

**ANALYSIS OF NRC REGULATORY HISTORY AND
INTENT RELATIVE TO VOLCANIC AND MAGMATIC
ACTIVITY**

Prepared for

**Nuclear Regulatory Commission
Contract NRC-02-88-005**

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September 1992

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ACKNOWLEDGMENTS

The authors wish to thank Barbara Long and Pamela Smith for their able assistance in production of this report. Stephen Spector provided a legalistic review of the report and his assistance is gratefully acknowledged.

This report was prepared to document work performed by the Center for Nuclear Waste Regulatory Analyses (CNWRA) for the U.S. Nuclear Regulatory Commission (NRC) under Contract No. NRC-02-88-005. The activities reported here were performed on behalf of the NRC Office of Nuclear Material Safety and Safeguards, Division of High-Level Waste Management. The report is an independent product of the CNWRA and does not necessarily reflect the views or regulatory position of NRC.

1 INTRODUCTION

NRC Regulatory requirements in 10 CFR Part 60 require the Department of Energy to determine the presence and assess the consequences of igneous activity at a proposed repository site. These requirements are necessary to address issues related to site suitability and repository performance. NRC DHLWM staff must review the Department of Energy's (DOE) program for investigation of igneous activity (i.e., both volcanic and magmatic) with a clear understanding of NRC regulatory intent regarding applicable requirements in 10 CFR Part 60. In this light, NRC DHLWM staff have requested an analysis of regulatory history and intent with respect to igneous (volcanic and magmatic) activity to ensure that guidance and methods developed to assist determinations of compliance with the applicable regulations are consistent with NRC intent.

Excerpts from applicable statutes, regulations, and NRC staff statements made during the rulemaking process are presented and discussed as a means to develop a clear understanding of the regulatory history and NRC intent. While no specific mention of igneous activity *per se* was identified outside of the pertinent texts of the regulation, there is relevant historical discussion regarding the requirements for consideration of the broad class of conditions (i.e., potentially adverse conditions) which include igneous activity. Other applicable areas of discussion identified include: establishment of technical criteria, modeling of conditions at the site, uncertainties, and the quantitative/qualitative nature of analyses. Chronological order is used in discussion of historical information to provide the natural development sequence of relevant statutes and regulations.

2 STATUTORY BASES FOR CONSIDERING IGNEOUS (VOLCANIC AND MAGMATIC) ACTIVITY

The responsibilities of NRC to oversee the licensing of a geologic repository to contain high-level radioactive waste (HLW) are founded in five sections of Federal statutes: The Atomic Energy Act of 1954 (42 USC 2232); Atomic Energy Act of 1954 (42 USC 2233); Energy Reorganization Act of 1974 (42 USC 5842); Nuclear Waste Policy Act of 1982 (NWPA)(42 USC 10132); and the Nuclear Waste Policy Amendments Act of 1987 (42 USC 10141). Applicable wording and its importance to the consideration of igneous activity is herewith presented.

2.1 Atomic Energy Act of 1954

The statutory language from the Atomic Energy Act of 1954, Section 182 (42 USC 2232) states:

"Each application for license . . . shall specifically state such information as the Commission, by rule or regulation, may determine to be necessary. . ."

This language applies to all NRC rules and regulations including those for disposal of HLW in a geologic repository. It requires the applicant to include within its license application (LA) all information NRC requests and requires to fulfill its statutory responsibilities. 10 CFR Part 60 is the regulation applicable to disposal of HLW in a geologic repository.

The Atomic Energy Act of 1954, Section 183 (42 USC 2233) states:

"Each license shall be in such form and contain such terms and conditions as the Commission may, by rule or regulation, prescribe to effectuate the provisions of this Act: . . ."

This language also applies to all NRC rules including those regulations for disposal of HLW in a geologic repository. It requires the applicant to present an application in proper form which contains responses to rules or regulations prescribed by NRC -- in this case, 10 CFR Part 60.

2.2 Energy Reorganization Act of 1974

The licensing and regulatory responsibilities of NRC regarding HLW storage were specified in Section 202 of the Energy Reorganization Act of 1974 (42 USC 5842):

". . . the NRC shall . . . have licensing and related regulatory authority pursuant to Chapters 6,7,8, and 10 of the Atomic Energy Act of 1954, as amended, as to the following facilities of the Administration: . . .

(3) Facilities used primarily for the receipt and storage of high-level radioactive waste resulting from activities licensed under such Act.

(4) Retrievable surface storage facilities and other facilities authorized for the express purpose of subsequent long-term storage of high-level radioactive waste generated by the Administration, which are not used for, or are part of, research and development activities."

This language specifically provides NRC with appropriate licensing and regulatory authority for the disposal of HLW over the long term. It gives NRC jurisdiction over the facilities used for receipt and storage of HLW licensed under the Energy Reorganization Act of 1974.

2.3 Nuclear Waste Policy Act of 1982

The Nuclear Waste Policy Act (NWPA)(42 USC 10132) amplified the existing statutory authority and specifically provided for criteria to be promulgated by DOE for site selection, and NRC for site approval and licensing of geologic HLW repositories. The proposed approval criteria, which NRC issued prior to passage of NWPA, were under the authority of the Atomic Energy Act and the Energy Reorganization Act of 1974. NWPA provides a consolidated HLW management framework requiring DOE to establish and use site selection guidelines. Section 112 of NWPA, which was written following consultation with interest groups and agencies (including NRC concurrence), identified requirements to be incorporated in the site selection guidelines.

Relevant statutory language in the NWPA includes:

"(a) . . . the Secretary [of Energy], following consultation with the Council on Environmental Quality, the Administrator of the Environmental Protection Agency, the Director of the Geological Survey, and interested Governors, and the concurrence of the Commission [NRC] shall issue general guidelines for the recommendation of sites for repositories . . . specify[ing] detailed geologic considerations that shall be primary criteria for the selection of sites in various geologic media. Such guidelines shall specify factors that qualify or disqualify any site from development as a repository, including factors pertaining to . . . hydrology, geophysics, seismic activity . . ."

This language was provided by the legislature to the Secretary of Energy in order to guide DOE's recommendation of candidate sites for characterization. While this language does not specifically mention igneous activity, the broad concern of the legislators with geologic aspects of the site can be construed to include igneous activity within the context of pertinent geological considerations. Since the legislators directed DOE to establish qualifying conditions regarding geologic events, by inference, NRC, as the license grantor, must be considerate of the same conditions in their evaluation of DOE's LA.

Additional language in NWPA (42 USC 10141) specifically addressed NRC:

"(b)(1)(A) . . . the Commission [NRC], pursuant to authority under other provisions of law, shall, by rule, promulgate technical requirements and criteria that it will apply, under the Atomic Energy Act . . . and the Energy Reorganization Act . . ."

(B) Such criteria shall provide for the use of a system of multiple barriers in the design of the repository . . .

(C) Such requirements and criteria shall not be inconsistent with any comparable sections promulgated by the Administrator under subsection (a)."

This language specifically amplified the authority of NRC to promulgate technical requirements and criteria for the licensing of a geologic repository for HLW. Previously discussed existing statutory authority is referred to in the language of NWPA (42 USC 10141). It is important to note the wording of (B) which gives credence to the philosophy of multiple barriers at a geologic repository. The presence of igneous activity is of regulatory interest in the context of stability and performance of these multiple-barriers.

2.4 Nuclear Waste Policy Amendments Act of 1987

In 1987, the Nuclear Waste Policy Act was amended (42 USC 10101) by Congress to narrow site characterization activities to Yucca Mountain, Nevada as the potential geologic repository site. No changes were identified which relate specifically to assessment of igneous activity.

3 IGNEOUS (VOLCANIC AND MAGMATIC) ACTIVITY AND LICENSING OF A HLW REPOSITORY: A REGULATORY HISTORY

This section details the history and documented intent associated with development of NRC regulations governing HLW repositories with respect to igneous activity. NRC is concerned with the presence or occurrence of igneous activity which could disturb a repository and unfavorably affect waste isolation. Therefore, it is necessary to consider such disturbances in assessing repository performance. The following discussion presents references relevant to identification and evaluation of igneous activity as addressed in the promulgation of the rules through the rulemaking process.

3.1 Proposed Licensing Procedures

In November 1978, NRC published a proposed General Statement of Policy outlining procedures for licensing geologic HLW repositories. This General Statement was followed by a proposed rule [44 Fed. Reg. 70408 (1979)] which contained procedural requirements for licensing. At that time, technical criteria for the LA were still under development; therefore, the proposed rule contains no specific mention of igneous activity. A general statement which encompasses igneous activity is provided in section 60.21(c)(1) [44 Fed. Reg. 70417 (1979)]: "the assessment shall contain an analysis of the geology, hydrology, geochemistry . . . of the site . . ."

In addition, the required type of exploration and testing to be conducted by DOE as a basis for construction authorization is discussed as a change in thinking from previously proposed policy. Under a 1978 proposed statement of policy, only surface exploration and a limited number of test borings were permitted [44 Fed. Reg. 70410 (1979)]. The proposed rule changed this to include exploration and *in-situ* testing at-depth. The reasoning behind this change was that surface testing would not provide a satisfactory basis for making the technical judgments necessary for construction authorization. Furthermore, staff analyses indicated testing at-depth would not be as (prohibitively) expensive as originally thought. The proposed rule states such exploration and testing at depth are needed [44 Fed. Reg. 70410 (1979)]:

" . . . not only to determine whether serious but not readily observed defects are present, but also to determine specific properties such as homogeneity, porosity, the extent of fracturing and jointing, and thermal response of the rock including expansion, fluid migration and decrepitation."

Thus, expanded testing and exploration were considered necessary to ensure that DOE obtained sufficient technical information to adequately characterize the extent to which adverse geologic conditions may be present. Igneous activity can be interpreted as one of these potentially adverse geologic conditions that may possibly be analyzed through expanded exploration efforts.

3.2 First Public Draft of Technical Criteria

The first public draft of 10 CFR Part 60 technical criteria (the *advance notice of proposed rulemaking*) [45 Fed. Reg. 31393] was published in 1980. Since the purpose of an advance notice is to

provide ideas from NRC for public consideration to facilitate development of the proposed rule, statements made do not represent specific regulatory policy *per se*, but provide a basis for those concepts and elements which have been maintained in subsequent stages of the rulemaking process.

The following portions of section 60.122 [45 Fed. Reg. 31401 (1980)] are considered pertinent to assessment of igneous activity (as well as other geologic conditions) for any site under consideration for a HLW repository. Certain conditions which represent potentially adverse effects on waste isolation, the potentially adverse conditions, are identified as particular issues of concern which require specific analysis by DOE:

*** §60.122 Siting Requirements**

(b) Potentially adverse conditions. The following paragraphs describe human activities or natural conditions which can adversely affect the stability of the repository site, increase the migration of radionuclides from the repository, or provide pathways to the accessible environment. The Department shall demonstrate whether any of the potentially adverse human activities or natural conditions are present . . . The presence of any of the potentially adverse human activities or natural conditions will give rise to a presumption that the geologic repository will not meet the performance objectives . . .

(2) Potentially adverse natural conditions — geologic and tectonic.

(vi) There is evidence of intrusive igneous activity since the start of the Quaternary Period.

(3) Potentially adverse natural conditions — hydrologic.

(iii) There is reasonable potential for natural phenomena such as landslides, subsidence, or volcanic activity to create large-scale impoundments that may affect the regional ground-water flow system.

(c) Favorable Characteristics. Each of the following characteristics represent conditions which enhance the ability of the geologic repository to meet the performance objectives . . .

(1)(i) The Department shall select the site so that to the extent practicable the candidate area exhibits demonstrable surface and subsurface geologic, geochemical, tectonic, and hydrologic stability since the beginning of the Quaternary Period."

In discussing these favorable and unfavorable site characteristics, NRC states in the preamble (also referred to as statements of consideration) of the draft technical criteria [45 Fed. Reg. 31397 (1980)]:

"Unfavorable site characteristics are identified to eliminate from consideration sites which would not be acceptable under any circumstances for a HLW geologic repository or which would present insuperable difficulties in terms of understanding the geology and hydrology of the site or would introduce or compound uncertainties

which would affect negatively confidence in any licensing decisions. Favorable site characteristics are identified where the likelihood of a site/facility combination (repository) being acceptable is greater or which would contribute to increased understanding of the geology and hydrology, permit uncertainties to be better handled, and increase confidence in any licensing decisions. However, neither kind of site suitability characteristics say anything about the ultimate acceptability of the repository system as a means to safely contain and isolate the wastes for the time required with the degree of confidence necessary fo[r] a licensing decision."

The preamble also mentions the need for criteria for site acceptability, however, generic criteria applicable to all sites had not been developed. Such criteria would eventually have to be developed for each site on a case-by-case basis. Therefore, while the potentially adverse conditions can aid in determining site unsuitability, specific criteria were not developed for determining suitability of a site.

Assessment of igneous activity at or near a repository site is dependent on modeling. The preamble to the draft technical criteria recognizes codification of models in the licensing process as a pertinent, yet controversial issue and provides the following discussion [45 Fed. Reg. 31397 (1980)]:

"The question of whether regulations should codify models to be used in licensing . . . or whether the criteria should only allow the use of models is a controversial one. In considering these questions the staff recognizes that it is necessary to:

- a) Use descriptions (models) of the behavior of geologic processes and of the repository and of the consequences associated with that behavior;
- b) Acknowledge that these descriptions are approximations to nature and as such introduce uncertainties into the process;
- c) Recognize that for the foreseeable future, the "old" models, in which there is the greatest confidence because of their "proven" use appear to be as qualitative as they are quantitative;
- d) Consider that the judgement of the appropriateness of these models for their intended purpose will be supported largely through expert opinion;
- e) Confront and explore fully these uncertainties and their ramifications including "uncertainties" arising from differences in expert opinion;
- f) Judge the acceptability of the consequences of events in the light of these uncertainties; and
- g) assure that the judgment itself will be detailed in the public record."

In further discussion on the codification of models [45 Fed. Reg. 31397 (1980)], NRC states:

". . . neither the process by which the technical criteria should be developed nor the process by which a licensing decision should be made should rely solely on quantitative calculations and assessments."

Hence, NRC staff recognized the need to use models which have inherent limitations for assessing behavior of natural systems and offered ways to use the information generated by such models. Emphasis is on the qualitative nature of the models, model use, and interpretation of results in light of current limitations. While statements in the preamble indicate quantitative modeling should be used to develop technical criteria for licensing decisions, where appropriate [45 Fed. Reg. 31398 (1980)], there is a recognition that circumstances will exist where the use of more qualitative forms of analysis is necessary and acceptable.

3.3 Final Procedural Rule

A final rule outlining the procedural requirements for licensing a HLW repository was published in 1981 [46 Fed. Reg. 13971] and did not impact the requirements or discuss issues related to assessment of igneous activity.

3.4 Proposed Technical Criteria

In 1981, NRC published proposed amendments [46 Fed. Reg. 35280] to 10 CFR Part 60. This action proposed adding technical criteria to the existing rule and considered both the draft technical criteria presented in the 1980 advanced notice of proposed rulemaking and comments received on that document. The preamble to the proposed amendments does not specifically address igneous activity *per se*; however, it discusses disruptive processes and events [46 Fed. Reg. 35281 (1981)] which could include magmatic or volcanic events. This section of the preamble states ". . . licensing decisions will be based, in part, on the results of analysis of the consequences of processes and events which potentially could disrupt a repository" [46 Fed. Reg. 35281 (1981)]. Furthermore, Subpart E of the proposed rule specifies "§60.123(a)(7) . . . volcanic activity of such a magnitude that large-scale surface water impoundments could be created . . ." and "§60.123(a)(11) Evidence of igneous activity since the start of the Quaternary Period" as potentially adverse conditions (PAC's) which, if present, could affect site suitability. The overall description of the proposed technical criteria in the preamble offers insight into the nature of analyses of repository features [46 Fed. Reg. 35284 (1981)] which can be interpreted to include the aforementioned PAC's:

"To enable the Commission [NRC] to reach a finding as to whether the generally applicable environmental standard . . . is met, . . . a careful and exhaustive analysis of all the features of the repository will be needed. That analysis necessarily must be both qualitative and quantitative although the analysis can and will be largely quantitative during the period that greatest reliance can be placed upon the engineered system. Thereafter, although the issues of concern, and certainly the physics of a repository itself, do not change, the numerical uncertainties begin to become so large that calculations become a weak indicator of expected repository performance."

This passage is considered applicable to assessment of igneous activity since it refers to all the features of the repository. Repository (i.e., geologic repository) is defined in 60.2 of the proposed rule to include the geologic setting. Since the time scale for consideration of igneous events is far greater than the period of reliance on the engineered system, and considerable uncertainties exist in long-term assessment of potential igneous activity, the passage is relevant and appears to imply a certain flexibility to include qualitative aspects of analysis in assessment of igneous activity in the geologic setting. The intent builds upon the statement noted in the advanced notice of proposed rulemaking (see Section 2.2)

which suggests use of qualitative analyses to develop technical criteria in light of current model and data limitations.

The following definitions which relate to assessment of igneous activity were included in the proposed rule (the terms geologic setting and site are defined identically):

"§60.2 Definitions:

'Geologic setting' or 'site' is the spatially distributed geologic, hydrologic, and geochemical systems that provide isolation of the radioactive waste . . .

"Site" means the geologic setting."

Subpart E of the proposed Technical Criteria [46 Fed. Reg. 35280 (1981)] contains section 60.122 which lists Favorable Conditions (FC), and sections 60.123 and 60.124 which were created for PAC's and assessment of PAC's, respectively. These provisions require certain assessments to be made with respect to the impact of igneous activity and volcanic events upon waste isolation. The proposal also allows for an adverse condition to be compensated by a combination of FC's and provides the option to the applicant to mitigate or remedy PACs. Applicable wording of the proposed technical criteria follows:

"§60.123 Potentially adverse conditions . . .

(a) Adverse conditions in the geologic setting . . .

(7) Potential for natural phenomena such as landslides, subsidence, or volcanic activity of such a magnitude that large-scale surface water impoundments could be created that could affect the performance of the geologic repository through changes in the regional groundwater flow.

(b) Adverse conditions in the disturbed zone. For the purpose of determining the presence of the following conditions within the disturbed zone, investigations should extend to the greater of either its calculated extent or a horizontal distance of 2 km from the limits of the underground facility, and from the surface to a depth of 500 meters below the limits of the repository excavation.

(11) Evidence of igneous activity since the start of the Quaternary Period.

(15) Processes that would reduce sorption, result in degradation of the rock strength, or adversely affect the performance of the engineered systems."

"§60.124 Assessment of potentially adverse conditions.

In order to show that a PAC or combination of conditions cited in §60.123 does not impair significantly the ability of the geologic repository to isolate the radioactive waste, the following must be demonstrated:

(a) The potentially adverse human activity or natural condition has been adequately characterized, including the extent to which the condition may be present and still be undetected taking into account the degree of resolution achieved by the investigations; and

(b) The effect of the potentially adverse human activity or natural condition on the geologic setting has been adequately evaluated using conservative analyses and assumptions, and the evaluation used is sensitive to the adverse human activity or natural condition; and

(c)(1) The potentially adverse human activity or natural condition is shown by analysis in paragraph (b) of this section not to affect significantly the ability of the geologic setting to isolate waste, or

(c)(2) The effect of the potentially adverse human activity or natural condition is compensated by the presence of a combination of the favorable characteristics cited in §60.122, or

(c)(3) The potentially adverse human activity or natural condition can be remedied."

In proposing the foregoing PAC's, NRC did not establish absolute criteria for the disqualification of a given site. Rather, as stated in the preamble, the proposed rule set out characteristics to be considered in the evaluation of the site [46 Fed. Reg. 35284 (1981)]:

"Thus, the Commission [NRC] has judged that these should not be made absolute requirements. Presence of all the favorable characteristics does not lead to the conclusion that the site is suitable to host a repository. Neither is the presumption of unsuitability because of the presence of an unfavorable characteristic incontrovertible. Rather, the NRC's approach requires a sufficient combination of conditions at the selected site to provide reasonable assurance that the performance objectives will be achieved."

3.5 Final Rule

In June of 1983, NRC published a final rule promulgating 10 CFR Part 60, including technical criteria and amended licensing procedures for a HLW repository [48 Fed. Reg. 28194]. This final rule responds to comments on the earlier proposed technical criteria [46 Fed. Reg. 35280 (1981)]. The preamble of the final rule discusses Anticipated Processes and Events and introduces the definition of Unanticipated Processes and Events [48 Fed. Reg. 28200 (1983)]. Both of these terms are applicable to igneous activity because they pertain to: "... natural processes and events affecting the geologic setting." Anticipated Processes and Events are defined as those: "... reasonably likely to occur during the period the intended performance objective must be achieved and from which the design bases for the engineered system are derived." Unanticipated Processes and Events are those judged: "... not to be reasonably likely to occur during the period the intended performance objective must be achieved, but which nevertheless are sufficiently credible to warrant consideration." The preamble further states:

"The Commission [NRC] intends that a judgment whether a natural process or event is anticipated or unanticipated be based upon a careful review of the geologic record. Such processes or events would not be anticipated unless they were reasonably likely, assuming that processes operating in the geologic setting during the Quaternary Period were to continue to operate but with the perturbations caused by the presence of emplaced waste superimposed thereon."

Furthermore, Unanticipated Processes and Events would include:

". . . processes and events which are not evidenced during the Quaternary Period or which, though evidenced during the Quaternary are not likely to occur during the relevant time frame. Identification of anticipated and unanticipated processes and events for a particular site will require considerable judgments and will not be amenable to accurate quantification, by statistical analysis, of their probability of occurrence."

Here, as in the proposed technical criteria [46 Fed. Reg. 35284 (1981)], there is an indication of a certain flexibility in identification of processes and events to allow for judgments to be made when accurate quantification is not possible.

Definitions for the words geologic setting and site were revised in the final rule [48 Fed. Reg. 28194 (1983)]. Furthermore, a definition of a controlled area was added in response to comments:

"§60.2 Definitions . . .

"'Controlled area' means a surface location . . . extending horizontally no more than 10 kilometers in any direction from the outer boundary of the underground facility, and the underlying subsurface, which area has been committed to use as a geologic repository and from which incompatible activities would be restricted following permanent closure . . .

"'Geologic setting' means the geologic, hydrologic, and geochemical systems of the region in which a geologic repository operations area is or may be located . . .

"'Site' means the location of the controlled area."

In the proposed rule [46 Fed. Reg. 35280 (1981)], the term geologic setting would have been limited to systems that provide isolation of the waste. NRC intended the adopted definition of geologic setting to cover a wider region of interest [48 Fed. Reg. 28202 (1983)]. The final rule calls for isolation to be provided within a controlled area rather than within the geologic setting [48 Fed. Reg. 28202 (1983)]. As a result, the definition of site, which had previously been defined as the geologic setting was changed to refer to the controlled area.

NRC states in the preamble to the final rule that changes to the proposed rule regarding Siting Criteria were made in order to clarify their purpose [48 Fed. Reg. 28201 (1983)]. No significant changes were made to the language of 60.122(c)(3) and 60.122(c)(15) — the texts of PAC's which specifically address volcanic and igneous activity, respectively. The concepts of FC's and PAC's were retained. Furthermore, it was emphasized there may exist a combination of PAC's and FC's which would be

acceptable for a repository site. Significant changes were made to adopt the updated definitions of geologic setting, site, and disturbed zone. In addition to merging sections 60.122, 60.123, and 60.124 into section 60.122, the final rule changed the siting criteria: "the presence of any of the enumerated conditions is to be regarded as potentially adverse if it applies to the controlled area. Furthermore, such a condition outside the controlled area is also to be regarded as potentially adverse if it may affect isolation within the controlled area." In turn, the final rule contains a provision which states PAC's may be compensated by the presence of FC's. NRC has included therein the standard for measuring the adequacy of such compensation — achievement of the performance objectives relating to isolation of waste. Portions of the rule relevant to this discussion include:

"§60.122 Siting Criteria . . .

(a)(2) If any of the potentially adverse conditions specified in paragraph (c) of this section is present, it may compromise the ability of the geologic repository to meet the performance objectives relating to isolation of the waste. In order to show that a potentially adverse condition does not so compromise the performance of the geologic repository the following must be demonstrated:

(a)(2)(i) The potentially adverse human activity or natural condition has been adequately investigated, including the extent to which the condition may be present and still be undetected taking into account the degree of resolution achieved by the investigations; and

(a)(2)(ii) The effect of the potentially adverse human activity or natural condition on the site has been adequately evaluated using analyses which are sensitive to the potentially adverse human activity or natural condition and assumptions which are not likely to underestimate its effect; and

(a)(2)(iii)(A) The potentially adverse human activity or natural condition is shown by analysis pursuant to paragraph (a)(2)(ii) of this section not to affect significantly the ability of the geologic repository to meet the performance objectives relating to isolation of the waste, or

(a)(2)(iii)(B) The effect of the potentially adverse human activity or natural condition is compensated by the presence of a combination of the favorable characteristics so that the performance objectives relating to isolation of the waste are met, or

(a)(2)(iii)(C) The potentially adverse human activity or natural condition can be remedied.

(b) Favorable conditions

(b)(1) The nature and rates of tectonic, hydrogeologic, geochemical, and geomorphic processes (or any of such processes) operating within the geologic setting during the Quaternary Period, when projected, would not affect or would favorably affect the ability of the geologic repository to isolate the waste.

(b)(3) Geochemical conditions that —

- (b)(3)(i) Promote precipitation or sorption of radionuclides;
 - (b)(3)(ii) Inhibit the formation of particulates, colloids, and inorganic and organic complexes that increase the mobility of radionuclides; or
 - (b)(3)(iii) Inhibit the transport of radionuclides by particulates, colloids, and complexes.
- (b)(4) Mineral assemblages that, when subjected to anticipated thermal loading, will remain unaltered or alter to mineral assemblages having equal or increased capacity to inhibit radionuclide migration.
- (c) Potentially adverse conditions. The following conditions are potentially adverse conditions if they are characteristic of the controlled area or may affect isolation within the controlled area . . .
- (c)(3) Potential for natural phenomena such as landslides, subsidence, or volcanic activity of such a magnitude that large-scale surface water impoundments could be created that could change the regional groundwater flow system and thereby adversely affect the performance of the geologic repository.
 - (c)(5) Potential for changes in hydrologic conditions that would affect the migration of radionuclides to the accessible environment, such as changes in hydraulic gradient, average interstitial velocity, storage coefficient, hydraulic conductivity, natural recharge, potentiometric levels, and discharge points.
 - (c)(7) Groundwater conditions in the host rock, including chemical composition, high ionic strength or ranges of Eh-pH, that could increase the solubility or chemical reactivity of the engineered barrier system.
 - (c)(8) Geochemical processes that would reduce sorption of radionuclides, result in degradation of the rock strength, or adversely affect the performance of the engineered barrier system.
 - (c)(15) Evidence of igneous activity since the start of the Quaternary Period.
 - (c)(24) Potential for the movement of radionuclides in a gaseous state through air-filled pore spaces of an unsaturated geologic medium to the accessible environment."

The FC's stated above are considered relevant to this discussion for the following reasons. It is conceivable that igneous activity may alter geochemical conditions and produce the benefits specified under 10 CFR 60.122(b)(3)(i), (ii), and (iii) through hydrothermal effects on rock and groundwater chemistry. In connection with mineral assemblages, hydrothermal effects from igneous activity may favorably affect their capacity to inhibit radionuclide migration.

In addition to the PAC's related directly to igneous activity [10 CFR 60.122(c)(3) and (15)], other PACs [10 CFR 60.122(c)(5), (7), (8), and (24)] are also considered relevant to this discussion. The latter group of PAC's may be equated, respectively, with possibly adverse effects resulting from volcanic,

magmatic, or related hydrothermal activity on hydrologic conditions, groundwater conditions in the host rock, geochemical processes, and gaseous state radionuclide movement as specified in the conditions.

3.6 Staff Analysis of Public Comments on Proposed Rule and Supplementary Information Section of 1983 Final Rule

NRC received 93 comment letters in response to the July 1981, publication of the proposed technical criteria [see 46 Fed. Reg. 35280 (1981)], 89 of which arrived in time to be considered for the final criteria. An extensive search of NUREG-0804 found no comments or responses which specifically addressed igneous activity.

3.7 Proposed Amendments to Rule

In 1986, NRC issued a list of proposed amendments to 10 CFR Part 60 [51 Fed. Reg. 22288] which were intended to conform existing NRC regulations to environmental standards published by the Environmental Protection Agency (EPA) [50 Fed. Reg. 38066 (1985)]. NRC found that EPA sometimes used terms differently from existing Part 60 wording. Most of the proposed amendments in this document reflect attempts to reconcile wording differences. This rulemaking has not been completed or withdrawn, in part due to litigation and remand of the EPA rule (40 CFR Part 191). It is anticipated that EPA's standard will be repropoed and finalized prior to the completion of this rulemaking action.

The preamble to the proposed rule [51 Fed. Reg. 22295 (1986)] mentions NRC had recently defined [50 Fed. Reg. 29641 (1985)] the term groundwater for Part 60 to include all water which occurs below the land surface. In contrast, EPA standards use the term to mean water below the land surface in a zone of saturation. These differences, however, were considered to have no effect on applying the EPA standards to NRC-licensed geologic repositories. This information was deemed applicable to the focus of this paper since the term groundwater is used in 60.122(c)(3). No other material relating to igneous activity was identified in the proposed amendments to the rule.

3.8 Update to Final Rule

In 1989, NRC published a final rule updating Part 60 [54 Fed. Reg. 27864] to adopt: "procedures for implementation of the National Environmental Policy Act." These changes involved a requirement for inclusion of an environmental impact statement in the application and some changes for filing and distribution of an application. This rulemaking did not affect provisions involving igneous activity.

4 CONCLUSIONS

NRC rules governing HLW repositories include requirements which are related to igneous (volcanic and magmatic) activity since the presence of such a condition could result in disturbance of the repository and possibly compromise waste isolation. As a result, igneous activity at a repository site must be evaluated when assessing repository performance. A review of the statutory basis and regulatory history relative to igneous activity provides useful insight to nature and intent of the current regulatory requirements. The statutory history elucidates the basis for NRC authority to regulate nuclear waste disposal and develop such technical criteria for selection of repository sites. The regulatory history provides insight into the character of analyses to be conducted with respect to such potentially adverse conditions of the geologic setting. Most of the historical discussion on record broadly focuses on the Siting Criteria, and how assessments should be considered to support a licensing decision. NRC has (unofficially) recognized that quantitative and qualitative analyses will have to be conducted to determine the presence and assess consequences of conditions, processes, and events which could affect performance of the site. While some modifications have been made to the Siting Criteria since the initial proposed rule, the fundamental concepts have been maintained in the final rule. The specific requirements regarding the need to assess volcanic events and igneous activity as potentially adverse conditions have not changed significantly since they were introduced in 1981.

5 REFERENCES

- 10 CFR 60** (U.S. Code of Federal Regulations), "Disposal of High-Level Radioactive Wastes in Geologic Repositories," Part 60, Chapter I, Title 10, "Energy."
- 40 CFR 191** (U.S. Code of Federal Regulations). "Environmental and Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel, High-Level, and Transuranic Radioactive Wastes." Part 191, Chapter I, Title 40, "Protection of Environment."