DISTRIBUTION: cy of Paper attached
WM: s/f
NMSS: r/f
RDMacDougall
JJSurmeier
PAltomare
MKearney
DMattson
JOBunting
LHigginbotham
MKnapp
HMiller
MJBell
REBrowning
~~JGreeves~~
PDR

~~105~~ 109.3/RDM/84/04/16



APR 27 1984

MEMORANDUM FOR: John T. Greeves, Chief
Geoengineering Branch

FROM: Joseph O. Bunting, Jr., Chief
Policy and Program Control Branch

SUBJECT: COMMENTS ON PAPER ENTITLED: "POLICY QUESTIONS ON ROLE OF FIELD TESTING IN THE ESTABLISHMENT OF A RADIOACTIVE WASTE REPOSITORY"

Per your request, we offer the following comments on the above paper.

We believe the enclosed paper prepared by Professor Hustrulid and Mr. McClain raises significant policy and legal questions about the overall regulatory approach set forth in 10 CFR Part 60. As we understand it, Professor Hustrulid is a widely-recognized expert in the field of mining engineering. Based on two and a half pages of references from current technical literature, the authors make a strong case that the uncertainties associated with available modelling and testing techniques make it unrealistic to expect early site investigations to produce the information necessary for "reasonable assurance" under our rules that a site is suitable for repository construction. In our view, the issue broached in the paper appears to be two-fold: (1) What level of technical confidence is required for a licensing board to find "reasonable assurance?" and (2) What is the time required to obtain the geologic data necessary to support that level of confidence? Since no deep geologic repository has ever been constructed or licensed, both issues are crucial. If the current state of the geotechnical art can not provide the necessary licensing data within the tight statutory timeframes provided for site characterization, it would suggest one or both of two things: our repository licensing procedures might be misdirected, or there may be a need for further clarification of the licensing information that will be necessary for a technically defensible finding of "reasonable assurance." As Mike Bell indicated in his memo to you on this paper, some staff members believe that the level of confidence required to find reasonable assurance under 10 CFR 60 is significantly less than the authors appear to assume in the paper. In any case, if the reasonable assurance standard for repository licensing differs from the standards for licensing reactors and other facilities and materials, these differences may have to be further explained.

Given what we understand to be the strong professional credentials of the authors, we believe it would be useful to submit the authors' concerns to a panel of highly-qualified geotechnical authorities. If there is a flaw in the underlying rationale of our repository licensing rule, we believe it should be

WM Record File 109.3
WM Project 1
Docket No.
PDR ✓
LPDR
Distribution:
(Return to WM, 623-SS)

| OFC | :WMPC | :WMPC | :WMPC | : | : | : |
|---|---|---|---|---|---|---|
| NAME | :RMacDougall | :JJSurmeier | :JOBunting | : | | |
| DATE | :84/04/10 | | | | | |

investigated before the program proceeds to the point where the accretion of program commitments makes it far more difficult to make adjustments. On the other hand, if the flaw is in Professor Hustrulid's paper, it is not too early to identify and put this issue to rest. The clearly unacceptable course of action is to ignore it.

To guide the panel's deliberations, it would also be useful to have a thorough legal analysis of the meaning of "reasonable assurance" as applied to geologic repositories; we know of no such analysis currently available.

We appreciate your having given us this paper for review.

Joseph O. Bunting, Jr., Chief
Policy and Program Control Branch

*See previous concurrence

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| OFC | :WMPC | :WMPC | :WMPC | : | : | : | : |
| NAME | *RMacDougall | *JJSurmeier | :JOBunting | : | : | : | : |
| DATE | :84/04/10 | : 4/26/84 | : 4/26/84 | : | : | : | : |

investigated before the program proceeds to the point where the accretion of program commitments makes it far more difficult to make adjustments.

To guide the panel's deliberations, it would also be useful to have a thorough legal analysis of the meaning of "reasonable assurance" as applied to geologic repositories; we know of no such analysis currently available.

We appreciate your having given us this paper for review.

Joseph O. Bunting, Jr., Chief
Policy and Program Control Branch

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| OFC | :WMPC | :WMPC | :WMPC | : | : | : | : |
| NAME | :RMacDougall | :JJSurmeier | :JOBunting | : | : | : | : |
| DATE | :84/04/10/18 | : 4/18/84 | : | : | : | : | : |

Fm "Rock Mechanics in Productivity and Protection", 25th Symp. on Rock Mechanics, 6/25-27/8

# Chapter 119

## POLICY QUESTIONS RELATED TO THE ROLE OF FIELD TESTING IN THE ESTABLISHMENT OF A RADIOACTIVE WASTE REPOSITORY

William A. Hustrulid and William C. McClain

Professor, Mining Engineering Department
Colorado School of Mines, Golden, CO

Executive Vice-President, RE/SPEC Inc., Rapid City, SD

### INTRODUCTION

Prior to the mid-1970's, the U.S. Radioactive Waste Disposal Program was focused on salt deposits as the geologic medium of choice, almost to the exclusion of other rock types. These efforts are illustrated by the Project Salt Vault experiment in a salt mine at Lyons, Kansas, in 1965-1967 followed by attempts to locate a repository site in central Kansas. Preliminary evaluation of other geologic media led, in 1978, to the GAIN (Geotechnical Assessment and Instrumentation Needs for Nuclear Waste Isolation in Crystalline and Argillaceous Rocks) Symposium held at the University of California (Berkeley), for the purpose of preparing a state-of-the-art document together with research needs for some of the other possible rock types.

Because possible sites had not been selected, nor would they be for some time, the primary emphasis was for research and development focused on generic rocks and generic sites. A basic ground rule at that time was that the host rock formation should provide the primary containment for the waste. Also, the U.S. Nuclear Regulatory Commission (NRC) was just drafting the proposed rules regarding site suitability so that this input was not available. The collection of baseline data, conduction of some critical experiments both in the laboratory and field, and the performance of scoping studies were deemed needed. Such work was indeed undertaken; and to date, a great deal of information has been compiled and much has been learned regarding the characteristics of rock masses, rock behavior

RSI PUBL. NO. 84-04

under various loading conditions, and the characteristics of various kinds of instrumentation.

Today (1984), the U.S., by Congressional order, has been placed on a very tight timetable to recommend a first disposal site. The proposed guidelines from the NRC as to what constitutes a suitable site are very specific, yet difficult to translate into tasks to which the geotechnical community can respond based upon the present state of knowledge. A question, such as, "What geotechnical experiments are necessary and sufficient to show constructability, retrievability, containment, and isolation to the required degree at a specific site?" is not easy to answer.

The objective of the paper is not to provide a comprehensive review of what is being done and why, but rather to serve as a discussion document as to where we are and where we are going. Some of the major points from the GAIN meeting will be reviewed, as this has provided the basis for much of the research done to date. Four types of field experiments (full-scale heater tests, block tests, mine-by, and blast damage assessment) will be critically examined in light of potential application at a future repository site. The ground rules for site selection and site suitability appropriate to the U.S. in 1984 will be presented with some indication as to the impact on geotechnical research. Finally, some thoughts and recommendations are provided as to where we believe the geotechnical community should be headed to respond to the present challenge.

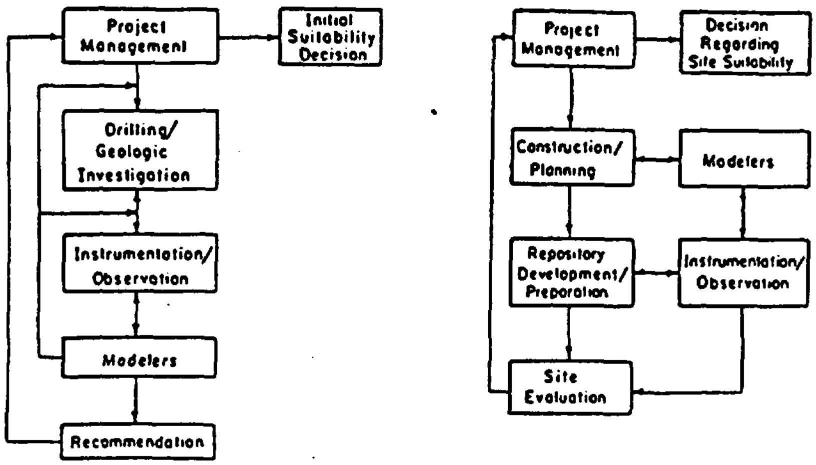
## GEOMECHANICS EXPECTATIONS (1978)

In July of 1978 at the GAIN (Anon., 1979) meeting, specialists in the fields of geomechanics, fracture hydrology, and geochemistry met for the purpose of making a statement regarding the present knowledge and research needs for isolating nuclear wastes in crystalline and argillaceous rock. The forum was conducted under the ground rules for waste disposal existing at that time.

The general objectives of the GAIN Symposium were to establish the state of the art in nuclear waste isolation in crystalline and argillaceous rock, to define the additional research that was needed to evaluate the waste-rock interactions, and to determine the instrumentation needs to measure the parameters used in site selection and development.

The general conclusions of the meeting related to the development of models that could be used for performance prediction. The distinction between approaches to analysis (often called "models") and "behavioral models" should be kept in mind. The latter are intended to accurately represent the behavior of the system under study and require the inclusion of site-specific input data.

Whereas, code development may not require close cooperation and interaction between the analysis and experimentally-oriented team members; the same is not true for behavioral model development. The interactions during the site evaluation and construction phases might be as shown in Figure 1.




Phase I Site Evaluation
Objective: To find suitable site for waste repository.

Phase II Site Construction
Objective: To construct the site with minimum disturbance to surrounding rock.

Figure 1. Time frame for data collection and instrumentation measurements (Anon., 1979).

It has been found convenient from a modeling (as defined above) viewpoint to break the repository design problem into four scales:

- canister scale
- excavation scale (single drift or room)
- repository scale
- regional scale.

The building block logic would suggest starting from the canister scale and working upward. Furthermore one would start by examining uncoupled problems and gradually progressing to the fully coupled problems. The discussion of the approach as contained in GAIN is given below (Anon., 1979).

"The regional analyses, which must particularly concern long-term radionuclide transport, are influenced by the engineering design of the canister, excavation, and repository. A subdivision of less than regional scale analyses is given in Figure 2. Although many of these areas may already be studied using quite simple

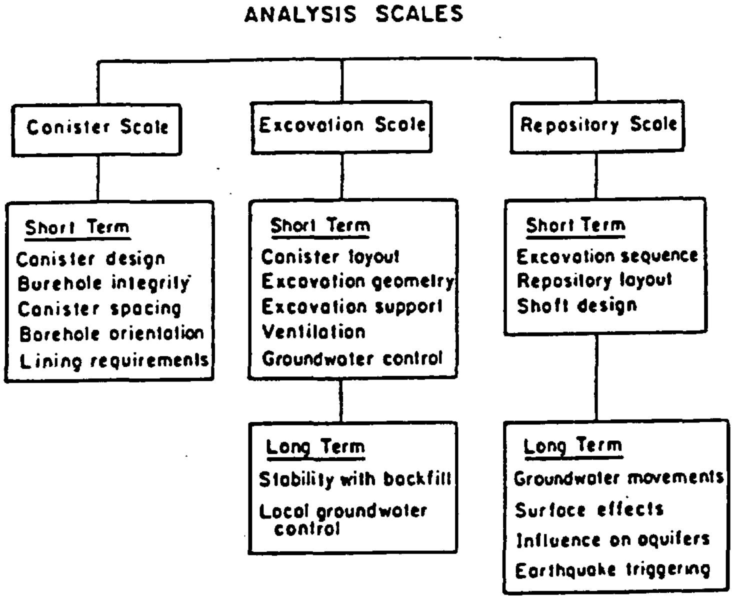



Figure 2. Scales for repository analysis (Anon., 1979).

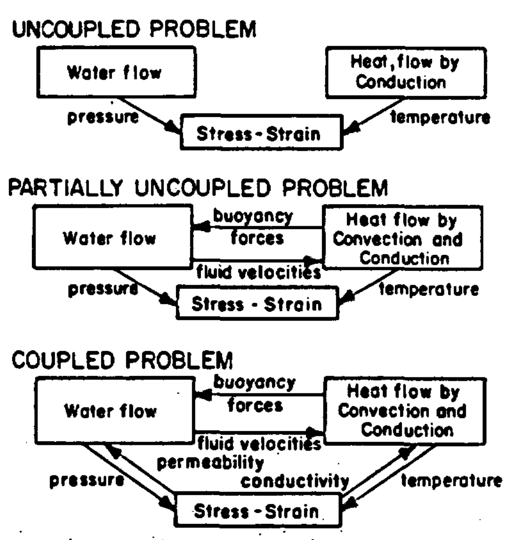



Figure 3. Schematic representation of different levels of coupling in modeling (Anon., 1979).

models, in the long-term, more complex models must be developed to stages where they can be used with a high degree of confidence. Much model development specifically concerns treatment of interactions between fluid flow, heat transfer, and mechanical behavior (Figure 3). Possibly the highest level of coupling indicated in Figure 3 is not essential for repository design, given reasonable levels of thermal loading. That cannot be proven, however, until such analyses have been made and necessary laboratory and field investigations of phenomena identified for the coupled problem have been completed. In the meantime, much simpler analyses provide quidelines for experimental work on both laboratory and field scales, as well as for preliminary repository design."

The thinking in the geomechanics section regarding experiment planning was aimed at providing the input data required for model development, calibration, and confirmation. Furthermore, one should understand the small scale before going to the big scale. Table 1

TABLE 1. Summary of In Situ Testing During Sequential Development of a Hypothetical Repository

| Type of Test | Baseline (0 Years) Underground Test Facility | Construction (1-10 Years) Confirmation Test Facility | Emplacement (10-30 Years) | 1st Phase Storage (30-100 Years) and 2nd Phase Storage (100+ Years) |
|---|---|---|---|---|
| Mechanical | Laboratory Tests | Displacement Closure | Backfill Experiments | Temperature Displacement, Stress |
| | Baseline Models | Virgin Stress State | (Retrievability) | |
| | Thermomechanical Test Conducted to Failure | Tests Not Conducted to Failure | | |
| | Canister-Scale Displacement | Temperature | | |
| | Excavation-Scale Displacement | Same | | |
| | Temperature | Same | | |
| | Permeability Pore Pressure | Same | | |
| | Elastic and Time Dependent Properties | Same | | |
| Thermomechanical | Absolute Stress; Temporal Change in Stress | | | |
| Geological | Three-Dimensional Representation of Joints and Fractures | Three-Dimensional Structural Representation of Geology | | |
| Hydrological | | | | |
| Radionuclide Transport | | | | |
| Radiological | | | | |

summarizes the type of in situ testing suggested as needed during the sequential development of a hypothetical repository. As indicated, the approach to the problem was a development based upon first principles. Fundamental rock property data were to be collected and used in models.

## SOME GEOTECHNICAL EXPERIMENTS (1978-1983)

### Introduction

Since the time of the GAIN meeting, a significant amount of geotechnical work related to the geologic disposal of radioactive waste has been done on a number of fronts (e.g., laboratory data collection, large-scale field experiments, and numerical-model development) for several rock types. Much has been learned, but much remains. In this paper four geotechnical field procedures (full-scale heater tests, block tests, mine-by experiments, and blast damage assessment) will be briefly discussed. For the most part, the examples to be examined were pioneering prototype experiments, and in looking back, they proved to have both positive and negative outputs. One can and must learn from both. The benefits from positive results are obvious. The problems or negative aspects should translate into ways of improving the experiment, developing new/different experiments, changing/improving the instruments, etc. It appears that several such "full-scale experiments" may become written into test plans to be carried out as part of a "standard" site characterization/suitability evaluation. Prior to this, a thorough review of the requirements/expectations/limitations/applications of such experiments is needed. The comments contained in this section are intended to stimulate such a review.

### Full-Scale Heater Tests

Several "Full-Scale Heater Tests" have been conducted to date in several rock types (Witherspoon and Degerman, 1978; Kurfurst, Hugo-Persson, and Rudolph, 1978; Cook and Witherspoon, 1978; Cook and Hood, 1978; Schrauf, et al., 1979; Hood, 1979; Hood, 1979a; Witherspoon, Cook, and Gale, 1981; Cook, et al., 1982; Case, Krug, and Williams, 1980), in addition to Project Salt Vault in salt. A major purpose of the experiments was to evaluate the response of the rock in the vicinity of the heater, powered in such a way as to simulate the thermal loading of an actual waste package. In this section focus will be on the Stripa experiments, but the findings apply to the BWIP tests as well.

The results of the Stripa heater tests have not been fully analyzed as yet, but this should occur in the relatively near future (Cook, et al., 1982). To date some very interesting things have come out of these experiments. The thermal fields appear to be well modeled using laboratory data in standard heat transfer codes.

Unfortunately, the same is not true for the stress and displacement fields. This is due, in part, to an inability to include the appropriate rock mass properties and structural geology. In particular, the presence of joints appears to allow some of the thermally-induced displacements to be absorbed internal to the rock mass. The time delay between the predicted displacements and the measured displacements was substantial with the predicted magnitudes being considerably greater than those measured. The measured data for inferring stresses were very difficult to interpret and varied widely.

If model and field results do not correspond, what does one do? Try and understand the basis for the differences and correct the models? Evaluate the source of the problem and develop new instruments, layout procedures, or experiments so that the new experiments provide what is needed? Carry on with new projects? It is suggested that the present inability to model the results of field experiments already conducted, substantially weakens any arguments to conduct experiments at least of the same or similar design at a potential repository site.

Block Tests (Ambient/Heated)

It has long been recognized that the value of measured rock properties depends upon the volume of rock tested. This is true for the strength, deformation modulus, and other properties. For a jointed rock mass, the behavior of the composite may be quite different from either that of the joints or the rock material. Although attempts have been made to model the behavior, it is still difficult to obtain reasonable results. One alternative is to test volumes of a size appropriate for the proposed application. Methods of loading relatively large volumes of rocks in situ have been under development for a long time. One technique is to cut a slot into the rock surface, insert a flatjack and measure the rock response as a function of the applied jacking pressure. This can be extended to cutting two parallel slots and loading the rock between them, or completely freeing a rock block on four sides and performing biaxial loading tests.

The block test is an example of this latter category. Several large scale block tests (Pratt, et al., 1977; Hardin, et al., 1981; Hardin, et al., 1981a; Hustrulid and Ubbes, 1983; Anon., 1980; Cramer, Cunningham, and Kim, 1933; Richardson, 1983; Zimmerman, 1983) have been or are being carried out as part of the geotechnical experiments for radioactive waste disposal.

There are some nontrivial questions regarding the conduct of the experiment and interpretation (and use) of the results. These include:

- What is the significance of the initial unloading of the block?
- What is the system contribution to the load-deformation curves?
- Are joint stiffnesses useful? How should they be measured in a block test?
- What is the significance of multiple loading curves?
- How should the unloading portion of the curves be used?
- How should a block test be run to get data useful for code application?
- Could a block test be replaced by a slot test?
- Should block tests incorporate hydrologic aspects?
- Can one model a block test? (If one cannot model the block test itself, it would be difficult to justify using the data for wider modeling application.)
- How does block test data relate to constructability, containment, and retrievability considerations?

Mine-By

The mine-by is a large-scale experiment intended to provide information about rock mass characteristics. Such an experiment has proven to be extremely useful in mining and civil applications in which the changes induced by known geometry changes are monitored and the mass properties calculated. Such a test was conducted in granite by the Lawrence Livermore Laboratory (Schrauf and Board, 1979; Heuze, 1981; Heuze, Butkovich, and Peterson, 1981) in the Climax stock, Nevada test site. The observed deformations and stress changes have been analyzed by a number of people. Some of the observed and calculated displacements agree quite well; whereas, others are in poor agreement (some even with the wrong sign) even though an elaborate model was used.

The kinds of questions that might be raised when planning such experiments in the future include:

- Is this agreement the best that can be obtained?
- What degree of data fitting is good?
- How does one account for joints/structural features?
- Is an equivalent modulus sufficient for application?
- Should one attempt a room opening test rather than a mine-by?
- Where should further research/testing be conducted to refine the model?
- How does the data get used?
- What information other than mass modulus is readily derivable?
- Is there some better or an "optimum" instrumentation program?
- Is the concept of equivalent rock mass useful in the design of a repository?
- How can one use the information gathered to assess the short- and long-term stability of an underground opening?

Disturbance Around an Opening

A quantification of the nature and extent of the disturbance induced around an opening (5 m wide by 3 m high by 30 m long) excavated (Holmberg, 1981) with explosives was done at the Colorado School of Mines Experimental Mine (Idaho Springs, Colorado) using a variety of techniques (Hustrulid and Ubbes, 1983; Chitombo, 1982; El Rabba, 1981; Montazer, 1982). The site is in jointed granitic gneiss at a depth of 100 m below the surface and lies above the water table.

A series of reports are currently under preparation in which the details of the techniques used and results obtained are given. Although the techniques are certainly transferable to other sites, the results must be applied with some caution. For example, how the "disturbed zone" changes with rock type and structure, mining depth, size of opening, and type of excavation technique still needs answering. As the size of opening is increased, the blasting 'stress' on the perimeter could be quite different from a smaller opening. The "volume" sampled by these measurement techniques is not easy to determine. If, for example, the permeabilities are basically point measurements how does one combine them to form an equivalent continuous zone? Is a conductive pipe analogy correct for approximating the perturbation induced by excavation? If in the backfilling of openings there exists a gap between the fill and the roof, is it relevant to know the equivalent permeability of the disturbed zone? Probably the answer is yes, but how should the measurement program be designed to provide the information? It has been suggested that in the careful creation of an opening, although the modulus might be reduced and the rock somewhat disturbed by the excavation process, the concentration of stress may in fact produce a layer of more highly contained rock around the opening than existed prior to excavation. What is the significance of this on the containment and evaluation of the overall system? Possibly the high degree of excavation excellence that can be achieved is more closely related to the structural competence of the opening and, therefore, to the retrievability than it is to containment. From a practical viewpoint, how does damage prevention and assessment fit into site construction practice?

## GEOTECHNICAL FRAME-OF-REFERENCE (1983)

In the U.S. today, the frame-of-reference for geotechnical programs related to radioactive waste disposal is quite different from that appropriate to GAIN. One now finds that:

- The NRC has published proposed performance criteria (Nuclear Regulatory Commission, 1983) with respect to releases to the biosphere for a geologic repository. These are:

(1) The length of time after closure during which radionuclides are contained - the waste package must be designed to contain the waste for 1000 years;
(2) The rate at which radionuclides are released from the engineered system after containment fails - the engineered system must be designed to limit annual releases of waste after 1000 years to $10^{-5}$ of the inventory of waste in the repository;
(3) The travel time through the geologic setting for radionuclides to reach the biosphere - the geologic setting must provide a ground-water travel time to at least 1000 years.

- As a further step to protect health and safety, the NRC considers that the repository should be designed to permit the retrieval of waste for a period of up to 50 years after the completion of emplacement operations.
- A number of large scale research/development projects have been and are currently being carried out greatly increasing our knowledge for several rock types.
- The Congress of the U.S. has established (97th Congress, 1983) the following timetable for the selection and development of a nuclear waste repository for the disposal of commercially generated high-level and transuranic wastes:

(1) The U.S. Department of Energy (DOE) is required to nominate at least five sites as suitable for site characterization for selection of the first repository site. By no later than January 1, 1985, the Secretary (of Energy) will make a preliminary determination that three of the nominated sites are suitable for development as repositories consistent with these guidelines and recommend those sites to the President for characterization as candidate sites.
(2) By March, 1987, the Secretary will recommend the site for the first repository to the President. In order to provide sufficient time to characterize and evaluate the three sites under consideration for the first repository, the DOE expects to begin nominating such sites in 1984.
(3) The Act requires that the process of nomination and selection be conducted for a second set of sites, with a recommendation of three sites to the President no later than July 1, 1989.
(4) The Act requires that the President recommend the first site to Congress no later than March 31, 1987 and a site for a second repository no later than March 31, 1990 (the Act does permit up to a year's extension in these dates if requested by the DOE).
(5) After a site is recommended to Congress, the state in which the site is located or the Indian tribe on whose reservation the site is located, as the case may be, can submit a notice of disapproval to Congress within 60 days. This disapproval prevents the use of the site for

a repository unless the Congress passes a resolution of siting approval within the next 90 days of continuous session.

(6) If the site designation becomes effective, the DOE must then submit to the NRC an application for construction authorization as part of the licensing process. The application must be submitted not later than 90 days after the effective date of the site designation.

(7) When a construction authorization has been received from the NRC, the construction of the repository will begin.

For the U.S. geomechanics community, there is an immediate need to assemble that which bears on the problem of assessing the suitability of a specific site. A few of the questions that should be asked are:

- Do we have a suite of experiments that are sufficiently well defined and understood that will contribute to the quantification of constructability, confinement, and retrievability at a particular site?
- What experiments/data constitute a necessary and sufficient set?
- What is the relevancy of the experiments?
- Would "critical" rather than "full-blown" experiments be sufficient?
- Are full-scale prototype experiments more appropriate than those yielding more "basic" data?
- If expediency and possibly the present state of the art requires a certain type of "quick-and-dirty" geomechanics review for initial site suitability studies, what type of a continuing program is needed?
- Are the experimental procedures recognized as a standard? Are the corresponding quality assurance procedures developed?
- Are instruments of the standard required available for application?
- Are the data reduction procedures well developed and generally accepted?

Based upon the work to date, it is not possible to provide concrete answers to many of these questions. Perhaps the questions are premature and should not as yet be asked. After all, it is a very difficult problem; much remains before good answers can be provided.

## RECOMMENDATIONS

In an earlier paper on this same subject, one of the authors (Hustrulid) expressed the recommendation that a second GAIN-type meeting be held to discuss where we have been, where we are, and where we are going with respect to the geotechnical basis for the disposal of high-level radioactive waste in deep geological formations. This meeting/workshop has now been scheduled for later this year and is expected to produce an up-to-date summary of the relevant capabilities in geotechnical testing.

The question of where we are going requires special consideration, and we hope to address some aspects in this section. In the past, the geotechnical community has not participated to a high degree in policy formation, rule making, and the formulation of a waste disposal strategy. We have been responders rather than the initiators. The present most pressing concern involves the type of information required at the time of application for construction authorization. It is our understanding of the present NRC position that the construction authorization application "must contain sufficient geotechnical information for the NRC to determine that there is reasonable assurance that the site is suitable." By "suitable" it is meant that it will satisfy retrievability and isolation requirements. What information is needed to provide this assurance? What is "reasonable?" Is it possible to provide such assurance a priori; that is, before construction of the repository has even commenced? Is it "reasonable" to even attempt to assure that the site is totally suitable at such an early time?

It is our feeling that if this interpretation of NRC's position is true, it will be impossible to meet these requirements at an early point in a site evaluation program.

The present situation is viewed as a rather serious and unnecessary stalemate between the DOE and the NRC. To break the current impasse, the geotechnical community is being asked to provide certain input which we feel cannot currently be done. In an effort to contribute to a solution hopefully satisfactory to both the regulators and the regulated, we propose the following.

- We do not believe that a long and expensive review of incomplete data for the site at the time of the construction authorization application is warranted nor needed based upon the stringent requirements for waste containment and retrievability. If the repository were not to operate under these two important requirements, detailed NRC review at the construction authorization stage would certainly be in order.
- We do believe that it is encumbent upon DOE to collect as much information as possible from all the potential sites prior to the submittal of the application for construction authorization. The reason for this exercise should be to minimize the chance that the selected site will subsequently be shown to be unsuitable, thereby wasting a substantial sum of taxpayers and ratepayers money. The reason for the exercise should not be that it is required by NRC to support a construction authorization application. In fact, the NRC evaluation at this stage should be limited to the question of whether the

planned construction (design and procedures) adversely affects the pertinent properties and characteristics of the proposed site.

- Once given construction authorization, the DOE would embark on the next stage of site evaluation. This might include major drifting, establishment of panels, drilling, geotechnical testing, and the initiation of large-scale, long-term tests. One of the primary purposes of the information produced during this stage would be to support the application for an operating license. However, this would be only a license to emplace waste not overall approval of the repository. Therefore, the NRC evaluation at this time need consider only the negative sides of the question: Is there any indication that the site may be found to be unsuitable at some time in the future? Is there any reason why development of the facility should not be continued, waste emplaced, and the testing programs extended?
- With an operating license, the site would become an Emplacement Evaluation Facility until it has been shown to meet all of the performance criteria for a "repository." This could occur fairly early in the operating period, late in the period, or perhaps not until the end of the retrievability period. Regardless of when the repository evaluation is made, this is the time of final commitment. Should not that evaluation and decision be made with the maximum amount of data, information, and actual experience? During the time until this decision and closure of the repository, DOE must be prepared to safely remove all emplaced waste from the facility and reclaim the site.
- With this approach, the two meaningful licenses or authorizations that would be required from the Nuclear Regulatory Commission would be: (1) the operating or waste emplacement license and (2) the closure or "repository" license. The construction authorization ceases to be a major stumbling block and a major point of in-depth review.

In conclusion, a geologic repository is a mine. It may have several pecularities and some unique features, but it is still a mine. In the development of a mine, it is never possible a priori, to have complete knowledge of all aspects of the conditions that will be encountered underground. A new mining operation is approached with the attitude of being prepared to back out of the venture if adverse conditions are encountered, and of modifying, improving, and fine-tuning the operations to accommodate conditions which differ from those expected. A similar approach can be, and we feel should be, utilized for a waste repository, given the retrievability requirement. A commitment to retrieve all emplaced waste and back out if there is ever an evaluation of new conditions or test results suggesting the site may be compromised must be made. The final decision on suitability can be made at the end of the operating period with the maximum amount of data and information in hand (including possibly the results of very long-term tests), rather than very early and based on minimum information. In other words, the retrievability requirement should be used as a mechanism permitting a more rational and orderly approach to the establishment of a repository, rather than as yet another layer of redundancy.

REFERENCES

Anon., 1979, "Geotechnical Assessment and Instrumentation Needs for Nuclear Waste Isolation in Crystalline and Argillaceous Rocks," Proceedings of the GAIN Symposium (July 16-20, 1978), Lawrence Berkeley Laboratory, LBL-7096, UC-70, January.

Anon., 1980, "Basalt Waste Isolation Project, Annual Report - Fiscal Year 1980," RHO-BWI-80-100, November, Rockwell Hanford Operations, Richland, Washington.

Case, J. B., Krug, A. D., and Williams, J., 1980, "Full-Scale Heater Tests #1 and #2 at the Near-Surface Test Facility: Preliminary Results," RHO-BWI-LD-34 (Informal Report), Rockwell Hanford Operations, Richland, Washington.

Chitombo, G. P. F., 1982, "Blast Damage Assessment Using Ultrasonic Cross-hole Measurements," MS Thesis T-2658, Colorado School of Mines.

Cook, N. G. W., et al., 1982, "Progress with Thermomechanical Investigations of the Stripa Site. Geologic Disposal of Radioactive Waste: In Situ Experiments in Granite," Proceedings of the NEA Workshop, Stockholm, Sweden, OECD, October 25-27, pp. 19-31.

Cook, N. G. W. and Hood, M., 1978, "Full-Scale and Time-Scale Heating Experiments at Stripa: Preliminary Results," LBL-7072, SAC-11, UC-70, December, Lawrence Berkeley Laboratory.

Cook, N. G. W. and Witherspoon, P. A., 1978, "In Situ Heating Experiments in Hard Rock: Their Objectives and Design," paper presented at OECD Nuclear Energy Agency Workshop on In Situ Heating Experiments in Geologic Formations, Ludvika, Sweden, September 12-15.

Cramer, M. L., Cunningham, J. P., and Kim, K., 1983, "Rock Mass Deformation Properties From a Large-Scale Block Test," Proceedings of the 24th U. S. Symposium of Rock Mechanics, Texas A & M University, June 20-23.

El Rabba, A. W. M. S., 1981, "Measurements and Modeling of Rock Mass Response to Underground Excavation," MS Thesis T-2470, Colorado School of Mines.

Hardin, E., et al., 1981, "A Heated Flatjack Test Series to Measure the Thermomechanical and Transport Properties of In Situ Rock Mass ('Heated Block Test')," Office of Nuclear Waste Isolation Report, ONWI-260.

Hardin, E., et al., 1981a, "Measuring the Thermomechanical and Transport Properties of a Rock Mass Using the Heated Block Test," Proceedings of the 22nd U.S. Symposium on Rock Mechanics, MIT, Cambridge, MA, June 29 - July 2.

Heuze, F. E., 1981, "Geomechanics of the Climax Mine-By, Nevada Test Site," Proceedings 22nd U.S. Symposium on Rock Mechanics, MIT, Cambridge, MA, June 29 - July 2.

Heuze, F. E., Butkovich, T. R., and Peterson, J. C., 1981, "An Analysis of the 'Mine-By' Experiment, Climax Granite, Nevada Test Site," UCRL-53133, June, Lawrence Livermore National Laboratory.

Holmberg, R., 1981, "Hardrock Excavation at CSM/ONWI Test Site Using Swedish Blast Design Techniques," ONWI Report 140-3.

Hood, M., 1979, "Some Results From a Field Investigation of Thermomechanical Loading of a Rock Mass When Heaters are Emplaced in the Rock," LBL-9392, SAC-26, UC-70, July, Lawrence Berkeley Laboratory.

Hood, M., 1979a "The Application of Field Data From Heater Experiments Conducted at Stripa, Sweden to Parameters for Repository Design," LBL-9392, SAC-26, UC-70, July, Lawrence Berkeley Laboratory.

Hustrulid, W. and Ubbes, W., 1983, "Results and Conclusions From Rock Mechanics/Hydrology Investigations: CSM/ONWI Test Site," Geological Disposal of Radioactive Waste: In Situ Experiments in Granite, Proceedings of the NEA Workshop, Stockholm, Sweden, OECD, October 25-27, 1982, pp. 57-75.

Kurfurst, P. J., Hugo-Persson, T., and Rudolph, G., 1978, "Borehole Drilling and Related Activities at the Stripa Mine," LBL-7080, SAC-05, UC-70, August, Lawrence Berkeley Laboratory.

Montazer, P., 1982, "Permeability of the Unsaturated Fractured Rock Near an Underground Opening," Ph.D. Thesis T-2540, Colorado School of Mines.

97th Congress, 1983, "Nuclear Waste Policy Act of 1982," Public Law 97-425, January 7, 96 STAT.2001-96 STAT.2263.

Nuclear Regulatory Commission, 1983, "10 CFR Part 60," Federal Register, Vol. 48, No. 120, June 21, pp. 28194-28229.

Pratt, H. R., et al., 1977, "Elastic and Transport Properties of an In-Situ Jointed Granite," International Journal of Rock Mechanics and Mining Sciences, v. 14, pp. 35-45.

Richardson, A., 1983, Colorado School of Mines, Golden, Colorado, Private Communication.

Schrauf, T. and Board, M., 1979, "Instrument Selection, Installation, and Analysis of Data for the Spent Fuel Mine-By, Nevada Test, Climax, Stock," Terra Tek Report TR 79-51, July.

Schrauf, T., et al., 1979, "Instrumentation Evaluation, Calibration, and Installation for the Heater Experiments at Stripa," LBL-8313, SAC-25, Lawrence Berkeley Laboratory.

Witherspoon, P. A., Cook, N. G. W., and Gale, J. E., 1981, "Geologic Storage of Radioactive Waste: Field Studies in Sweden," Science, February 27, pp. 894-900.

Witherspoon, P. A., and Degerman, O., 1978, "Swedish-American Cooperative Program on Radioactive Waste Storage in Mined Caverns: Program Summary," LBL-7049, SAC-02, UC-70, May, Lawrence Berkeley Laboratory.

Zimmerman, R., 1983, Sandia National Laboratories, Albuquerque, NM, Private Communication.