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WORKING GROUP ON INTEGRATION OF GEOPHYSICAL TESTS INTO SITE CHARACTERIZATION OF A HIGH-LEVEL WASTE REPOSITORY
APRIL 22, 1991, BETHESDA, MARYLAND

The meeting was chaired by Dr. William Hinze. Participants in the Working Group included: Mr. Carl Johnson, State of Nevada; Dr. Abou-Bakr Ibrahim, NRC HLW staff; Dr. Walter Mooney and Dr. Phil Nelson, U.S. Geological Survey; Mr. Vincent Murphy, Weston Geophysical Corporation; Dr. Jeff Daniels, The Ohio State University; Jack Corbett, ACNW Consultant; and Dr. Chris Fridrich, DOE Yucca Mountain Project Office. In addition, comments were heard from the floor from Dr. King Stablein and Dr. Phil Justus, NRC HLW staff, and Dr. Jane Stockey and Mr. Steve Brocum, DOE OCRWM.

Dr. Hinze opened the meeting with a statement of the objective of the meeting and a brief discussion of concerns and questions related to geophysics for site characterization. He stated that the objective of the working group was to provide the ACNW with knowledge on the role of geophysical methods, both surface and subsurface, applicable to the study of potentially adverse conditions at the proposed high-level waste repository site at Yucca Mountain. He also stated that he believed a related objective should be to investigate and to learn more about the integration of geophysical data and the use of those data in planning and analysis of proposed tests at Yucca Mountain.

Dr. Hinze further explained that the role of geophysical tests in characterization of Yucca Mountain is very important, especially since those type of tests are generally non-intrusive and would not compromise the integrity of the site. He added that the Site Characterization Plan (SCP) of DOE does not define how geophysical tests and results will be integrated and synthesized with other proposed geological and engineering tests and their results. He also noted that the NRC staff had expressed similar concerns in their Site Characterization Analysis (SCA). He stated that the DOE document, "Status of Data, Major Results, and Plans for Geophysical Activities at Yucca Mountain" (white paper), reviews the existing geophysical data and discusses the role of geophysics in site characterization investigations of the site, but the white paper serves only as a starting point for the integration of geophysical activities.

The meeting participants were encouraged to develop discussions of the importance, advantages, and limitations of, and potential results from geophysical methods. Discussion of the importance of timing of geophysical tests and their integration into the results

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and planning of studies at Yucca Mountain was also encouraged. Dr. Hinze stated that geophysical data should be available to also identify the best sites for drillholes, trenches, and drifts.

Some questions that Dr. Hinze put forth for discussion were:

1. What are the roles of the various geophysical methods in determining the existence and location of potentially adverse conditions?

2. What is the sensitivity and resolution of the geophysical methods that are most appropriate for characterizing the structure, composition, and physical properties of this proposed site?

3. How will the various data sets be integrated and what does this suggest regarding the sequencing of tests?

4. What is the next thing to be done to integrate the data?

5. How much testing is required, and of what nature, to validate the appropriate geophysical methods to be used in the study of the proposed site?

6. Is specialized research into the acquisition, processing, and interpretation needed prior to characterization, and, if so, what types of research would be recommended?

7. Can geophysical studies at Yucca Mountain be started without permits from the State of Nevada?

8. Can existing data be qualified so that it can be employed in site characterization and how will it be done?

9. Are there geophysical tests that will be compromised by geological or engineering tests that may precede the actual performance of geophysical tests?

Carl Johnson began the presentations with a discussion of the applicable regulatory requirements, a generic approach for defining an effective geophysical program for site characterization, and the State of Nevada's views of the Yucca Mountain geophysical program.

He stated that there are no specific regulatory requirements for geophysical data or tests, but geophysics should be part of any site characterization program as it can provide information that will aid in the understanding of natural processes. He added that the NRC draft format and content guide for the license application

does state that if geophysical investigations are conducted, those investigations should be described and documented in the license application. Regulatory guides of the NRC also provide a list of information needs, such as stratigraphy, tectonics, geohydrology, natural resources, and rock characteristics, that will require a geophysical data input.

Mr. Johnson noted that geophysical methods are the only cost-effective and non-destructive way to examine large blocks of rock in three dimensions. Dr. Fridrich added that in order to gather the same amount of three dimensional data by drilling rather than geophysical testing, the site would have to be drilled extensively and Part 60 states that drilling should be limited. Mr. Johnson pointed out a need to combine various types of geophysical methods to provide a understanding of the site.

The group discussed the reproducability of geophysical data and Mr. Corbett noted that most geophysical tests are reproducible, but the interpretations may not be and any set of geophysical data is subject to multiple interpretations. Dr. Hinze noted that the white paper specifies that one way existing data may be qualified is by reproducing selected portions of those data. Dr. Daniels stated that types of measurements that are difficult to reproduce probably should not be used. He added that it is important to know the limitations of the different geophysical techniques. "Ground truthing" of the data is always important.

Mr. Johnson added that a combination of multiple geophysical data, combined with high-quality geological data can provide solutions. An effective geophysical program must have the geologist, hydrologist, and geophysicist objectively determining what all of the plausible geological models are for the area of study. For characterization of a potential repository site, a geophysical program should have the objective of identifying the presence or absence of all geological features of regulatory concern. The second objective of a geophysical program is to establish the geological conditions that characterize a region, site, or an area. An ideal program is directed toward achieving scientific consensus by the regulators and the applicant on the three-dimensional geological models or range of models for a region, area, or structure. After the models are established, a well-organized geophysical program can be designed with the objective of refining those models.

Mr. Johnson explained that it is necessary to define a program that will provide a systematic and uniform survey of the region, area, and site, with a level of detail commensurate with the geological

features of concern. The program must also be designed keeping the size and heterogeneity of the geological features in mind.

In comments about the white paper, Mr. Johnson stated the paper is one of the better documents the DOE project has produced. The State of Nevada would like to see similar types of documents for geology, hydrology, and other areas, because of the focus on the current data and how investigations and tests will be designed to resolve issues. He added that a document like the white paper is much clearer than the SCP.

Mr. Johnson noted that there has been work at Yucca Mountain for ten-plus years, and there is still no integrated geophysical program to assist in the understanding of the Yucca Mountain geological system. The State is concerned over the emphasis on feasibility testing in the white paper. They believe that no alternatives have been considered if feasibility testing shows that some of the geophysical methods are not appropriate for use at the site.

Dr. Mooney asked what other tests were needed in light of the fact that all types of geophysical tests are planned? Mr. Johnson explained that "an integrated program is a uniform, systematic program to collect geophysical information across a specific area in order to identify the presence or absence of features of geologic concern." What the State believes is needed is a program that focuses on the evaluation of features that are already identified. He added that gravity and aeromagnetics are the only two geophysical methods that appear to have some uniformity throughout the whole region, area, and site.

Mr. Johnson stated that there also needs to be a geophysical program to examine stratigraphy, structure, and natural resources beneath Yucca Mountain. He reiterated that geophysical methods are the only cost-effective and non-destructive way to obtain three-dimensional data. Those methods are non-unique, and all appropriate geological models must be defined before the geophysical investigations are planned. Geological features and rock properties at all scales should be examined and taken into account in the planning phase and it should be recognized that some geological features of concern for performance assessment may not be resolvable with geophysics.

Dr. Hinze asked what the State was doing in the area of geophysics at the Yucca Mountain site? Mr. Johnson responded that the State does not have a specific program directed toward geophysics, but if funds were available it was an area in which the state would become involved. Dr. Hinze also asked if geophysical studies at

Yucca Mountain could be initiated without state permits. Mr. Johnson responded that the State is processing the permits that deal with surface disturbance such as drilling, trenching, and the construction of roads. If the geophysical techniques do not require those types of surface-disturbance, then there is no reason to delay those studies. The DOE has also applied for a permit for tests requiring the use of radiological tools.

Dr. Abou-Bakr Ibrahim followed Mr. Johnson's presentation. His presentation concentrated on the staff's comments on DOE's geophysical program as stated in the SCP and some comments on the white paper. Staff concerns with the tests as proposed in the SCP were not with the types of tests that DOE planned, but with the indecisive language of the SCP, such as the timing or plans for many tests being listed as "to be determined." Therefore, it was not clear from the SCP which of the geophysical methods identified would be applied in the investigation of Yucca Mountain. In addition, the staff saw plans for single line surveys, but no well-planned grid to produce a uniform data set for the site.

The SCP was not clear on the correlation between different geophysical tests or the approach that would be used to integrate the various tests with each other and with other geological data.

Dr. Ibrahim stated that what he meant by integration was to combine the various geophysical methods such as gravity, magnetic, reflection, refraction, electric, and bore hole to develop a three-dimensional model. He added that for the site scale, he would expect high resolution data.

Other NRC comments on the geophysical program were concerned with the sufficiency of the program to identify and characterize the deep crustal and shallow geological features and their interrelation; volcanic/igneous features and their extent under or close to the site; and zones of natural resources. With respect to volcanic studies, Dr. Ibrahim noted that the white paper directs the reviewer to the Study Plan, but the information is not present in the Study Plan.

Mr. Johnson noted that in the licensing process, the focus is going to be on the types and sizes of features that are missed by the geologic investigations and the importance of those features to the performance of a repository. He added that it is important in developing the geophysical testing program to consider the size of the feature being investigated and ensuring and justifying that features that could be missed by a particular survey are too small to be of concern.

Dr. Ibrahim commended DOE on the white paper which he said gathers all the information regarding geophysics in one report, but he asked what was DOE's next step? He called for DOE to review the existing geophysical data prior to initiating additional geophysical surveys. He stated that integration among activities is needed to ensure that maximum benefit is obtained from geophysical surveys and interpretations to ensure that the characterization program provides timely information appropriate to support a repository license application. One of the areas that he called attention to was the location of the trenches in Midway Valley. He asked if geophysical methods had been used to locate the optimum location for these trenches.

The NRC staff expected the white paper to be more specific about the geophysical activities. They expected the white paper to include locations of the planned geophysical traverses and the interrelation among the various investigations. They also hoped to be provided with the rationale for the locations of test lines and a description of their appropriateness for characterization of the site. Dr. Ibrahim added that the white paper failed to close the NRC staff's SCP comments.

Dr. Stablein stated that the NRC staff did not believe that there was enough new or different material in the white paper to warrant a detailed review and publication of comments by the staff.

Dr. Fridrich stated that part of the information wanted by the NRC would be in the Study Plans and additional information will be in working papers that will address individual issues such as specific geological problems and potentially adverse conditions and DOE's plans to resolve them. He added that he would also like to see more justification for the location of the geophysical lines and a discussion of the specific issues toward which those surveys are directed.

Dr. Hinze asked if the current prioritization of tests study would complement the white paper. Dr. Jane Stockey explained that the prioritization task force effort has been subsumed into the site suitability evaluation that DOE is conducting. After the site suitability evaluation is complete, the prioritization task force will resume. The suitability group has been tasked to re-evaluate the 10 CFR Part 960 qualifiers and disqualifers in terms of data that have been collected since the DOE published the final site environmental assessments. That group also is developing a documentable methodology that will help with the unsuitability evaluations (determination of items that would immediately declare the site to be unsuitable). The preliminary evaluation will be sent to Dr. Bartlett by May 9. A report will be submitted for peer

review in fall 1991 and the final report should be released by January 1992.

Dr. Stockey also stated that some Study Plans are already undergoing revision as a result of ongoing work. Comments from groups external to DOE are also taken into consideration during revisions for the Study Plans, but there is no formal process to notify the commenter unless the revision of the Study Plan was required to resolve the comments.

Dr. Mooney discussed four geophysical techniques that are being used to characterize the proposed site. Those techniques are gravity, aeromagnetic, seismic reflection, and seismic refraction. He explained that by integrated he meant that the geophysicists talk to each other and are trying to use the physical parameters that are determined from one method to constrain the interpretation in each area. Integration also includes the use of other geophysical data from national laboratories and published sources.

Dr. Hinze asked what kind of interaction occurs between the geologists, hydrologists, and geophysicists to define specifications for surveys? Dr. Mooney replied that at irregular intervals there are meetings where all the USGS participants come together. There is also some interaction at the meetings of the Committee for the Advancement of Science at Yucca Mountain. Other contacts include informal interactions and the reviews of Study Plans.

Dr. Mooney showed one area planned for study was the area of the steep hydrologic gradient in the northern portion of Yucca Mountain. The proposed approaches to studying this problem include a shallow seismic refraction line across the gradient and higher-resolution aeromagnetic and gravity data. Additional drilling is also planned.

Mr. Murphy noted that a single line would not provide sufficient information and that a gridded program should be initiated. . Dr. Mooney agreed.

Dr. Mooney was also asked what other geophysical programs are planned to evaluate Paleozoic stratigraphy? He replied that the primary activity in the Paleozoic rocks was surface mapping. It has also been proposed that some deep penetrating refraction profiles be recorded from Death Valley to Yucca Mountain to tie the surface mapping to subsurface structure and define the geometry of detachment faults and the mechanism of extension in the Death Valley area.

Dr. Mooney also discussed the seismic reflection feasibility study that was conducted in the Amargosa Valley. He stated that the resultant data quality was good because of the contract specifications which stipulated that the contractor must have a complete field processing unit so that every day's acquisition effort was processed overnight to find the correct parameters for data collection. The contractor used the best-quality, most advanced equipment available at the time and work was stopped whenever wind speed was greater than about three miles per hour. Because the data collected were part of a feasibility test, the quality assurance criteria did not apply the same as QA would apply for the collection of licensing data.

Mr. Murphy suggested that it may be appropriate to perform the same type of survey on parallel lines around Yucca Mountain.

A peer panel of academic and industrial experts has reviewed the seismic refraction and reflection data collected to date. Dr. Fridrich provided a copy of that report to attendees of the working group.

Dr. Mooney stated that a technical paper using data from the seismic reflection feasibility line has been submitted to the Geological Society of America Bulletin. That report is authored by Brocher, Fox, and Carr and is entitled, "Evidence for Mesozoic Detachments in the Southern Basin and Range." The report discusses the geometry of detachment faults and the mechanics of faulting in the Yucca Mountain area.

Dr. Phil Nelson spoke about borehole geophysical methods for site characterization. He described borehole data from holes that were previously drilled at Yucca Mountain and showed how borehole geophysical data can be combined with geological and mineralogical data to determine zones of zeolites, lithophysae, or fractures and degree of porosity and water saturation.

Dr. Daniels also pointed out that at the Nevada Test Site,the geologists use the density log data to define the degree of welding. As the degree of welding goes up, the porosity decreases and the density increases.

Dr. Nelson showed how the low electrical resistivity deflections correlated with the zeolitic zones in the core. He also showed how the borehole geophysical data could be used to estimate the porosity of the rock and related that to the number of lithophysae in the rock. He noted that the location of zeolites relates

to where the water table once was. He added that the neutron log was difficult to interpret above the water table and is not very reliable under those conditions.

Mr. Vince Murphy provided the Working Group with his views on the application of shallow seismic refraction in site characterization. He also discussed vertical seismic profiling, topographic imaging, and the need for measurements in horizontal drill holes. Mr. Murphy began by stating that in order to interpret the deep seismic profiles, the geophysicist needs shallow seismic data. Shallow seismic studies have been a data gathering problem at Yucca Mountain, but shallow reflection in a range of 100 to 1000 meters depth is an important method that needs to be used at Yucca Mountain.

He advocated the use of horizontal holes to gather geophysical data on vertical fractures and features at Yucca Mountain. He stated that if a thorough geophysical characterization of Yucca Mountain is conducted, most of the major surprises to be found underground will be precluded. He also believes that, if the site is not characterized thoroughly by velocity analysis, there will be surprises with respect to what is underground and at the surface facilities location.

Mr. Murphy believes the seismic refraction studies should be the first studies to be made. He stated that the method of surface seismic refraction profiling is the fastest and easiest method to perform. He added that a gridded system is needed for refraction.

Cross-hole measurements were another method advocated by Mr. Murphy. He believes this method to be especially applicable for characterization of the surface facilities.

Mr. Murphy also discussed a geophysical method to determine the extent of the damage zone around excavations by using velocity measurements. Damage zones in drill and blast excavations vary from a half a meter to two or three meters. Those zones in machine bored tunnels are about half a meter or less.

In summary, Mr. Murphy believes that surface measurements such as sonic logging with multiple source points in the hole are needed. Where there are multiple holes he suggests cross-hole tests. In the subsurface, he suggests that measurements be performed in horizontal holes. He believes that good geophysical data can be collected from the Yucca Mountain area.

Dr. Mooney questioned whether some conventional geophysical techniques will work well at Yucca Mountain.
Dr. Daniels discussed borehole geophysics and ground penetrating radar, with some examples of uses from the Nevada Test Site. He recommended using standard surface geophysical techniques in boreholes to characterize the subsurface geology. This can be done for resistivity, electromagnetics, and seismic techniques. Each technique does have certain limitations and some are more applicable in some areas than others. For example, there are problems in gathering resistivity data in the unsaturated zone, but there are methods that can compensate for those problems. He added that resistivity is used in the unsaturated zone at the Nevada Test Site, along with seismic, gravity, and magnetic methods. He acknowledged that high resolution techniques do not always provide good penetration.

Dr. Daniels advocated the use of hole to hole measurements, rather than single hole reflection techniques, for better data. He believes that tomographic imaging combined with surface techniques and hole-to-surface techniques is a useful tool for defining anomalies.

He is uncertain as to whether ground-penetrating radar can be a useful tool in the Nevada Test Site/Yucca Mountain environment. Ground penetrating radar (GPR), Dr. Daniels stated, should be run at the locations of proposed trenches and after the trenches are cut. GPR should also be run in the bottom and along the sides of those trenches.

Dr. Daniels believes that there are techniques that will help in the definition of the fracture distribution in the unsaturated zone and surface magnetics may be a useful tool to examine an integrated volume of fracturing within the Topopah Springs tuff. Dr. Daniels also stated that instead of individual fractures or faults, the focus should be on the characterization of fault zones. Dr. Fridrich agreed, unless the target is small-scale, such as for specific areas like the locations of exploratory shaft or the surface facilities. He added that for all the hydrologic applications, the focus should be on fracture zones or networks.

Dr. Hinze asked if GPR had been used to examine the calcite/silica veins in trench 14 and the answer was "no."

Mr. Corbett discussed shallow electrical methods for characterization of Yucca Mountain. He showed examples of data that should be integrated into the seismic work for the site. He also stressed the importance of a grid of lines, rather than

randomly placed lines. Also, electrical methods can provide information important to the evaluation of the mineral resource potential of the site.
In commenting on the DOE report of the Technical Assessment Review (TAR), Mr. Corbett stated that the report does address the problem of interpretation of geophysical data, but it leaves the problem unresolved.

According to Mr. Corbett, electrical methods can be used to define shallow faulting, economic resources, shallow aquitards, and possibly the hydrologic gradient. Problems may exist in the definition of unsaturated zone versus the saturated zone due to the high degree of saturation in the unsaturated zone at Yucca Mountain.

Before Dr. Fridrich's technical presentation began, he and Mr. Brocum answered some questions on the programmatic aspects of the project.

Dr. Hinze asked about the status of integration plans and activities for the characterization of the proposed Yucca Mountain site. Dr. Fridrich responded that the SCP laid out all of the data that the DOE proposes to collect. The white paper went a step further and attempted to lay out the coordination between the data collection studies and the different studies that needed the data. The prioritization and integration details are still being worked out. Study Plans are another step in the integrating process.

Dr. Fridrich stated that the project now needs to examine the existing data to determine what is known and plan from that. This type of progress is not made through planning documents, but will involve technical analysis of the problems and issues.

Mr. Brocum explained that the DOE has recently signed a contract with TRW to be the management operating contractor. As such, TRW will be working to integrate the program and provide technical direction. The effort to integrate the program has already begun. Woodward and Clyde is the main earth sciences subcontractor. TRW is now in a 12 to 18 month transition period, but in approximately four months they will provide DOE with a transition plan that will also address the integration of geophysics into the site program.

Mr. Brocum added that the SCP followed the standard format on site characterization plans issued by the NRC.

Mr. Brocum also stated that the DOE has a major effort underway to reassess the site's suitability. This effort should be completed by early 1992. The effort is in two parts. One is to develop a

methodology for site suitability and the second is to implement that methodology. This effort is being conducted by the DOE staff independent of the new contractor, TRW.

Dr. Fridrich spoke about the integration of geophysical and geological data and provided an example of a recent study that he conducted using existing data to examine the problem of the large hydrologic gradient located north of Yucca Mountain. He first reviewed the existing data to determine what information would correlate with the large gradient. Four features that he found to correlate with the gradient were an aeromagnetic anomaly, a heat flow anomaly, a gravity anomaly, and a stratigraphic change at depth across the area of the hydrologic gradient. Based on his interpretation of these data, coupled with regional data, Dr. Fridrich concluded that the gravity anomaly is a buried graben and the reason for the change in the hydrologic gradient is that there is an increase in permeability across this zone due to the position of the contact between the clastic aquitard and the carbonate aquifer.

He suggested that a useful test would be to drill a well in the center of the large gradient. He also recommended that additional geophysical surveys such as gravity and magnetics be conducted across the gradient. Additional analysis of the heat flow data was also suggested along with the gathering of more heat flow data.

Dr. Fridrich stated that these types of technical analyses are needed for the site. He believes that planning documents, strategy planning, and coordination exercises are not the way to assess the site. Dr. Hinze congratulated Dr. Fridrich on providing an excellent example of what integration of geophysical, geological and geochemical data can do.

Dr. Hinze closed the meeting with some conclusions.

1. Geophysics has a major role in characterization at all depths. There are problems with the interpretation of geophysical data, but these problems can be constrained by the addition of geological data and the use of multiple geophysical methods. Some of the problems can be resolved with surface geophysical methods, but to increase resolution the focus will also have to be upon measurements at depth through drill hole methods.

2. Integration and the proper sequencing for the gathering of geophysical data are important. These areas are still not satisfactory, but the DOE has stated efforts are underway to rectify these concerns.

3. The existing geophysical data are valuable as a first step toward the developing feasibility studies, models, and planned tests. Some of the existing data are out-of-date and need to be supplemented with newer techniques and feasibility studies.

Some of the meeting participants had concluding remarks. Dr. Nelson began with comments on the work conducted by Dr. Fridrich. He stated that there are a number of problems associated with the site that could be focused upon in the same manner as the hydraulic gradient. Some suggested problems for review are the state of stress at Yucca Mountain, near-surface percolation, and excavation designs. He suggested that in addition to just thinking about the integration of geophysical data, scientists should work on the "real" problems that will be found in licensing.

Mr. Johnson stated that the type of analysis that Dr. Fridrich conducted is what the State expected to appear in the SCP for all known geologic features of concern. Then based on these analyses and the resultant interpretations, the Study Plans could be developed around resolving those particular features of concern. He suggested that the DOE focus attention on these types of analyses and interpretations to define the various applicable models before a comprehensive and well-focused program of investigations can be defined and carried out. He also added that the types of interpretations and analyses that Dr. Fridrich carried did not require environmental permits.

Dr. Mooney commented that the project investigators see Study Plans as fixed documents that are difficult to change and that none of the data used by Dr. Fridrich was gathered under a study plan.

Ms. Stockey added that all data acquiring study plans (62) are now in the review process or completed. This means that the project investigators should not still be writing, but should be free to pursue the work.

Dr. Hinze encouraged the meeting participants to provide ideas for follow-up to this working group and then closed the meeting.

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Note: A transcript of the meeting is available at the NRC Public Document Room, Gelman Bldg. 2120 "L" STreet, N.W., Washington, D.C., Telephone: (202) 634-3383 or can be purchased from Ann Riley & Associates, LTD., 1612 K St., N.W. Suite 300, Washington, D.C. 20006, (202) 293-3940.