NEVADA NUCLEAR WASTE PROJECT OFFICE COMMENTS

ON

DRAFT GENERIC TECHNICAL POSITION

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"INTERPRETATION AND IDENTIFICATION OF THE DISTURBED ZONE IN THE HIGH LEVEL WASTE RULE (10 CFR 60)."

NRC

JUNE 20, 1986

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CONTENTS

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1. INTRODUCTION

The Nuclear Regulatory Commission (NRC) has drafted guidance intending to clarify the definition of the "disturbed zone". The outer surface of this zone is used as a starting point for the calculation of the 1000-year Ground Water Travel Time (GWTT) criteria in the NRC Rule [10 CFR 60.113 (a) (2)]. The calculation for GWTT is taken from the outer edge of the disturbed zone rather than from the edge of the underground excavations. The reason for this convention is that the effects from heat and excavations may make predictions of near-field performance of the geologic barrier difficult. The GWTT criteria is supposed to be a measure of the natural, unperturbed geologic system. The definition of the "disturbed zone" in the rule reads:

> "that portion of the controlled area the physical or chemical properties of which have changed as a result of underground facility construction or as a result of heat generated by the emplaced radioactive wastes such that the resultant change of properties may have a significant effect on the performance of the geologic repository."

In the subject draft Generic Technical Position (DGTP), requests for further guidance on the definition of the disturbed zone are cited. For example, CHU (et al. 1983) call for an unambiguous determination of the extent of the disturbed zone. It is apparent in that study what the authors are really calling for is a definition, perhaps even with numerical values, of the term "significant effect" within the disturbed zone terminology.

The usefulness and adequacy of this DGTP is therefore dependant on the degree to which it defines what the NRC considers "significant" in terms of affecting repository performance.

2. AREAS OF CONCERN

2.1 Redefinition of Disturbed Zone.

In defining the disturbed zone, the DGTP explicitly states that the effects of buoyancy (ground water flow in response to temperature gradients) should not be considered in the determination of the extent on the disturbed zone. The DGTP correctly states that this convention is in keeping with the intent of the proposed rule (10 CFR 60, 51 FR 22295, June 19, 1986). While this is true, it must be noted that such a definition is not in keeping with the existing rule.

It is clear the NRC did intend to include the buoyancy affected zone in the disturbed zone in 1983 when 10 CFR 60 was promulgated. This is evident from at least three (3) sources as follows:

1) Federal Register Notice (48 FR 28210) June 21, 1983, which states in the supplementary information:

> "Some commenters suggested that the groundwater travel time be expressed in terms of post-emplacement as well as pre-emplacement conditions. This assumes that post-emplacement changes would be significant. By definition, however, the portion of the geologic setting significantly affected by waste emplacement constitutes the "disturbed zone."The groundwater travel time provision applies to transport from the disturbed zone to the accessible environment. This parameter is not dependent upon the effects of waste emplacement."

This quote, particularly the last sentence, makes it clear that the GWTT parameter was intended to reflect post-emplacement conditions and therefore must be evaluated outside the area affected by heat. This mandates the disturbed zone encompass the zone of thermal buoyancy of ground water.

2) The definition of disturbed zone in the existing rule (10 CFR 60) as quoted above in the introduction.

The definition does not distinguish between properties of the rock media and the included fluids. A geologic repository, by definition, includes the portion of the geologic setting important to isolation. The geologic setting includes the hydrologic system, which is indeed important to isolation. the fact that repository performance is considered also implies the fluid changes must be considered. For example, temperature increases in the fluid cause changes in fluid density and viscosity, thereby increasing hydraulic conductivity. Small increases in hydraulic conductivity can significantly increase release rates from a repository (when solubility dependence is assumed), and therefore is significant to repository performance. Density changes will also produce buoyancy effects, thereby altering flow direction.

3) Additional evidences indicating the NRC originally envisioned a disturbed zone on the scale of kilometers (rather than meters as in the subject DGTP) appear in Section 60.123(b) of the 1981 proposed rule (Federal Register notice of July 8, 1981). This section reads:

> "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."

Outward distances of this magnitude are of the order roughly equivalent to the outer extent of buoyant effects.

The NRC is clearly changing the intent of the rule, however, it is equally clear that NRC is trying not to admit it. The following quote from June 19, 1986 Federal Register notice (51 FR 22295) regarding the proposed rule change reads:

> "One potential type of effect which could alter local ground water flow conditions is thermal buoyancy of ground water. Because buoyancy effects could extend over significant distances (see, e.g., M. Gordon and M.Weber, "Non-isothermal Flow Modeling of the Hanford Site," available in the NRC Public document room) and because the Commission is proposing to reduce the maximum allowable distance to the accessible environment, it is particularly important to emphasize that the Commission did not intend such effects to serve as the basis for defining the extent of the disturbed zone. The Commission recognizes that such effects can be modeled with well developed assessment methods, and therefore were not the type of effects for which the disturbed zone concept was developed. Any contrary implication in our statement of considerations at the time the technical criteria were issued in final form (see 48 FR 28210) should be disregarded."

In the above quote, NRC is justifying the change in the intent of the disturbed zone because 1) the accessible environment is now limited to no more than 5 kilometers from the underground workings and 2) thermal induced ground water flow can now be adequately modeled. It is very doubtful that the scientific community would agree that coupled water/heat flow modeling has been advanced to the point where it could be defended technically in a licensing procedure. Of particular question is the adequacy of input data and data collection techniques for such a sophisticated modeling. The first reason, a nearer accessible environment, is totally inappropriate. It appears that the NRC is concerned that marginally-acceptable sites (those that might qualify under the GWTT requirement with a 10 km distance to the accessible environment, but not under a 5 km distance) may not be licensable.

The NRC should not change the rules of the game unless it is willing to explicitly acknowledge the change and go through the necessary steps to make such a rule change.

It is very important to point out that by not including buoyancy effects in the disturbed zone, the licenseability of a given site may be greatly impacted. An intrinsically good site would not be greatly affected, however marginal sites would, under the new intent of the rule, be much easier to license under the GWTT requirement. The two sites in fractured volcanic rock terranes may well fall under this category of marginal sites.

2.2 Stress redistribution.

The generic relationship presented in the DGTP of stress re-distribution to changes in permeability and porosity appears to be a reasonable approach. It clearly defines the extent of the zone of significant changes in hydraulic properties to be equal to that of any finite stress redistribution. The supporting information suggesting 50 meters as a adequately conservative estimate of the disturbed zone resulting from stress redistribution is well documented and persuasive. We note that this value of 50 meters is not supported for the salt sites.

This section of the subject DGTP addresses the effects of large openings such as access drifts. It fails to mention the effects of the thousands of rock bolts that will be installed to aid in roof control. It further neglects to discuss vertical canister emplacement versus horizontal emplacement which would seem to be important in estimating the dimensions of the disturbed zone.

The issue of interaction of existing stress fields and the excavation of the repository is not discussed, but should be. Measurements in boreholes USW-G1 and USW-G2 clearly show a stress field of tectonic origin at the Yucca Mountain site. (Healy, et al, 1984; Stock, et al, 1984; Springer, et al,1984).

The section should also discuss the effects of backfilling or not backfilling the repository. Backfilling is mentioned for the Deaf Smith and Hanford sites. However, no backfilling is planned for the Yucca Mountain site and the disturbed zone could increase significantly within a few hundred years and may even reach the surface.

While the section does mention that the anisotropy of the rock has a significant effect on stress distribution, this point should be emphasized by pointing out the experience observed at the WIPP site. There, large horizontal cracks 2 inches high have been observed in the marker bed beneath the repository floor. These cracks have necessitated a re-evaluation of the shaft sealing program.

2.3 Construction and Excavation

As is the case for stress redistribution, the DGTP appears to offer no guidance for the salt sites in defining the extent of the disturbed zone due to construction and excavation of the underground workings.

On page 12, paragraph 1, the statement is made: "The extent of porosity and permeability changes caused by dewatering of the facility should also be considered on a site-specific basis." It appears that this statement concerns the sites in saturated zones. At Yucca Mountain, in an unsaturated zone, similar concerns should be addressed, but for different reasons. During excavation it is possible that large amounts of water will be used for dust control and roadway maintenance. This could lead to the addition of considerable water to the saturated zone below.

It is important that the extent and dimensions of the disturbed zone be regarded as flexible during construction and excavation. Underground development projects seldom are completed without revision of the plans and layout due to unanticipated conditions (faults, roof control problems, etc.) encountered during development underground. Early GWTT based on design layouts of the facilities could be flawed as the actual configuration of the repository changes.

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2.4 Thermomechanical Effects

As stated above, the DGTP clearly excludes thermal effects on fluids as part of the definition of the "disturbed zone", stating that these will be treated during assessment of compliance with the overall system standard (10 CFR 60.112). We assume that this exception also includes phase changes in fluids, yet we anticipate these to have significant impact in the Yucca Mountain vadose environment. Phase changes in fluids and associated moisture redistribution as the result of the phase change should be explicitly addressed within the technical position, because such changes will occur in the vadose zone and will constitute the "disturbed zone" as originally defined.

We believe, however, that even with the simplifying exclusion of fluid responses to thermal effects, the objective "...establishment of generic and easily evaluated guidance on the disturbed zone is desirable in order to allow for the demonstration of compliance with the groundwater travel time criterion (10 CFR 60.113(a)(2)) consistent with NRC's intent in the criterion..." (DGTP, page 16) will not be realized without additional guidance and specific (if arbitrary) definitions of the word <u>substantial.</u> Even with such a definition, considerable additional characterization effort will be required to confidently judge the thermal impacts on the rock properties within the thermal envelope produced by the waste at the Yucca Mountain site.

Before the DGTP definition of the "disturbed zone" can be applied to the Yucca Mountain site, the thermal history envelopes for the site need to be accurately established. Figure 1 is a site specific thermal envelope model developed for Yucca Mountain for 14.2 W/m^2 spent fuel (SF) with a repository midplane at 390 m (Braaithwaite and Nimick, 1984, page 10).* Commercial high-level waste (CHLW) not considered in this example, would produce higher peak temperatures in a shorter time frame give identical initial thermal loadings. Based on the EA (DOE, 1986) the average depth to the repository horizon will likely be between 250 and 300 m below land surface (see Figure 6-19, EA Pg 6-248).

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* It should be noted that the source document for these thermal envelope studies (Svalstad, 1984) is not referencable, <u>i</u>.<u>e</u>. Sandia National Laboratory (SNL) has not reviewed it for external distribution. Details of parameter estimation, boundary conditions, and key assumptions used in constructing the predicted Yucca Mountain thermal envelopes, all of which constitute baseline information for mineral stability studies, must therefore be considered speculative.

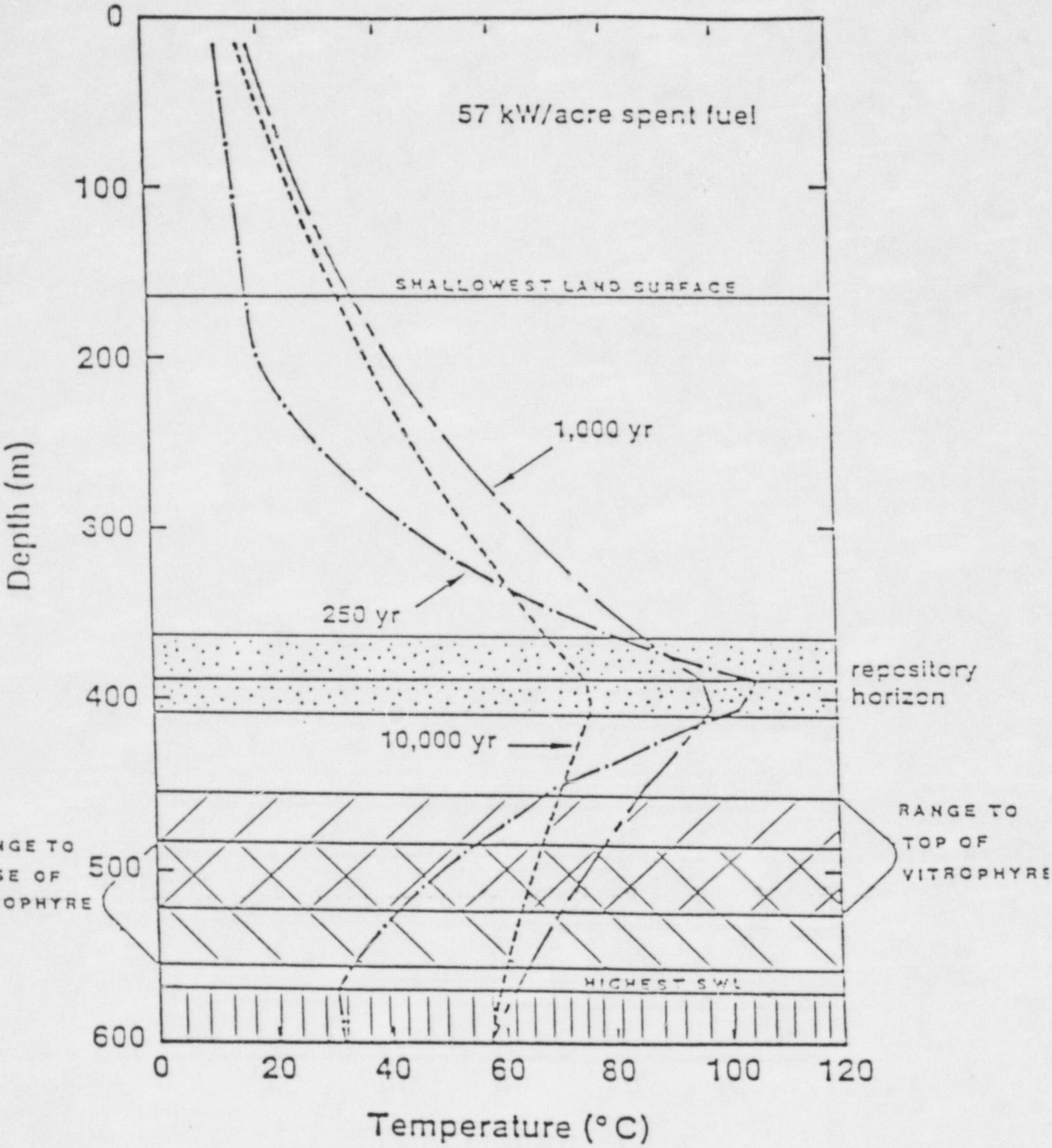

FIGURE 1

Temperature distribution for a proposed repository at Yucca Mountain containing 57 kW/acre spent fuel. The repository horizon is at 390 meters.

Modified after Braithwaite and Nimick, 1984.

We have added to Figure 1 (which depicts the **maximum** overburden scenario) the position of the repository zone and the range in position of the basal vitrophyre of the Topopah Spring Member. Also, the relative ranges in position of the landsurface and the water table with respect to the repository horizon have been indicated. It is important to note that the figure at best represents uncertain approximations in terms of accurately determined envelopes and relative positions of the important features such as land surface, water table, and basal vitrophyre. The thermal envelopes neglect the effects of convective transport of heat via vapor and water transport in fractures, as well as the more complex issue of possible heat sinks and sources triggered by endothermic and exothermic mineral alteration reactions that may occur due to the thermal envelope and migrating steam and hot water. We emphasize that no site-specific, referencable predictions of convective heat flow are available for Yucca Mountain; a highly preliminary study by Lawrence Berkeley Laboratory (LBL) is being reviewed by Sandia National Laboratory (SNL) at the time of this writing (September, 1986), and is not available for external review or comment.

Our objective in presenting Figure 1 is to lend perspective to the problem of establishing the boundary of the disturbed zone as proposed by the DGTP definition. We anticipate at least 30° C rise in temperature down to the water table in some areas , and major impact on the basal vitrophyre, with temperatures up to 80° C or more. In some areas, it seems likely that 40 to 50° C temperatures will occur at or near land surface if convective heat transport occurs and CHLW constitutes a supplementary waste form.

The following statement is made in Appendix A, page 20: "Based on this equation, the intrinsic properties of the geologic setting which are anticipated to directly affect groundwater flow for fractured and porous media include only the intrinsic permeability and effective porosity of the geologic medium." The effective porosity as defined in Appendix A is not consistent with the definition in the DGTP on groundwater travel time. Also, in the unsaturated zone at the Yucca Mountain site, the groundwater flow is also affected by the degree of saturation or the the pressure head (E.A. Klavetter, et al, 1986). The DOE has theoretized that above a flux of 1 mm/yr water flows primarily in the fractures and below 1mm/yr the flow is entirely in the porous media (S. Sinnock, et al, 1984). The NRC should address the validity of this hypothesis.

2.5 Thermochemical Effects

The following examples are factors that affect the complexity of determining the "disturbed zone" boundary at Yucca Mountain:

a. Bish and Semarge (1982) state that clinoptilolite and mordenite are not stable over 80-100o C in Yucca Mountain tuffs. Iijima and Utada (1971) have studied the Niigata Oil Field in Japan which contains buried authigenic facies through zeolite-metamorphic facies mineral associations. Temperatures at the top of the mordenite and clinoptilolite zone are 41-49o C, and at the analcime-albite transition, they are 120-124o C. The alkali clinoptilolite stability zone appears to range from 55-91o C and the calcite-clinoptilolite appears to be stable at 84-91o C. If for argument's sake, we ignore the aqueous chemistry (not necessarily a conservative approach), zeolite stability for at least clinoptilolite might be safely placed as Bish and Semarge (1982) did, that is between 80-100o C. The term "stability", however, needs to be defined as mineral stability does not reflect the loss of adsorbed water.

b. It has been shown be various students of zeolite that Na and K concentrates in the aqueous media greatly affect the zeolite temperature stability field by reducing the stability of the zeolite below calculated and/or observed zeolite stability temperatures.

c. Zeolite stability may be viewed as its endothermic reaction temperature, which liberates water; its exothermic reaction temperature which condenses its structure and causes mineral transformation. In the light of Differential Thermal Analysis (DTA) on clinoptilolite, it is reasonable to presume that temperatures above its formational temperature will yield endothermic water loss. Whether or not this loss of water is accompanied by cation escape (from the super-cage) is unknown, as there is a paucity of data on this subject.

d. The transformation of clinoptilolite to analcime has been studied by Boles and Wise (1977) and Boles (1977). They report the reaction of deep-sea clinoptilolite to analcime as follows:

$$4.4\ Na^{+} + \text{Clinoptilolite} = 6.8\ \text{analcime} + 3K^{+} + 0.3\ Ca^{++} + 0.4\ Mg^{++} + 15.6\ SiO_2 + 13.2\ H_2O$$

where: clinoptilolite composition is:
$Na_{2.40}K_{3.00}Ca_{0.30}Mg_{0.40}Al_{6.80}Si_{29.20}O_{72} \cdot 20H_2O$

and analcime composition is:
$NaAlSi_3O_3 \cdot H_2O$

In addition to pressure and temperature controls, the above reaction would be dependent upon sodium and to a lesser extent other cation and water activities. Gieskes (1976, Table 1) cited in Boles (1977) indicates that sediments sharing the clinoptilolite to analcime reaction have pore fluids with molar Na/K ratios of about 160; whereas clinoptilolite-bearing sediments show average molar Na/K ratios of about 60. Consequently, the presence of analcime may be due to high Na/K ratios.

If vadose water evolved from mineral dehydration (such as smectites) were to trend towards relatively high Na/K ratios the transformation of clinoptilolite to analcime might occur even though the temperature regime of the zone(s) of transformation might be below the 120° C Stage 4 (Iijima and Utada, 1971). This reaction would (on the basis of Boles, 1971, calculation above) evolve significant quantities of water and SiO_2 and could also be responsible for a vital change in overall porosity and/or permeability.

2.6 Hydration and Dehydration

a. Smectites contain both adsorbed water (as interlayer water between lattice sheets) and high-temperature water (as OH^-) which is an essential portion of the crystal lattice structure. Dehydration curves for montmorillonite are s-shaped. Variations are dependent upon Na, H, and Ca-montmorillonite structures more stable than Ca. Adsorbed water loss is usually indicated below 150-200° C with a flattening of the curve between this and 300° C where high-temperature water is generally evolved and structural transformation is indicated.

Any temperatures above formational ambient temperature should provide adsorbed water loss until curve flattening temperatures are reached at 150-300° C. This water loss may be accompanied by cation-loss where the cations are in exchange interlayer sites. Na-bentonites may swell to 8-10 times their original volume upon hydration; comparable volumetric decreases accompany dehydration. Thus, in fluctuating temperature regimes, smectites may act as water (and cation) pumps adsorbing and releasing these constituents depending upon temperature fluctuations.

Since the smectites can accommodate more adsorbed water than the zeolite, they are apparently more sensitive to temperature changes (under 80° C), loss of adsorbed water and cations can be responsible for producing fluids which may lower the effective zeolite stability temperatures. Additionally, porosity, permeability, and hydrofracturing effects may be greatly enhanced by changes in the hydration structure of the smectite minerals.

b. Perry and Hower (1972) have developed a four stage model for dehydration in deeply buried pelitic sediments based upon smectite and mixed-layered clay associations. Above 80° C (1972, figure 7) they show significant changes in clay stability and mineral associations. These changes may also be somewhat dependent upon aqueous chemistry and burial pressure.

c. Jackson (1956, page 266, figure 5-3) shows a Differential Thermal Analysis (DTA) curve for montmorillonite from 0 to 1,000° C. There are two major endothermic peaks between 0-240° C and 550-700° C indicating water loss. The first peak has a rapid water loss from 0-25° C, a significant water loss from 25 to 100° C and thereafter a sharper decline to about 160° C which is the maximum of the peak. This indicates that there is a significant water loss immediately upon heating. The rate of water loss upon heating at low temperatures (from 0-100° C) will be partially dependent upon isomorphous substitution in the octahedral layer of the montmorillonite (as indicated by Jackson, 1956, page 295). Consequently, the thermal behavior of the smectites at Yucca Mountain will be in part a function their composition; therefore, detailed field data are required prior to attempting to determine the implications of dehydration due to repository heating.

d. Porrenga (1967) has found that for montmorillonites that there is a tendency for Ca and Na in montmorillonite to be replaced by Mg. This exchange of Mg for Na and Ca is extremely important to the evolution of vadose water chemistry and therefore on zeolite stability at elevated temperatures.

e. "Surdam and Boles (1977) calculated that the hydration of andesine to laumontite in a sandstone with a density of 2.3 g/cc, to 40% andesine, and an initial temperature of 60° C at 1.5 km burial would raise the temperature of the rock by 40° C if the heat of the reaction is conserved." (Boles, 1977b).

Boles (1977(b), page 129, states that "Zeolitization of volcanic glass should also evolve heat." Consequently, authigenic reactions, which might take place within the disturbed zone as a consequence of repository heating, may also be influenced by the heat-of-reaction produced during diagenetic hydration and this heat evolved may be outside as well as inside the defined "disturbed zone" boundary.

If this is a factor to be considered, then the temperature distribution envelope for a repository must not only take into account the repository heating, but also, heat evolved due to authigenic reactions which may be beyond the near-field. The heat of reaction temperatures as postulated by Surdam and Boles (1977) are almost as significant as the repository heating itself if those reactions proceed in demonstrably rapid fashion.

f. Friedman, <u>et al</u>., (1966) have determined the rate of obsidian (rhyolitic glass) hydration in terrigenous environments exposed to humidity and ground water. Rates determined are not intrinsic and are based upon Fick's Law of Diffusion with experimental evidence derived at 100° C. During the diagenetic transformation of obsidian to perlite (hydrated glass) the rates are approximately five times faster at 100° C than at 70° C, and about one order of magnitude faster at 70° C than at 30° C. Consequently, the hydration rate has been shown to be temperature dependent. Perlite further hydrates to transition metal oxhydroxides, zeolite, and smectites. The rates of formation of this phase of authigenics is unknown. Other significant controlling parameters relating to the hydration of glass are the alkalinity of both the glass and surrounding fluids, bonding chemistry of the glass, initial water (HOH and OH) composition of the glass, among other parameters (which are less significant). Although it has been shown that diffusivities of glass are related to it viscosity which is a function of the original state of polymerization of the melt (Scholze, 1966; Stopler, 1982) it has also been documented that hydration rates are dependent upon the activity of dissolved alkali metals in the environment. Consequently, glass hydration becomes an effective and rapid mass transition process during elevated temperatures in the presence of high concentrations of dissolved alkali metals.

Hydration proceeds along any exposed glass surfaces, causing increases in volume. Many of the glasses respond to volume by increases in tensile fracturing, geometrically providing additional surfaces for hydration. The resultant configuration of the alteration mass is a reticulate pattern of interconnected fractures with expandable and exchangeable authigenic mineral fracture coatings and fillings. Glass vesicles previously segregated from the exposed environment are either filled with authigenic minerals or are associated with fracture surfaces. The permeability is significantly increased even when total porosity changes are negligible due to the relatively small effective porosity of the fractures.

At Yucca Mountain, a vitrophyre is present between 45 and 113 meters below the repository horizon and partly within the 50 meter minimum "disturbed zone". Temperature elevation above geothermal-ambience in the presence of high humidity will provide adequate conditions to promote glass hydration. Under these conditions "significant amounts of water" might be construed as 80-100% humidity (not necessarily a situation of liquid saturation).

g. The diffusion mechanism of water entering glass and other solids is poorly understood in fractured media. Although, diffusion appears to follow Fisk's Law, when single surfaces are present, it appears that it is anomalous in behavior in fractured media (Anacker and Kopelman, 1984). Consequently, rates of diffusion require empirical observations especially when these reactions may affect obtaining accurate "disturbed zone" boundaries.

h. Knauss, et al., (1985, Tables 1 and 2) show a significant increase in dissolved alkali metals in water reacted with crushed tuff during short term experiment (an increase of sodium of about 25% at 90^{o} C in less that 80 days). At this temperature, which is about 7^{o} C higher that the calculated maximum vitrophyre temperature at 1,000 years (fig. 1)what would the increase be for sodium in 250 to 1,000 years? And how might this contribute towards driving various reactions whose ultimate result would be a significant increase in permeability?

In addition to the dissolved alkali metals, Knauss, et al., (1985) show a decrease in pH which would aid in promoting dissolution of glass and other silicate minerals.

2.7 Silica Dissolution

It is stated in the DGTP (Appendix B, page 15, paragraph 2) that generic calculations presented in Appendix B indicate that silica dissolution and resultant porosity increase are not expected to be significant beyond the mechanically "disturbed zone". It is also recognized that the distance to the edge of the thermochemically "disturbed zone" is strongly dependent on the thermal loading of the repository and the ground-water flux in the host rock. The following paragraphs offer specific comments on the treatment of silica dissolution in the thermochemically "disturbed zone" present ed in Appendix B.

Heat Transfer Model:

Codell's analysis of silica dissolution is intended to address 'typical to conservative' conditions expected near HLW repositories. However, the assumption that convective heat transfer by flowing ground water is negligible (DGTP, 1986, page B2) is certainly not conservative in our opinion, and the basis for this assumption is contained in an unpublished memorandum. The statement that effects of phase changes are expected to be negligible (DGTP, page B2) should be supported by mineralogical data.

Two errors in the thermal data are noted: on page B3 the units for heat capacity of rock, Cp, which should be $J/(m^3 {}^oC)$ are incorrectly given as $J(m^3 {}^oC)$. On page B8, the geothermal gradient, which is on the order of 20^o C to 30^o C per 1,000 m (Turcotte and Schubert, 1982), is incorrectly given as "on the order of 5 C per 1,000 m " and neglected on this basis.

Transport Model:

The transport model is unconvincing, because of the following: choice of the conceptual model based on total silica in the rock rather than a surface area to fluid volume ratio; the exclusion of convective heat transport, although convective solute transport is treated explicitly; the exclusion of geothermal gradient from the analysis; and the exclusion of kinetic effects. The rate of silica dissolution is fast on a geologic time scale, but should be considered on the time scale (1,000 years) of the heating of a repository and vicinity. An important aspect that effects silica kinetics is the solid-surface area to fluid mass ratio. Higher surface areas to fluid mass ratio yield faster dissolution rates, and therefore, a quicker approach to equilibrium.

This ratio varies widely for different porosity models.

Dissolution rates of silica are also affected by flow velocity. Faster moving water has less time to equilibrate with rock and less material is dissolved. Thus, marked differences in dissolution rates of silica would be expected between matrix flow and fracture flow, if fracture flow velocities are relatively high.

The inclusion of kinetic effects will result in a smaller amount of silica dissolution than the equilibrium model. However, the distribution of the dissolution sites may be somewhat different. Codell's model indicates "that silica dissolution is greatest where the temperature gradient is steepest". (Codell, 1986, page B9). Areas of the repository with the steepest temperature gradients are likely to have the shortest residence time for aqueous fluids and thus little resulting dissolution. The maximum amount of dissolution may ensue when the thermal envelope around the repository is fully developed and the fluid has the longest residence time to approach equilibrium with the rock. This could be in a halo of saturated fractures beyond the zone of vaporization of water. Dissolution will then be maximized in the hottest areas.

In summary, other porosity models need to be considered, and kinetic affects of silica dissolution need to be considered if flow rates are expected to be significant.

A sign error is present in Table B2: the b-coefficient for quartz should be -2.028×10^{-3} (Rimstidt and Barnes, 1980).

3. SUMMARY

The summary section of the DGTP appropriately estimates the extent of the mechanically disturbed zone at 50 meters from the excavated opening. The extent of the thermochemically disturbed zone however is not estimated. Instead, the DGTP states that it should be determined on a site-specific basis.

The statement of technical position, the crux of the document, over-reaches its supporting information in its conclusion that the disturbed zone is likely to be less than 50 meters. A caveat, much like that in the summary section concerning the unknown extent of thermochemical effects, should be included in the statement of technical position. Until processes such as thermally-induced hydration, dehydration and dissolution (other than for silica) are adequately considered in the GTP, it cannot be considered acceptable. The DGTP is particularly deficient in providing guidance for the salt sites. Furthermore, some numerical examples should be provided to demonstrate what NRC considers "significant" in terms of changes in porosity and permeability.

Finally, NRC should acknowledge that the intent of the rule regarding definition of the disturbed zone has be significantly changed. It is clear that the rationale for 10 CFR Part 60, as discussed in the June 21, 1983 Federal Register notice, intended the disturbed zone to encompass buoyancy effects. By adopting this position, the GWTT parameter was intended to be an indicator of **post-emplacement** performance. The proposed new definition,which excludes buoyancy effects, is much less strict and in some cases seriously influence the licenseability of a particular site.

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