WM Res File
D1016
ITASCA

WM Project 10,11,16
Docket No.
PDR ✓
LPDR (B,N,S)

Distribution:
Tiktinsky
Joan-Hickey

(Return to WM, 623-SS)

ITASCA Consulting Group, Inc.

26 November 1985

David Tiktinsky - SS623
U.S. Nuclear Regulatory Commission
Division of Waste Management
Washington, D.C. 20555

"NRC Technical Assistance for Design Reviews"
Contract No. NRC-02-85-002
FIN D1016

Dear David:

Transmitted with this letter are the document reviews for the two documents requested for review in the letter received from you on 28 October 1985:

(1) "Preliminary Characterization of the Petrologic, Bulk, and Mechanical Properties of a Lithophysal Zone Within the Topopah Spring Member of the Paintbrush Tuff," by R. H. Price, F. B. Nimick, J. R. Connolly, K. Keil, B. M. Schwartz, and S. J. Spence (SAND84-0860); and

(2) "A Comparative Study of Radioactive Waste Emplacement Configurations", H.F. Gram, L. W. Scully, R. I. Brasier, and M. L. Wheeler (SAND83-1884).

Both of these documents are summaries of work reported elsewhere. We are concerned that our reviews are not complete because we did not have access to the supporting documents. In particular, the supporting documents for Johnstone et al (1984), SAND83-0372 (see Itasca Document Review 001-02-01), should be reviewed as that document appears to be the principal reference for thermal/mechanical stability considerations in SAND83-1884. Review, in this case, should include independent calculations. We cannot see how else the numerical results can be accepted.

Please call if you have any questions

Sincerely,

Roger D. Hart
Program Manager

Encl.
rdh/ks

cc: John Greeves
Office of the Director, NMSS
Elois Wiggins
DWM Document Control Room

P.O. Box 14806 • Minneapolis, Minnesota 55414 • (612) 623-9599

2631

ITASCA DOCUMENT REVIEW

File No.: 001-02-9

Document: "Preliminary Characterization of the Petrologic, Bulk, and Mechanical Properties of a Lithophysal Zone Within the Topopah Spring Member of the Paintbrush Tuff," by R. H. Price, F. B. Nimick, J. R. Connolly, K. Keil, B. M. Schwartz, and S. J. Spence (SAND84-0860)

Reviewer: Itasca Consulting Group, Inc. (J. Daemen)

Date Approved:

Date Review Completed: 26 November 1985

Significance to NRC Waste Management Program

Mechanical property test results presented in this document indicate that fundamental differences exist between the mechanical behavior of lithophysal and non-lithophysal zones of the Topopah Spring tuff. This implies that repository sections constructed within the lithophysal zone, if any, would require significantly different performance assessment analyses.

The report presents data on the lithophysae-rich upper zone of the Topopah Spring member of the Paintbrush Tuff. The lower, lithophysae-poor, zone is the preferred repository horizon (e.g., draft EA, DOE, 1984, Section 3.2.1.3, p. 3-11 and Section 6.3.3.2.3(1), p. 6-264). It appears that virtually all mechanical and thermal-mechanical analyses performed in support of the site have been based on properties characteristic for the lithophysae-poor zone. The results of the mechanical tests presented in this report clearly indicate that the mechanical response of the lithophysae-rich zone will be significantly different from that of the lithophysae-poor rock. It is implied in the introduction to this document (p. 7, paragraph 2) that a lithophysae-rich zone might be considered for at least part of the repository, particularly near the east boundary of the site. It is essential to recognize that, if the repository does include sections within the lithophysae-rich formations, their response to construction and to waste emplacement is likely to be significantly different from that in lithophysae-poor zones.

A second important implication is that it is not helpful (and is probably misleading) to identify the repository formation only as the "Topopah Spring member". All indications are that this member includes widely differing rock types which need to be identified if the location is to have any mechanical meaning. The results of the mechanical tests presented here indicate that analyses provided previously of repository rock performance within the Topopah Spring member apply to the lithophysae-poor zone only— NOT to the member as a whole. Some specific examples suggest how severe the implications of the mechanical differences between lithophysae-rich and lithophysae-poor zones might be.

The average uniaxial compressive strength measured here (Table 6, p. 40) is lower by a factor of five (5) compared to the value used in the primary repository horizon selection reference [Johnstone et al (1984), Table 3, p. 8, and Fig. 43, p. 63). As a consequence, all Topopah Spring member safety factors listed in Johnstone et al, 1984 (e.g., Table 5, p. 16; pillar safety factor, p. 17, and Fig. 44, p. 64; effect of stress concentrations, pp. 17-18, and Fig. 46, p. 66; and effect of waste decay heating, p. 18, and Fig. 47, p. 67) should be considered as being valid only for the lithophysae-poor zone of the Topopah Spring. Significant reductions in the rock mass classification rock qualities (Johnstone et al, 1984, pp. 18-21, Table 6) and of the consequent construction and engineering (e.g., support) results also would follow for the lithophysae-rich zone compared to the lithophysae-poor zone.

It is to be noted that the Johnstone et al (1984) report has been referenced extensively in the Draft Environmental Assessment (EA) for Yucca Mountain Site. All Draft EA sections concerning rock characteristics would require extensive revision, or addition, if a significant fraction of the repository were to be constructed within a lithophysae-rich zone.

A second example of a document, in which the strength of the lithophysae-poor Topopah Spring member is applied indiscriminately to the entire member, is the Gram et al (1985) comparative study of radioactive waste emplacement configurations. Although the rock strength values used in Gram et al (1985) are not nearly as high as those in Johnstone et al (1984), they still are considerably higher than the values reported in SAND84-0860 for lithophysae-rich tuff.

Attention in this review has been focused on differences in uniaxial compressive strength. Less dramatic, but nevertheless potentially-significant differences exist for the Young's modulus, the Poisson's ratio, the clay content, and the porosity.

In conclusion, it is important to recognize that the mechanical response of various zones within the Topopah Spring tuff is likely to differ significantly. It therefore is necessary to qualify all statements with regard to (at least) the mechanical behavior of this member by specifically identifying for which zone of the member the statement applies. It seems probable that similar qualifiers should apply for other aspects of rock behavior (e.g., thermal, hydrological, geochemical).

The test results confirm a frequent observation on tuffs—namely, a considerable variation in mechanical properties. This raises the question of the extent to which any mechanical analysis of tuffs can postulate the rock to behave as a uniform, homogeneous medium, even on a macroscopic scale. It appears that the relationships between mechanical properties (e.g., strength, modulus) and porosity, strongly emphasized in earlier NNWSI project reports, might not be as broadly valid as earlier assumed.

Summary of the Document

The document presents detailed petrological and mineralogical analyses, porosity determinations, and mechanical properties measurements (uniaxial compressive strength, Young's modulus, Poisson's ratio, axial strain at failure, stress-strain curves) on samples of lithophysal Topopah Spring tuff. Samples have been obtained from an outcrop a few miles east of the southern edge of Yucca Mountain. Test procedures, results, and analyses are included in complete detail. Brief comparisons with non-lithophysal Topopah Spring tuff (USW G-1 core) and with the Grouse Canyon member (G-Tunnel tuff) are included. An extensive list of references on Nevada Test Site tuffs is included.

Problems, Limitations, and Deficiencies

Samples have been collected from a surface outcrop—i.e., might have been subjected to weathering and have been in a different stress and hydrological-geochemical environment from that existing at repository depth.

As pointed out by the authors (p. 26), the size of the samples listed in compression might have been somewhat too small relative to the size of the cavities. (It must be recognized that the sample size already is unusually large compared to most rock mechanics tests.)

The argument developed on p. 27 to explain the lower strength (yet higher Young's modulus) of the lithophysal tuff is not convincing, especially not with regard to the influence of permeability and with regard to the influence of a relatively soft inclusion such as water within a (much stiffer) rock skeleton. A more rigorous mathematical analysis could be performed and would be warranted if NNWSI (or NRC) intends to predict mechanical behavior on the basis of porosity.

Furthermore, if the logic presented on p. 27, regarding higher modulus for lithophysal tuff, is accepted, then the reported moduli for the saturated tuff samples may not be conservative. Drained samples would be more appropriate to determine conservative values.

The comparison between the lithophysal tuff properties, nonlithophysal tuff properties, and between the Topopah Spring member and the Grouse Canyon member remains vague and superficial.

Recommendations

It is recommended that there be a review of all NNWSI repository design and performance-related documents—in particular, the draft EA and its major supporting documents, in light of the possibility that parts of the repository might be constructed within, or very near to, the lithophysal zone of the Topopah Spring member. Such a review should include, as a minimum, a judgmental evaluation of the validity of the conclusions for repository sections within or near to the lithophysal zone. Preferably, the review should include some numerical analyses of mechanical and thermal-mechanical problems (e.g., room stability).

It is also recommended that geologists review all NNWSI site characterization literature with the specific objective of identifying the probability that part of the repository might be constructed in or near the lithophysal zone. The extent of the repository that might be located in or near the lithophysal zone should be estimated. The results of this assessment will determine the potential importance of the problem and, hence, of the type and amount of follow-up work that is warranted.

During DOE-NRC NNWSI interactions, the great uncertainty associated with identifying the repository horizon only as "Topopah Spring" and the ambiguity left by maintaining the option of construction in the lithophysal zone should be pointed out.

A systematic (e.g., tabular) comparative summary should be developed of the results presented here (i.e., petrology, mineralogy, porosity, strength, etc.) with similar results on samples from deep boreholes and on G-Tunnel tuffs. Such a comprehensive summary, especially if updated whenever additional data becomes available, will assist greatly in assessing the feasibility of extrapolating and comparing results of various tests from one location or formulation to another.

Given the engineering significance of clay content, a careful, detailed comparison of mineralogy is recommended, based on Bish et al (1981) and Carroll et al (1981).

REFERENCES

Bish, D. L., F. A. Caporuscio, J. F. Copp, B. M. Crowe, J. D. Purson, J. R. Smyth, and R. G. Warren. "Preliminary Stratigraphic and Petrologic Characterization of Core Samples from USW-G1, Yucca Mountain, Nevada," Los Alamos National Laboratory Report LA-8840-MS, 1981.

Carroll, P. I., F. A. Caporuscio, and D. L. Bish. "Further Description of the Petrology of the Topopah Spring Member of the Paintbrush Tuff in Drillholes UE25A#1 and USW G-1 and of the Lithic-Rich Tuff in USW-G1, Yucca Mountain, Nevada," Los Alamos National Laboratory Report LA-9000-MS, 1981.

Johnstone, J. Keith, Ralph R. Peters, and Paul F. Gnirk. "Unit Evaluation at Yucca Mountain, Nevada Test Site: Summary Report and Recommendation," SAND83-0372, 1984.

Gram, H. F., L. W. Scully, R. I. Braisier, and M. L. Wheeler. "A Comparative Study of Radioactive Waste Emplacement Configurations," SAND83-1884, 1985.

U.S. Department of Energy. "Draft Environmental Assessment, Yucca Mountain Site, Nevada Research and Development Area, Nevada," DOE/RW-0012, 1984.

ITASCA DOCUMENT REVIEW

<u>File No.</u>: - 001-02-10

<u>Document</u>: "A Comparative Study of Radioactive Waste Emplacement Configurations", H.F. Gram, L. W. Scully, R. I. Brasier, and M. L. Wheeler (SAND83-1884)

<u>Reviewer</u>: Itasca Consulting Group, Inc. (J. Daemen, L. Lorig))

<u>Date Approved</u>:

<u>Date Review Completed</u>: 26 November 1985

<u>Significance to NRC Waste Management Program</u>

This document strongly supports a horizontal canister emplacement, with multiple canisters in long horizontal holes. The document explicitly states that

> "The evaluation of the impact (of configuration) on postclosure containment and isolation is beyond the scope of this report. No work has been done yet to assess the impact of configuration on preclosure waste package performance . . . . [T]he potential impact of any emplacement configuration on the postclosure performance must be addressed before a final configuration is chosen. This study compares three emplacement configurations from the perspective of preclosure repository operations, suggests a preferred configuration, and identifies the configuration's engineering problems that require resolution." (p. 1).

This lengthy quote form the "Purpose and Justification" section of the introduction summarizes exceedingly well potential NRC concerns about the emplacement selection procedure. This procedure is driven exclusively by operational considerations and influenced predominately by cost considerations. The conclusion that horizontal emplacement is preferable follows immediately because this method permits a much denser emplacement with multiple canisters in long horizontal holes.

The document relies heavily on conclusions and results from other documents, many of which are not presently available to the reviewers. Hence, an independent assessment of the validity of the results, and of the conclusions drawn therefrom, is not possible. Because of the great importance of the emplacement configuration, it would be appropriate to acquire and review these back-up documents.

The document presents a valuable summary of the state of engineering analysis for a Yucca Mountain repository as of September 1983.

Summary of the Document

A comparative evaluation is presented of three waste emplacement configurations: a self-shielded package placed on the floor of an emplacement drift; a vertical borehole emplacement in which a single canister is placed in a short (7.6 m) hole in the floor of the drift; and a horizontal borehole emplacement in which 34 canisters are stacked together in long (200 m) horizontal holes drilled in the sidewall of a drift. Estimates of dependability, safety, and cost effectiveness are used to compare the three configurations. These estimates are based on waste package design, thermal, structural and hydrological analyses of near-field short-term (operational) repository performance, construction, emplacement and retrieval operations, ventilation requirements, and backfilling operations.

Principal differences identified between the three configurations are:

- length, volume, and cost of drifts (mining)
- heat flow from the waste into open ventilated drifts
- the extent to which technology is available to achieve each alternative configuration.

It is concluded that horizontal emplacement is the preferred method because it requires the least mining and ventilation and the least time for waste emplacement. It is recommended that prototype equipment for horizontal drilling and hole lining, as well as for waste emplacement and retrieval, be developed and tested to resolve remaining uncertainties.

Problems, Limitations, and Deficiencies

The selection of the emplacement configuration is based exclusively on operational considerations—predominantly on cost comparisons. It is implied that post-closure requirements will not depend on the configuration [e.g., (on p. 1) "The evaluation of the impact on postclosure containment and isolation is beyond the scope of this report."; (on p. 15) "Postclosure repository performance is not evaluated because the repository will be designed to comply with all applicable standards. . . "].

This document relies heavily on other documents and, in fact, essentially is a comprehensive summary of a large number of other studies. Very few of these are presently available to the reviewers, many are internal memos and letters, and some are not included in the references. As a consequence, it is not possible to make an independent evaluation of the validity of many of the results, conclusions, and statements on which this report is based. This is particularly significant in light of the fact that the report integrates numerous results and hence, from necessity, treats each individual technical subtopic only very superficially.

The work was performed before September 1983.

Specific Comments

The following detailed comments are based almost exclusively on the report itself—i.e., they include minimal cross-checking with references. These detailed comments are organized by report-page numbers.

Page i Although the abstract lists "sealing of the repository" among the factors evaluated and "time required for waste emplacement or retrieval" as one of the primary differences between the three configurations, neither of these aspects is discussed in the main text and is certainly not analyzed in any detail.

Page xi, paragraph 3 (also pp. 3-4, paragraphs 2-3)

It is not obvious that basing a comparative evaluation on the waste generating the largest thermal output is necessarily conservative. This choice will enhance the relative performance of the configuration most favorable (in terms of the analysis performed here) in terms of coping with thermal loading (i.e., the horizontal emplacement).

Page xiv Several of the definitions in the glossary are either too restrictive (e.g., rockbolting, shaft), vague (e.g., sealing), or non-technical.

Page 1, paragraph 5

No reference for Johnstone and Peters (1984) is listed. This probably is Johnstone et al (1984)—i.e., Johnstone, Peters and Gnirk, 1984 (SAND 83-0372). The reference to Johnstone and Peters (1984) is repeated throughout the document (pp. 3, 61, 62) and is one of the major references with respect to thermal/mechanical analysis and stability. If a Johnstone and Peters (1984) really does exist, it needs to be identified and reviewed. If, as assumed here, this reference should be Johnstone et al (1984) (i.e., SAND 83-0372), it needs to be noted that Johnstone et al (1984) use rock strengths which are different and, for some parameters (i.e., cohesion, matrix tensile strength), substantially higher than those listed here (Appendix A.6). Conversely, Johnstone et al (1984) use a somewhat higher thermal load (57 kW/acre) compared to the thermal load mentioned here (50 kW/acre, pp. 3-4, paragraph 4).

Pages 3-4, paragraph 5

It is quite possible that the change from open-ended to blind-bored holes does not significantly modify the temperature stress. However, contrary to the claim in the last sentence of this paragraph, the second paragraph on p. 54 suggests that no analysis of the blind hole, 200 m long, has been performed.

Page 5 The last paragraph indicates that alcoves are required at each horizontal emplacement site. This is not reflected in later discussions or on Fig. 5.

Page 7 The sectional view of the drift (left) is very misleading, as is the size of the SSP relative to the drift size.

Page 11 The sectional view of emplacement drift (top) is misleading.

Page 13 Contrary to the last sentence of the second paragraph of Section 3.1 ("Waste Package Design"), neither plugs nor borehole liner designs are given in Appendix A.1.

Page 14 Contrary to the statement in the last paragraph, sealing techniques are not detailed in Appendix A.5. (See, in particular, Section A.5.1.)

Page 16 What does "KW" in the matrix stand for?"

Page 17 It is questionable to assume an identical reliability for the waste package in three totally different configurations and totally different environments—temperature (see Fig. 8, p. 57, Table 21, p. 55), stress (e.g., rock load), water flux, and corrosion).

Is there any justification for the claim in the last sentence that dehydration impacts will only be those common to other underground openings?

Several firm statements are made in Section 4.1.1.1 ("Thermal Hydrology") for which the back-up evidence is extremely weak, conjectural, or non-existent. In particular, the rationale for given horizontal emplacement (a rating of "good" versus the "acceptable" for vertical emplacement) is unclear and unconvincing.

Page 18, Section 4.1.1.2 ("Thermal/Structural Stability")

This section is based entirely on a reference (Flanigan and Subia, 1983b) which is not available for review.

Page 19 The third paragraph states that "Some tension cracks may also develop near the center of the borehole . . ." —this statement is puzzling.

Page 21 Although Section 4.1.5 is entitled "Sealing", it only addresses backfilling.

Pages 17-21, Section 4.1 ("Reliability")

Throughout this section, horizontal emplacement is given the rating "unknown", even though it is recognized repeatedly, although probably underemphasized, that the reliability of horizontal emplacement and retrieval must be significantly less than that of vertical emplacement given the complete lack of experience with almost all aspects of a horizontal emplacement configuration.

Page 21, Section 4.2 (Flexibility)

It is to be noted that flexibility refers only to flexibility with respect to accommodating different types of waste. It does not consider, for example, flexibility with regard to variations in geological/geomechanical/hydrological conditions—variations which, if significant, almost certainly would impact much more severely on the horizontal emplacement configuration.

Page 22 The justification for the statement in paragraph 4 that "The flexibility criterion does not apply to thermal hydrology or ventilation of drifts during mining because these factors impose constraints that are similar and not significant for the three emplacement methods." depend entirely on whether the conclusions of Section A.2.2 ("Thermal Hydrology") can be accepted. This requires review.

Pages 22-23

The last sentence on p. 22 ranks the flexibility of horizontal emplacement as "good". Table 3 ranks it "acceptable".

Page 25, Section 4.2.4 ("Operations")

Horizontal emplacement and retrieval, as stated here, clearly is less flexible than the other two configurations. The "unknown" ranking tends to hide this.

Page 26, Table 4

Why are values for civil underground construction not included? It should be noted that accident rates depend on the skill and size of the local labor pool. In any case, the lowest accident rates are achieved by scheduling that does not exhaust the local labor pool.

Pages 31-33, Section 4.6 ("Scheduling")

Retrieval is excluded from consideration.

Page 37, Table 12

The much lower costs for borehole construction for horizontal emplacement in most categories is very surprising given that horizontal emplacement requires 5,555 m (with 80 cm diameter) versus 7,620 m (with 70 cm diameter) for vertical emplacement (Table 24) and is an untried new technology. The reference document appears to be dated incorrectly—i.e., 1983 in the table and 1984 in the reference list.

Page 54 The ventilation circuit implied by the last two paragraphs remains very unclear. Will air be recirculated from emplacement drifts through access drifts?

Page 56 It is unclear whether the heat flow to the access drifts, significant for horizontal emplacement, has been taken into account in any other analyses—particularly ventilation requirements.

Page 61 If the Johnstone and Peters (1984) reference is actually Johnstone et al (1984) (i.e., SAND 83-0372), it needs to be noted that Johnstone et al (1984) use significantly higher strengths for some parameters than those listed in Appendix A.5 and that, particularly with regard to far-field effects, more recent data (Price et al, 1985) indicates that some zones of the Topopah Spring tuff are significantly different in terms of thermomechanical behavior (e.g., much weaker) than what is assumed either in Johnstone et al (1984) or in Appendix A.5.

The last paragraphs on this page appear to be extremely optimistic. The steel liner will do nothing to the tension crack, which could become a preferential (e.g., convective) flow path and certainly would accelerate steel liner corrosion. How is it concluded that the horizontal tension cracks do not pose a stability concern?—that conventional rockbolt technology is adequate?

Page 67 The statement in the first sentence that ". . . the mining industry routinely drills horizontal holes" is literally true, but irrelevant. The horizontal holes drilled routinely in the mining industry are not 200 m long nor 80 cm in diameter. The statement on p. 44 (Section 5.4.2, "Factors Rated Unknown") that "The technology for drilling long horizontal holes is not in use" more accurately describes the present situation in this regard.

The basis for the cooling requirements (5° to 20°C) is unclear.

Page 77 The study was conducted in 1983, yet several references are dated 1984?

Recommendations

The document reviewed is a critical reference with respect to emplacement configurations. It relies heavily on other sources. These, moreover, have much broader implications than emplacement configurations only—i.e., they concern repository stability, thermal-mechanical-hydrological effects, retrieval, etc. Therefore, It is urgently recommended that the NRC:

- acquire and review essential supporting documents
- independently perform some numerical calculations to assess the validity of the results presented (in particular, thermal/mechanical, thermal/hydrological, and thermal calculations)

It is specifically recommended that NRC perform an independent assessment (literature review and calculations) of Sections A.2.1 ("Temperature Distributions and Heat Flow"), A.2.2 ("Thermal Hydrology"), and A.2.3 ("Thermal/Structural Stability").

Documents to be reviewed with high priority are:

(1) Sisson (1982) and Peters (1983), with regard to temperature distribution;

(2) Mansure (1983), Sisson (1982), and Mondy et al (1983), with respect to thermal hydrology; and

(3) and the original sources from which Johnstone et al (1984) have taken their results for thermal/mechanical stability analysis (see Itasca Document Review File No. 001-02-1).

The latter document is particularly important in light of the significant differences between the rock properties listed in Appendix A.5 and those used in Johnstone et al (1984), Table 3.

References

Flanagan, D. D., and S. R. Subia. "Thermo-Mechanical Analysis of the Horizontal Waste Emplacement Scheme," Internal Memo to L. W. Scully, Sandia National Laboratories (November 17, 1983).

Johnstone, J. K., et al. "Unit Evaluation at Yucca Mountain Nevada Test Site: Summary Report and Recommendation," SAND83-0372, June 1984.

Mansure, A. J. Personal Communication with M. L. Wheeler (May 4, 1983).

Mondy, L. A., et al. "Comparison of Waste Emplacement Configurations for a Nuclear Waste Repository in Tuff IV. Thermo-Hydrological Analysis," SAND83-0757, August 1983.

Peters, R. R. "Thermal Response to Emplacement of Waste in Long Horizontal Boreholes," SAND82-2497, April 1983.

Price, R. H., et al. "Preliminary Characterization of the Petrologic, Bulk, and Mechanical Properties of a Lithophysal Zone Within the Topopah Spring Member of the Paintbrush Tuff," SAND84-0860, February 1985.

Sisson, C. E. "3-D Thermal Analysis of a Horizontal Borehole Emplacement Scheme for Nuclear Waste Storage in Tuff," Internal Memo to L. W. Scully, Sandia National Laboratories (December 10, 1982).