has occurred within the geologic setting during the Quaternary Period." However, there is then an emphasis placed on the "Late Quaternary" which dominates the rest of the thinking. The location and controlling geologic structure for anticipated processes and events are defined by the entire 1.8 million-year Quaternary period, but the rate of that process or event would emphasize the late Quaternary period, 700,000 years. This apparent contradiction will probably have little, if any, effect on climatic variations which would be considered, however, it might affect considerations related to tectonics and volcanism.

Page 4. 2nd paragraph

"The "anticipated event" should be assumed to occur at the location, or along the controlling geologic structure, where this event occurred during the Quaternary Period."

This sentence along with footnote 3, implies that at a minimum the DOE must establish the base cases for all "processes and events" for the entire Basin and Range province before any realistic categorization can be made as to whether a "process and/or event" is significant and whether it would be anticipated or unanticipated.

Page 4. Footnote 3

"The definition of geologic setting in 10 CFR 60.2 discusses the "systems of the region in which the geologic repository operations area is located." For the purpose of this GTP, the staff considers these systems as a regularly interacting or interdependent group of items forming a unified whole within the region of the geologic repository operations area, such a groundwater basin or an area of similar tectonic processes."

Is the "system of the region" synonymous with the term "province" as used in 10 CFR 100, Appendix A? If so, what is the significance of the new term "region"?

Page 4. Footnote 3

"It will be necessary, therefore, to define which systems are relevant, and their geographic extent."

It is assumed that the DOE has the responsibility to define which systems they consider relevant. At what point in the process does this take place? What mechanism will the NRC employ for

concurring with the DOE's position? How will any differences in interpretations outside of the DOE and NRC be dealt with? Before any judgement can be made as to the relevance of any DOE proposed "anticipated and/or unanticipated processes and events" some kind of agreement must be reached by all parties as to what will constitute the "systems of the region." Without such an agreement prior to issuing the statutory SCP it will be impossible to effectively judge the adequacy of the proposed program to provide the data that will be required for resolution of the issues.

Page 4. Footnote 4

The definition used for the Plio-Pleistocene and Holocene by the NRC agrees with the standard world-wide definition established by the International Quaternary Association (INQUA). Other definitions would probably be acceptable as long as they conform to world-wide criteria (since the Quaternary is defined in large part on the basis of worldwide climatic data), and does not unnecessarily complicate generally understood and accepted meanings.

When viewed from the perspective of the Yucca Mountain candidate site and associated environs, the entire Quaternary period maximum event and process rates may prove very difficult to establish due to the complexity of the record, and the tectonic deformation during the Quaternary. The "late Quaternary" used in the sense of the last 700,000 years is generally better understood, but still complex.

It would be appropriate to use several references to establish the time scales in footnote #4, page 4.

Page 5. 1st and 5th paragraph

"An unanticipated process should be assumed to occur at any credible location within the geologic setting, to determine its effect on waste isolation..."and ..."Natural processes and events that are generally treated as "random" processes and events will normally be considered as anticipated processes and events."

There appears to be a conflict between these two statements. If the DOE has enough evidence to support a conclusion that a process or event has not occurred at the site but has occurred within the region then paragraph 1 allows the classification of unanticipated. If at the same time this process or event cannot be tied down to any specific location within the region and therefore must be considered as random, paragraph 5 requires the classification of anticipated.

Page 5. 1st paragraph

How is a "credible location" defined? Who determines what is a "credible location"? As an example, are all identified faults within the Geologic Setting considered "credible locations" for unanticipated events?

Page 5. 2nd paragraph

The definition of "unanticipated processes and events" is somewhat indistinct when related to naturally-occurring events. There is no clear explanation of the term "sufficiently credible to warrant consideration." This term needs some measure by which a process is included or excluded. The unanticipated processes and events related to human activities are better defined together with constraints which determine when they should be considered.

Page 5. 2nd paragraph

"An "anticipated process" should consider reasonable and conservative projection of the rate of the process that is occurring or that has occurred, within the geologic setting during the Quaternary Period."

Establishing the anticipated process will be difficult in most cases particularly if the processes are coupled. Establishing the rate of the process or processes will be even more difficult. It is suggested that this GTP recognize this problem and provide some alternative mechanisms to deal with the entire scope of defining anticipated/unanticipated processes and events throughout the characterization phase.

Page 5. 2nd paragraph

"As with anticipated and unanticipated events, an anticipated process should be assumed to occur at the location where the process is occurring, or has occurred."

In paragraph 1. above it is stated that an anticipated and unanticipated event must also be assumed to occur along the controlling geologic structure. Given the difficulty in separating discrete events from coupled processes it is suggested that anticipated processes should also be assumed to occur along the controlling geologic structure in addition to the location where the process is occurring unless the DOE can provide hard evidence to the contrary. The same requirement would be assumed that the DOE has sufficient evidence to justify the categorization of a process being unanticipated. That is the DOE would have positive evidence for a negative occurrence.

Page 5. 2nd paragraph

"A natural "unanticipated process" should consider the maximum sustained rate of this process during the Quaternary Period."

There is potential ambiguity in the use of the word "sustained". The determination of a sustained rate requires the definition of a bounding period of time. As written, the bounds could encompass the beginning of the Quaternary to the present day (approximately 1.8 million years), resulting in the sustained rate determination possibly being an average rate. It is recommended to substitute the word "discernable" (meaning identifiable as a distinct maximum) for "sustained". This language would assure the use of any identified maximum rate, which could be no less than a sustained rate. The bounding period would then be applied to the credible transposition of the process to the site location and its expected results in that setting.

Page 5. 3rd paragraph

The third position is essential in that it will be absolutely necessary to consider modifications of human activity beyond DOE's control. As an example, the continued current or projected future increased use of groundwater from either the valley fill or carbonate aquifers is a distinct possibility which has to be examined.

Page 5. 4th paragraph

The rationale for this position (page 13) is not fully applicable to the existing situation of the Yucca Mountain site being on and adjacent to the Nevada Test Site, with its history of underground weapons testing and the potential future testing at uncertain energy levels, rates and location. The testing-induced processes and events are not well known, given the necessarily limited period and experience. The potential cumulative effects are known to an even lesser extent. Therefore, neither the DOE nor the Commission can adequately substantiate specific conditioning of either a weapons testing program or a repository license to protect waste isolation.

It is recommended that any ground-disturbing activities directly associated with the DOE's weapons testing program at the Nevada Test Site will be considered human-induced processes and events that will not be under DOE's control, and Position 3 will be fully applicable. The rationale is as follows: with the recommended application of Position 3, in conjunction with Position 4, the uncertainty associated with the induced effects of weapons testing program will require full evaluation during site characterization and license application review. This will provide far greater protection than placing heavy reliance on the

assumption of adequate institutional control within the DOE, or as may be imposed by the NRC.

Page 5. 4th paragraph

We disagree with the classification of all human-induced processes and events as "unanticipated". For whatever reason that control of human activity is no longer maintained at the Site, and regardless of the assumption in the definition of "unanticipated processes and events" in 10 CFR 60.2, it should be considered reasonably likely that humans will attempt to explore the Site for items or resources future value, real or perceived, that may not be present within the Site. A pertinent analogue in human history is the condition of the tombs of the ancient Egyptian aristocracy. Notwithstanding the precautions taken against intrusion, and hazards associated with intrusion that were assumed to be the culture that built the tombs, most tombs were violated within a few generations of their closure. This occurred despite the fact that organized, technologically equivalent societies existed in the region, adequate records were maintained, etc.

Page 5. 5th Paragraph

It is stated that random events are considered as "anticipated events". This does not consider the likelihood of such events, however; and extreme example, for instance, would be a meteorite impact, which is certainly a random event but is rare enough to be discounted.

Page 5. 5th paragraph

"Natural processes and events that are generally treated as "random" processes and events will normally be considered as anticipated processes and events." It is not clear which natural processes and events should be treated as random and, therefore, examples should be listed or identified.

Page 5. 6th paragraph

The sixth position is necessary in evaluating the waste emplacement and resultant heat on the geologic-hydrologic-geochemical systems' responses to possible future changes in climate or stress.

Page 6. 2nd paragraph

The rationale for identifying "anticipated and unanticipated processes and events" is a reasonable approach, however, there is no discussion of how NRC will resolve issues of differing professional judgement. There should be some mechanism for issue

resolution when, for example, the State considers that a process or event should be considered and NRC does not.

Page 6. 2nd paragraph

It is not clear whether the NRC will also consider unidirectional, non-periodic processes and events. As an example, it is possible that the "greenhouse effect" may dampen or terminate the global climatic fluctuations which have dominated the Quaternary. Such unidirectional shift may have important climatic implications that would not be predicted by an analysis of the late Quaternary climatic records. Additionally, seismicity within a structural domain (i.e. southern Basin and Range) may exhibit a non-cyclic "temporal clustering" behavior (Ni and Wallace, 1988<sup>6</sup>, Coppersmith, 1988<sup>7</sup>) (See attached item labeled as Appendix B).

Page 6. 3rd paragraph

It is gratifying to observe that the NRC recognizes the need for study of geologic analogues of geologic phenomena and processes in the Yucca Mountain area.

Page 6. 4th paragraph

What history of similar deposits? name?? If a deposit is present, a very thorough program of exploration drilling and excavation would likely be required to gain sufficient information to make any meaningful determination of similarity to other deposits. If such a determination can be made, it is likely to be difficult, or impossible, to obtain or determine the drilling histories of the analogue deposits.

Page 8. 2nd paragraph

The definition of "unanticipated processes and events" is somewhat indistinct when related to naturally-occurring events. There is no clear explanation of the term "sufficiently credible to warrant consideration." This term need some measure by which a process is included or excluded. The unanticipated processes and events related to human activities are better defined together with constraints which determine when they should be considered.

Page 9. 1st Paragraph

Will the NRC continue with the deterministic assessment of anticipated and unanticipated processes and events during the construction and operation phase of the repository? It is possible that new studies, techniques, etc. which evolve during these phases may affect the results of earlier conclusions.

Page 9. 1st paragraph

Recommendation of a deterministic basis for classifying processes and events is a positive step, and certainly the Quaternary geologic record is a reasonable test of what is anticipated and what is not. However, we question the statement (page 9) that probabilities will probably not need to be estimated to determine compliance. The EPA standard (40 CFR, part 191) is by definition probabilistic, requiring that cumulative releases of individual radionuclides to the accessible environment from all significant processes and events for 10,000 years after disposal shall, (i) have a likelihood of less than one chance in 10 of exceeding specified quantities, and (ii) have a likelihood of less than one chance in 1000 of exceeding ten times these quantities. The risk assessment methodology (Campbell and Cranwell, 1988<sup>8</sup>) calls for superposition of the complementary cumulative distribution function (CCDF) for each scenario on the step-function form of the containment requirement, such that any intersection or overlap of the two curves may signify noncompliance. How can the comparison be made if scenario probability is not considered?

Meaningful probability estimates for some geologic processes and events are probably unattainable in the complex and active tectonic regime of the southern Nevada region. Thus, the risk assessment methodology for compliance assessment is only theoretically sound in such an environment. If NRC has recognized the above and has therefore abandoned the performance assessment methodology, this position should be clearly expressed and discussed. If not, the mechanics of compliance assessment, specifically estimation of scenario probability, should be reconciled with statements in this GTP.

Page 9. 2nd paragraph

"The staff considers that the geologic record of the geologic setting for the Quaternary Period should provide the basis for determining the classification of events and processes. This is consistent with both the wording and intent of 10 CFR 60, and is also in agreement with several scientific studies that suggest that the Quaternary record, and especially the late Quaternary record, provides the best basis for projecting future geologic events (e.g., see Ref. 2, Allen, 1975)."

Allen, 1975 essentially focuses on the design earthquake problem as it applies to engineered structures with economic lifetimes of 30-50 years. This reference may not be appropriate for all the processes and events that have to be considered for a HLW Repository with an effective lifetime of 10,000 years. In addition, Allen was using the late Quaternary in a more restricted sense with the emphasis on the Holocene. In areas such as the Great Basin where the Quaternary is not well preserved or when dealing with "catastrophic" processes or events

that have unusually long recurrence intervals a different basis will need to be developed before projecting future geologic events during the next 10,000 years."

Page 10. 2nd paragraph

"However, natural processes and events of concern for a high-level geologic repository can be grouped as either tectonic, climatological, geochemical, hydrological, or geomorphic processes and events."

Perhaps the phrase "high-level geologic repository" should be revised so that the reader gets the idea it is a geologic repository for containing high-level radioactive waste and not a geologic repository that sits at a high-level in Yucca Mountain.

In the second part of the sentence the definition may be to simple. Where do volcanic events or thermal perturbations, either of which can occur without significant tectonic activity, fit into the scheme.

Page 10. 2nd paragraph

Volcanism is omitted from the list of natural processes that may be of concern for a high-level repository. We suggest the addition of volcanic processes and events to the list of basic natural processes and events.

Page 10. 2nd paragraph

The NRC divides the basic natural processes and events into driving and resultant processes and events. It is not clear whether this division implies possible "coupling" of events (i.e. basaltic ash found in fault fissure filling in Yucca Mountain suggests possible temporal coupling of faulting and volcanic eruptions). How are coupled processes categorized if all components have not occurred in the Quaternary (e.g. basaltic volcanism, and anticipated process, may be coupled with hydrothermal activity which is currently recognized only from the Miocene at Yucca Mountain. Is hydrothermal activity therefore "unanticipated")?? The NRC should clarify its position regarding possible coupled processes/events.

Page 10. 2nd paragraph

The breakdown of the natural processes into two categories, 1) driving and 2) resultant, is a very logical way to categorize those to be considered. The first category being climate and tectonic leaves out the volcanic activity which would be considered when we include the entire Quaternary or even only the late Quaternary.

The changes to the hydrological, geochemical, and geomorphical systems being only a result of climatic or tectonic changes ignores the possible volcanic activity at or near the repository site which could change the entire geologic framework.

Page 10. 2nd paragraph

"In simplest form, it can be stated that only tectonic and climatological processes and events are driving processes and events; all others are basically resultant processes and events."

This statement is not necessarily true. Such events as reservoir induced seismicity at Lake Mead and the increased seismic activity in the Columbia Basin, WA in response to a rise in groundwater levels following irrigation are just two examples of significant non-tectonic and non-climatological processes that could affect additional static load. There is also the possibility of focused stress release within the repository as excavation proceeds.

Page 10. 2nd paragraph

"In other words, if the general geologic conditions such as lithology, structure and mineralogy of the geologic setting are known, along with the present state (either static or dynamic) of the hydrological, geochemical and geomorphological system, then any expected change to, or response of, these systems could only occur if there were a change in the tectonic or climatological systems."

There is no such thing as a static geologic system. The word static implies without change. In geologic terms, all systems are undergoing change. There are probably ongoing processes in the Yucca Mtn. region that are changing so slowly that for all practical purposes could be treated as static. The challenge however will be for the DOE to demonstrate from a "deterministic basis" what the true conditions are and where in the cycle the present state lies.

Page 11. 2nd paragraph

Our ability to understand the range of variability and periodicity of natural processes and events may restrict the levels or intensities considered.

Page 11. 2nd paragraph

The last sentence reads "the anticipated and unanticipated processes and events should, therefore, reflect the variability of the processes and events and must be expressed conservatively, commensurate with the uncertainty." This sentence needs to be rewritten to be more specific. The meanings of the terms

"uncertainty" and "conservatively" are not clear. Does "conservatively" mean the maximum variability value? Is the uncertainty supposed to be related to estimating the variability?

Page 11. 3rd paragraph

The use of the term "floating earthquake" requires clarification. Is this term equivalent to "random earthquake"?

Page 12. 1st paragraph

"In the Western United States, where it is easier to define and locate definite causative mechanisms, the design earthquake event has been defined by the characteristics of a nearby structural feature, for many of the nuclear facilities."

There are exceptions to this statement. The most notable recent examples are the blind thrust fault at Coalinga, CA and the issue of the subduction zone earthquake in the Puget Sound. Until the DOE has completely defined the geologic system in three dimensions, the question of what constitutes anticipated an/or unanticipated processes and events and the source structure where they occur will be extremely difficult to resolve.

Page 12. 3rd paragraph

The GTP classifies cyclic events as unanticipated if a portion of the cycle is not recorded in Quaternary time. However, if a cycle can be shown to occur and a recurrence of the cycle is predicted for the performance period of the repository, it should be classified as an anticipated event.

Page 12. 3rd paragraph

The third paragraph on page 12 appears to be key to the definitions and distinction between anticipated and unanticipated natural processes and events. This reasoning is permissive rather than restrictive and should be followed to include all possibilities.

Page 13. 2nd paragraph

With respect to the discussion of human-induced processes and events, the concept put forth that the applicant have appropriate controls outside the controlled area (U60.121) appears to be unlikely with respect to DOE controlling future resource use. There needs to be further clarification of how NRC could require "additional constraints" to protect public health and safety. There also needs to be some clarification of "area that can come under the applicant's control." This could be interpreted to apply to all adjacent lands both federal and private-owned.

Page 13. 3rd paragraph

It is indicated that the human-induced activity of introducing pollutants to the atmosphere could cause modification of the climate cycles. The following statement is made: "Such activities must be accounted for in determining the final anticipated and unanticipated processes and events for performance evaluation and design." The discussion should be more specific and indicate which of the following processes must be accounted for: 1) green house effect; 2) depletion of the Ozone layer; and 3) acid rain.

Page 14. 2nd paragraph

What guidelines control how a process or event is considered "not sufficiently credible"? Who makes these decisions?

Page 14. 3rd paragraph

"If we expand on this example, the various references on the Pasco Basin suggest that there have been only minor variations in the magnitude of the stress and resultant strain since approximately the Miocene (see Ref. 3, Rockwell, 1983). Therefore, both the anticipated and unanticipated processes and events would occur under a compressional regime."

These two statements are respectively inaccurate and misleading. The first statement is contradicted by the NRC Staff review of the BWIP SCR (NUREG-0960, Mar. 1983) wherein (c.f. page 4-6) it is stated "important contradictions between tectonic models (for Pasco Basin) are estimates of the rate of deformation, the degree to which sub-basalt strata are involved in deformation and the location of strain within the basalts." In the review of the Dec. 1984 draft EA and the May 1986 final EA, the NRC staff took an even stronger position that their could have been significant changes in the strain rate since the Miocene. The staff did not question that the stress direction had changed. The second statement deals with strain rates. It would be difficult to find evidence that significant changes in stress direction could take place over time frames of 10,000 years or less.

Page 14. 3rd Paragraph

"More weight would normally be given to the later Quaternary evidence. It must be recognized, however, that relatively little information is available for the late Quaternary in this area (Pasco Basin). Therefore, the projections may need to rely more heavily than in the ideal case on the pre-Quaternary geologic record."

The Ringold formation (late Miocene - lower Pleistocene) within the Pasco Basin, a number of late Pleistocene deposits around the

Columbia Plateau, and the Touchet deposits and Pasco Basin combine to provide a record that is far superior to that available in the southern Basin and Range. If the NRC considers that this constitutes "relatively little information ... for the late Quaternary in this area (Pasco Basin)" then by comparison the Yucca Mountain area has no information at all. If such critical information cannot be obtained it will prove difficult to establish what should constitute significant anticipated or unanticipated processes and events.

Page 14. 3rd paragraph

The NRC uses an example from the Pasco Basin in which Miocene strain rates are projected to the present and considered applicable to the Quaternary. They state that "a conservative projection for the next 10,000 years would be made to evaluate the "anticipated" amount of stress and/or strain that would be expected to occur during the 10,000 year post-closure period." This statement is misleading and possibly incorrect. The 10,000 year period is a design value, not a natural process time period. This statement does not consider interseismic intervals or where we might be with respect to the interseismic strain build-up. Thus, there is no way to know if this is indeed a "conservative projection"; and in light of this uncertainty, the opposite may be true--That it is a non-conservative projection. Further, this example seems to ignore statements made on p. 11 in which they look for "...reasonable projections..of the system under investigation with respect to the periodicity of the cycle."

Page 15. 2nd paragraph

The following statement is made in reference to tectonics at Yucca Mountain: "However, either strike-slip faulting or normal faulting would be considered reasonably likely, whereas pure thrust faulting, associated with compressional tectonics, would be considered not sufficiently credible to warrant consideration." It should also be mentioned that detachment faulting is likely to be present a Yucca Mountain.

Page 15. 2nd paragraph

The report states that Yucca Mountain "lies in an area between the dominant right-lateral shear related to the California tectonic system." This statement should be corrected to read--The Yucca Mountain site lies within an area affected by extensional tectonics of the Basin and Range system, and to the east of the area of dominant right-lateral shear related to the California tectonic system.

Page 15. 2nd paragraph

It should be noted that compressional deformation can occur as a result of an extensional event. For example, transpressional folding may occur adjacent to strike-slip faults during regional extension. Also, strike-slip faults may terminate in broad folds. In addition, oroflexural bending of ranges may fold rocks adjacent to strike-slip faults.

It is apparent that folding is an anticipated hazard during extension and not an unanticipated hazard as stated in the NRC GTP.

Page 15. 3rd paragraph

The processes and events related to climatic changes based on the "late Quaternary" record should adequately consider the wetter periods for which evidence is available. This, together with projected changes in world climate due to man's past, current, and future activities, should then provide a complete basis for evaluating the resultant hydrological, geochemical, and geomorphical system and its performance. The emphasis on future climate may well need to emphasize the projected changes resulting from CO<sub>2</sub> and the ozone layer changes rather than from reconstruction of past climate.

Page 16. 2nd paragraph

"Further examination of the various references on Pleistocene climates, such as Imbrie and Imbrie (1979)(see Ref. 4), shows that their best projection for the next 10,000 years does not reach the climatic extremes these authors extrapolated from the Quaternary data."

This statement appears to ignore the real possibility of significant changes in sea level that can occur without reaching climatic extremes. An increase in the groundwater level exclusive of climatic changes needs to be considered.

Page 17. 3rd paragraph

It is previously stated on page 6 that "evidence from analogues in other geologic settings" will be used if the Quaternary record is potentially insufficient. However, here the possibility of silicic volcanism is discarded entirely on the basis of the Quaternary record. Although the probability of occurrence is obviously low over the next 10,000 years, it is possible that basaltic volcanism can cause melting of the lower crust sufficient to generate silicic volcanism (Hildreth and others, 1984<sup>9</sup>). This suggests that the potential for silicic volcanism may warrant consideration as an unanticipated event. This is a good example of where analogue studies may prove valuable.

Page 17. 3rd paragraph

The NRC GTP states that basaltic volcanism at Crater Flat is anticipated event and since silicic volcanism has not occurred during the Quaternary, it is unlikely to occur in the future. Three points need to be made with respect to this statement.

(a) Basaltic volcanism may trigger silicic volcanism as it did in the Inyo Craters, California. Since the two types of volcanism have occurred at Crater Flat in the past, they may also occur in the future.

(b) The eruption of basalt is often accompanied by the intrusion of more silicic (more highly evolved) plugs of basalt in the cores of existing cinder-scoria cones.

(c) Basaltic eruptions may trigger explosive eruptions (phreatomagmatic activity) that may be potential hazardous to surface activities at the Yucca Mountain site. Surge deposits resulting from explosive eruptions have already been described by Crowe in some of the older deposits from the Lathrop Wells Cone. Even though these explosive eruptions are not the result of the eruption of more silicic magma, the eruptive products are similar (ash, scoria, base surge).

Page 18. 1st paragraph

The NRC GTP states that future volcanic events at Crater Flat will occur along pre-existing structural features (anticipated events). The State's work strongly demonstrates that eruptions may occur in areas not previously faulted or adjacent to existing faults and that volcanism is rarely directly controlled by a major structure. Therefore, volcanism not related to major structures at Crater Flat should be classified as anticipated event, not an unanticipated event.

Page 18. 1st paragraph

"To determine the unanticipated volcanic event, the staff would consider both the results of such probabilistic studies as Crowe, et al., (1982) (see Ref. 6), and the evidence regarding the presence of structural features similar to the structural features related to the known instances of basaltic volcanism."

Crowe, et. al., (1982) may be in error, given recent information presented at the Las Vegas GSA Cordilleran Section Meeting. This points up the fundamental problem of establishing an adequate data base before any probabilistic inferences or irreversible siting decisions are made. There is a need to agree on the

geologic region first before the decision can be made as to what data base will be used to determine anticipated/unanticipated processes and events.

Page 18. 1st paragraph

Define "related structures". Is any related structure (i.e. fault) in the site area considered a potential basalt conduit?

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**NATIONAL WORKSHOP ON SEISMOGENESIS  
IN THE EASTERN UNITED STATES**

Abstracts

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Temporal Clustering of Earthquakes:  
Examples from the Basin and Range Province

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Accurate forecasting of earthquake hazards depends on whether seismicity is time-stationary or variable. Detailed studies of late Quaternary faulting in two parts of the Basin and Range suggest that seismicity cannot be considered time-stationary, and there may be temporal clustering of earthquakes. In west central Nevada there appear to be three "peaks" of activity, (1) the historical activity along the Nevada Seismic Belt, (2) a temporal cluster at 2,000-3,000 ya, (3) a cluster at 5,000-6,000 ya. For the two older episodes the ages of faulting are determined by morphologic analysis of fault scarps. Similar analysis of Quaternary fault scarps in southeastern Arizona show clustering of events at 20,000-25,000 ya and 80,000-90,000 ya. In both Arizona and Nevada the temporal clustering is not related to spatial clustering. However, the historical Nevada activity shows a spatial correlation.

Two basic issues need to be resolved: (1) why is there temporal clustering, and (2) how much communication is there between faults?

**Issues Regarding the Future Location and Recurrence Rate  
of Earthquakes in the Eastern United States: Temporal  
and Spatial Clustering**

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Historical seismicity data are typically used to assess both the location and recurrence of future eastern earthquakes. Inherent in these assessments are assumptions of spatial and temporal stationarity. The purpose of this paper is to examine the viability of stationarity assumptions in light of our emerging knowledge of eastern U.S. seismotectonics. The reasons for using the locations of seismic activity to define future earthquake locations generally stem from our ignorance of the causative mechanisms for earthquakes in the East. To supplement the historical record, evaluation of geologic structures and tectonics may be helpful, but considerable work is needed to further define the mechanisms for earthquakes (e.g., zones of "weakness" or stress amplification). The concept of lower crustal strain localization holds promise in identifying active regions if systematic evaluations of geodetic data can be made.

Geologic estimates of recurrence as well as those based on seismicity at New Madrid and Charleston indicate strain rates that would imply significant amounts of Quaternary deformation. This cumulative deformation, however, is not observed. One way, supported by studies in other parts of the U.S., to explain this discrepancy is to have spatial and temporal clustering of seismic activity. Repeated large earthquakes in the Charlevoix region and paleoseismicity studies at New Madrid, Charleston, and the Meers fault all suggest that a temporal "cluster" consists of several large events and persists for at least a few thousand years, followed by long periods of quiescence. The spatial "scales" of these clusters is uncertain but the paleoseismic evidence in the Charleston region suggests that the prehistoric region of activity did not extend very far beyond the presently active zone.