WILLIAMS & ASSOCIATES, INC.

P.O. Box 48, Viola, Idaho 83872 (208) 883-0153 (208) 875-0147

Hydrogeology • Mineral Resources Waste Management • Geological Engineering • Mine Hydrology

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Pohle

(Return to WM, 623-SS)

Mr. Jeff Pohle
Division of Waste Management
Mail Stop 623-SS
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

RE: NTS

Dear Jeff:

A copy of the review of each of the following documents is enclosed.

1. Anderson, L.A., 1981, Rock Property Analysis of Core Samples from Calico Hills UE25a-3 Borehole, Nevada Test Site, Nevada. U.S. Geological Survey Open-file Report 81-1337, Denver, 29 p.

2. Anderson, L.A., 1981, Rock Property Analysis of Core Samples from the Yucca Mountain UE25a-1 Borehole, Nevada Test Site, Nevada. U.S. Geological Survey Open-file Report 81-1338, Denver, 36 p.

3. Klavetter, E.A., and Peters, R.R., July 1986, Estimation of Hydrologic Properties of An Unsaturated, Fractured Rock Mass. Nevada Nuclear Waste Storage Investigations Project, Sandia National Laboratories, Albuquerque, NM, SAND84-2642.

Please contact me if you have any questions concerning these reviews.

Sincerely,

Jim Osiensky

Jim Osiensky

JO:sl

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WMGT DOCUMENT REVIEW SHEET

FILE #:

DOCUMENT #: USGS-OFR-81-1337

DOCUMENT: Anderson, L.A., 1981, Rock Property Analysis of Core Samples from Calico Hills UE25a-3 Borehole, Nevada Test Site, Nevada. U.S. Geological Survey, Open-file Report 81-1337, Denver, 29 p.

REVIEWER: Williams & Associates, Inc., James L. Osiensky

DATE REVIEW COMPLETED: December 15, 1986

ABSTRACT OF REVIEW: APPROVED BY: Roy E. Williams

The report under review presents results of rock property measurements of core samples from borehole UE25a-3. Borehole UE25a-3 is located approximately 12 km east of Yucca Mountain within the Calico Hills. The borehole was drilled to a depth of 771.2 m into Unit J and possibly Unit I of the Eleana Formation. The purpose for drilling borehole UE25a-3 was to obtain rock property data to evaluate the potential suitability of the Eleana Formation in the Calico Hills as an underground repository for nuclear wastes. Core samples from the borehole were measured for density, porosity, resistivity, induced polarization, compressional sonic velocity, and magnetic properties. The report is not significant with respect to the local geology and hydrogeology in the vicinity of Yucca Mountain. However, some of the data presented in the report may be of value with respect to understanding the regional geology and hydrogeology of the Nevada Test Site.

BRIEF SUMMARY OF DOCUMENT:

The report under review describes measurements taken on core samples from borehole UE25a-3 located in the Calico Hills, approximately 12 km east of Yucca Mountain. Forty-nine core samples were collected as part of a large scale site evaluation program to identify potentially suitable underground repositories for radioactive waste products.

Borehole UE25a-3 was drilled to a depth of 771.2 m. The borehole penetrates into Unit J and possibly Unit I of the Eleana Formation. According to the report, Unit J persists to a depth of 720.6 m. Below this level the hole penetrates marble that tentatively has been identified as Unit I of the Eleana Formation.

According to the report, the samples that were believed to be representative of the significant lithologic variations within major stratigraphic units were selected from the core. These samples were "labeled for identification, wrapped in heavy aluminum foil, and coated with beeswax to preserve, as nearly as possible, the in-situ conditions of the rock." The samples were shipped to the USGS laboratory in Denver where they were trimmed to uniform length and measured for electrical resistivity, induced polarization, porosity, bulk density, compressional seismic velocity, and remnant and induced magnetization. Page 3 through 10 of the report describe the laboratory procedures followed for sample measurement.

Table 1 of the report lists the values of electrical resistivity and induced polarization for natural state and saturated samples. Resistivities at 100 hertz (Hz) for natural state and resaturated samples are plotted in Figure 5 of the report with respect to depth of origin. According to the report, rapid changes in resistivity within the borehole reflect the high degree of stratification of the rock column. Resistivity and induced polarization data obtained on saturated samples with a Huntec receiver are plotted against depth on Figure 6 of the report.

Natural bulk density, saturated bulk density, dry bulk density, grain density, and porosity (calculated from density in volume determinations) were measured from samples of the cores. Table II lists these data plus the measured values of compressional sonic velocity. Figure 7 of the report shows bulk density values for core samples plotted as a function of depth. According to the report, the graph of natural bulk density probably reflects the manner with which textural changes occur within the penetrated rock section.

Grain densities of the three argillite subunits are described as being relatively uniform; the report suggests that variations in the grain densities reflect subtle differences in the composition of the argillites. The report notes that the effect of compositional variations on the bulk density of the argillites is negligible compared to the effect on the porosity.

Figure 8 of the report presents porosity and compressional sonic velocity values for borehole samples plotted as a function of depth. According to the report, the velocity shows an inverse dependence on porosity; grain size, lithification, and chemical composition also influence the seismic velocity.

According to the report, magnetic susceptibility and remnant magnetization measurements were made on as many samples as possible following their removal from their protective coating. Figure 9 and Table III present plots and tabulated results, respectively, of these measurements. The report notes that major gaps in the data plot of Figure 9 represent sections of core that disintegrated during handling.

SIGNIFICANCE TO NRC WASTE MANAGEMENT PROGRAM:

The report under review represents a data interpretation report of rock property measurements of core samples from borehole UE25a-3. The report is not significant with respect to the local geology and hydrogeology in the vicinity of Yucca Mountain. However, the report may be of value with respect to understanding the regional geology and hydrogeology of the Nevada Test Site. Data presented in the report are specific to the Eleana Formation in the Calico Hills.

PROBLEMS, DEFICIENCIES OR LIMITATIONS OF REPORT:

The report under review contains no significant problems, deficiencies or limitations. The report is a data interpretation report describing the results of rock property analyses of core samples from borehole UE25a-3.

SUGGESTED FOLLOW-UP ACTIVITIES:

No follow-up activities are suggested.

WMGT DOCUMENT REVIEW SHEET

FILE #:

DOCUMENT #: USGS-OFR-81-1338

DOCUMENT: Anderson, L.A., 1981, Rock Property Analysis of Core Samples from the Yucca Mountain UE25a-1 Borehole, Nevada Test Site, Nevada. U.S. Geological Survey, Open-file Report 81-1338, Denver, 36 p.

REVIEWER: Williams & Associates, Inc., James L. Osiensky

DATE REVIEW COMPLETED: December 15, 1986

ABSTRACT OF REVIEW: APPROVED BY: Roy E. Williams

The report under review is a data interpretation report. Core samples from borehole UE25a-1 on Yucca Mountain were measured for bulk density, porosity, resistivity, induced polarization, compressional sonic velocity, hydraulic conductivity, magnetic susceptibility, and remnant magnetization. This report presents valuable information with respect to the rock properties of the Topopah Spring Member on the eastern edge of Yucca Mountain. Rock property measurements were taken on 59 core samples from the borehole.

BRIEF SUMMARY OF DOCUMENT:

The report under review is a data interpretation report of rock property measurements on core samples from borehole UE25a-1. The borehole was drilled to a depth of 762 m; it penetrates the Tiva Canyon and Topopah Spring Members of the Paintbrush Tuff, the tuffaceous beds of Calico Hills, and the Prow Pass and Bullfrog Members of the Crater Flat Tuff. Fifty-nine core samples were obtained from borehole UE25a-1. Borehole UE25a-1 is one of a series of test holes drilled on the Nevada Test Site to help evaluate potentially suitable strata for an underground repository for nuclear waste. Borehole UE25a-1 is located on the eastern edge of Yucca Mountain

According to the report, core samples were selected so as to be representative of major lithologic variations within the principal stratigraphic units. Core samples were brought to the USGS laboratory in Denver for measurement of electrical resistivity, induced polarization, porosity, bulk density, compressional sonic velocity, hydraulic conductivity, remnant magnetization, and magnetic susceptibility. According to the report, the results of the measurements are to be used for the interpretation of in-hole and surface geophysical surveys, and to provide a means for rock property characterization beyond conventional borehole techniques.

Pages 3 through 9 of the report describe the laboratory procedures used for sample measurements. The results of electrical resistivity and induced polarization for natural state and saturated samples are listed in Table I of the report. Resistivity values measured at 100 Hertz (Hz) are plotted with respect to depth in Figure 5 of the report. Values of porosity and compressional sonic velocity for borehole samples are plotted as a function of depth in Figure 6 of the report. Comparison of Figures 5 and 6 shows that there is an inverse relationship between resistivity and porosity throughout essentially the entire measured section.

According to the report, the resistivity of the Topopah Spring Member generally is high; this is true particularly within the lower two-thirds of the unit showing an inverse correlation with porosity. The report suggests that spherical cavities within specific intervals of the Topopah Spring Member influence the resistivity values strongly. According to the report, resistivities measured in the tuff beds of Calico Hills are appreciably lower than most tuffs of the Topopah Spring Member. The report suggests that the higher porosity of the tuff beds of Calico Hills is the primary reason for the lower resistivity values.

According to the report, resistivity values of samples from the Prow Pass Member of the Crater Flat Tuff vary as a function of changes in texture, the degree of welding, and the intensity of silicification. The report notes, however, that porosity variations are responsible principally for the resistivity changes observed within the Crater Flat Tuff. Resistivity and induced polarization data obtained from resaturated samples are plotted against depth in Figure 7 of the report. The lowest induced polarization values were measured near the base of the tuffaceous beds of Calico Hills. The highest induced polarization values were measured in samples from the Bullfrog Member of the Crater Flat Tuff. The report notes that no obvious explanation exists for the high induced polarization values measured for samples from the Bullfrog Member.

Table II of the report lists measured values of natural bulk density, saturated bulk density, dry bulk density, and grain density. The values of dry bulk density, saturated bulk density, and dry bulk density are plotted against depth in Figure 8 of the report. Sonic compressional velocity data, hydraulic conductivity data, and porosity data (calculated from density and volume determinations) are listed in Table III of the report.

Compressional sonic velocities along with the porosity are plotted as a function of depth in Figure 6 of the report. This figure illustrates the inverse relationship between porosity and sonic velocity. The highest sonic velocities occur within the densely welded tuffs of the Paintbrush Tuff. However, according to the report, acoustic attenuation is apparent near the top of the Topopah Spring Member where cavities within the welded tuff constitute as much as 30% of the bulk volume of the rock.

Intrinsic permeability values (microdarcies) for the samples are listed in Table III of the report. Figure 4 of the report shows a diagram of the stainless steel hydraulic conductivity cell used to measure permeability of the samples. According to the report, gaps in the permeability data are due to sample losses that occurred during the reshaping of poorly welded samples. The report notes also that some samples were unsuitable for measurement because of large lithophysal cavities. A general increase in permeability with depth was measured in the tuffaceous beds of Calico Hills.

Values for magnetic susceptibility, remnant magnetization, induced magnetization, remnant vector inclination, and Koenigsberger ratio are listed in Table IV of the report. Remnant and induced magnetic values are plotted in Figure 9 of the report. This figure shows a dramatic decrease in rock magnetization at the contact of the Paintbrush Tuff and the tuffaceous beds of Calico Hills. The report notes that beneath the Topopah Spring Member, the magnetic properties of the rock are so variable that recognition of formation contacts on the basis of magnetics becomes virtually impossible.

SIGNIFICANCE TO NRC WASTE MANAGEMENT PROGRAM:

The report under review is a data interpretation report of rock property measurements on core samples from borehole UE25a-1 on Yucca Mountain. The report is significant with respect to the NRC Waste Management Program because it presents useful rock property data of the Topopah Spring Member.

PROBLEMS, DEFICIENCIES OR LIMITATIONS OF REPORT:

The report under review contains no significant problems, deficiencies or limitations. The report is a data interpretation report that presents important data with respect to the properties of the Topopah Spring Member.

SUGGESTED FOLLOW-UP ACTIVITIES:

Data reports of this kind should be reviewed so the NRC can keep current records of the data available. This document constitutes a potentially important source of data on the rock properties of the Topopah Spring Member.

WMGT DOCUMENT REVIEW SHEET

FILE #:

DOCUMENT #: SAND84-2642

DOCUMENT: Klavetter, E.A., and Peters, R.R., July 1986, Estimation of Hydrologic Properties of An Unsaturated, Fractured Rock Mass. Nevada Nuclear Waste Storage Investigations Project, Sandia National Laboratories, Albuquerque, NM 87185.

REVIEWER: Williams & Associates, Inc., George L. Blomsburg

DATE REVIEW COMPLETED: December 15, 1986

ABSTRACT OF REVIEW: APPROVED BY: Roy E Williams

Theoretical relationships are developed for combined matrix and fracture flow in the unsaturated zone of Yucca Mountain. Two methods are used: a microscopic method in which the actual geometry and size of pores are considered, and a macroscopic procedure in which the conceptual model of Wang and Narasimhan (1985) is used. Agreement between the two methods is good. Composite curves for hydraulic conductivity as a function of capillary pressure are presented for flow in both the matrix and the fractures. It is assumed and justified that the pressure in the matrix and fractures at a particular elevation is the same during steady downward flow. This report appears to be a good first step in developing the theory for combined matrix and fracture flow.

BRIEF SUMMARY OF DOCUMENT:

The report presents two theoretical developments for the analysis of flow in fractured rock masses in which matrix flow also occurs. The authors first present a general discussion of the Yucca Mountain hydrogeologic system reviewing the various stratigraphic units in the formation. The authors accept the basic conceptual model of the USGS in which there may be diversion of flow along the contact between units. However, this conceptual model is not used in their theoretical development.

The authors also use the conceptual model of Wang and Narasimhan (1985) for the analysis of unsaturated flow within the fractures. They assume an average fracture aperture of 25 micrometers and an average matrix pore diameter of 0.03 micrometers (Peters et al., 1984). These numbers are justified in an appendix of the report from the analysis of mercury injection data. The Wang and Narasimhan (1985) analysis shows that under relatively low values of saturation in the fractures, flow will occur across the fractures from one porous block to another. At high fracture saturation values, the flow will be parallel to the fractures. The implications of this conceptual model are that

1) The fracture conductivity for water movement across the fracture is probably much larger than the adjacent matrix conductivity, thus flow across the fracture is controlled by the adjacent matrix conductivity. The fracture conductivity across the fracture can be replaced by the matrix conductivity in flow calculations.

2) The average fracture conductivity for water movement in the plane of the fracture is a highly non-linear function of fracture saturation or pressure head. If the flux is less than the saturated conductivity of the matrix then the water will tend to flow only in the matrix. If the flux is greater than the saturated conductivity of the matrix then the matrix will saturate and the fractures will also carry water.

The discussion in this report assumes that the distribution of flux in the horizontal direction is uniform and that a definite value of hydraulic conductivity exists for each unit. The variability of hydraulic properties within each unit is not considered. The theory in this report is being used for development of the computer code TOSPAC. The code is not presented in the present report. The development is based upon the equation for conservation of mass (continuity equation) in the absence of either sources or sinks. The equation includes terms for the rate of change of moisture content with time within an element, the flux in and out of an element and a term allowing deformation of the porous medium. When the Darcy equation is substituted into the conservation of mass equation, Richard's equation is obtained. The authors discuss the following two alternatives to modeling a situation where water movement may occur in both fractures and the matrix:

1) Model the fractures explicitly by simulating them in the computational mesh as a second region that has different properties than those of the matrix.

2) Use an equivalent porous medium taking into account that there are two porosity systems: the matrix porosity and the fracture porosity.

In the present situation it is necessary to use the second method since the fractures are small scale and numerous. It would not be possible to map all fractures. Equation development is done on both macroscopic and microscopic scales. The macroscopic model assumes that the fracture and matrix properties are representative statistically of a large volume of rock. Samples of the rock must be used to determine the conductivity and saturation values as a function of pressure head for a representative sample, but there is no actual knowledge of the physical structure of the system. Basically the volume of rock is treated as a black box with the constitutive equation as a transform function and hydrologic properties as coefficients to be determined to relate the input and output parameters.

The microscopic approach considers the microscopic structure of the system, a theoretical analysis of fluid flow in the pores and storage of fluid in the pores, and determines relative conductivity and saturation values as a function of pressure head. The description of size and distribution of pores is based on mercury injection data. Both derivations use capillary bundle theory in their evaluation of hydrologic coefficients.

The authors state that the "calculation of the rise in height of water in a capillary tube as a function of tube radius indicates that for tubes with a radius on the order of a few millimeters, the fluid rise, due to capillary forces, is the same as the tube radius." This statement gives an erroneous impression that this relationship is valid if the radius of the tube is sufficiently small. Such an impression is not valid because the rise is equal to the radius of the tube only at a diameter of 3.86 mm. The quoted statement is then used to justify the limit of applicability for capillary bundle theory to tubes having radii on the order of millimeters. This limit actually has nothing to do with the statement that is quoted above.

The macroscopic derivation consists of writing the continuity equations separately for flow in the matrix and in the fractures. A term is included to allow for flow between the matrix and fractures which is dependent on the pressure difference between the fluids in the fractures and matrix. The authors present considerable discussion to justify the assumption that the pressure in the fractures and that in the matrix is the same. The assumption is justified and completely consistent with information from Yucca Mountain. The justification is based on the fact that pulses of water from the surface are damped out within a matter of a few meters below the surface of Yucca Mountain. Travis et al. (1984) and Martinez (in press) have shown by independent calculations that the penetration distance into fractures in densely welded tuff of low conductivity (similar to those in Yucca Mountain) are on the order of 10 m or less if the fracture apertures are 100 micrometers or less. Wang and Narasimhan (in press) have simulated episodic flooding events which concentrate the estimated annual flux at Yucca Mountain over many years into a time period of 0.2 years. This concentration of annual flux caused little change in hydrologic condition. Wang and Narasimhan (1985) also have simulated drainage of fractures in a welded tuff cube of approximately 1.5 cubic meters. They have shown that the pressure in the fractures and matrix will be the same at the same elevation. The form of the continuity equation which the authors use can be considered to have two general parts:

1) Consideration of all storage aspects of the water within a unit volume, and

2) Flow in and out of the volume due to flow both in the fractures and in the matrix.

The storage terms are written in terms of saturation and are grouped such that one coefficient (capacitance coefficient) is given as a function of pressure head. The capacitance coefficient includes the sum of the storage due to the change of saturation, and compressibility of the matrix, fractures, and water. Curves for the capacitance coefficient as a function of pressure are presented for each of the materials in Yucca Mountain. Information about hydraulic conductivity as a function of pressure head also is presented in the form of a curve for the matrix, a curve for the fracture, and a composite curve for each unit. These curves were calculated from capillary pressure-saturation data by the methods of Brooks and Corey, and Mualem. The two methods are similar.

The microscopic derivation begins with a discussion of the actual geometry of the tuff and uses mercury intrusion data to obtain values for pore sizes and pore size distributions. Data are presented for each of the hydrogeologic units of interest. Analyses of these data show that the fracture aperture was about 25 micrometers while the pore sizes were considerably smaller, although no actual number is given. The Burdine equation was used to calculate the relative permeability from the capillary pressure-saturation data. Both of the above approaches (microscopic and macroscopic) enable the calculation of hydrologic parameters for an unsaturated fractured rock mass. Both methods incorporate the assumptions that the pressure is the same in the matrix and in the fractures and that capillary theory is valid. The latter assumption implies that laminar flow exists and that fracture apertures are small enough for capillary pressure to have meaning. A lognormal aperture width distribution also is assumed. A comparison is made of the hydraulic conductivity vs pressure head for each of the materials for the two methods of analysis. In general, good agreement exists between the microscopic model and the macroscopic model. In the case of the Tiva Canyon unit some discrepancy exists between the two models for pressure heads between 100 and 1,000 meters.

In summary, this is an excellent start in developing the theory of flow in a combined matrix/fracture situation for Yucca Mountain. The development is relatively easy to understand and the results appear to be excellent. Future work should concentrate on the development of a computer code for the use of the author's equations and evaluation of the best method for modeling the variation in hydraulic properties of the various units. The present work assumes that one characteristic sample exists for each of the units in the formation; the variation of hydraulic properties is ignored. The appendices of the report under review,contain a detailed derivation of the flow equation and a comparison of several models of relative hydraulic conductivity. The four models used include the Brooks-Corey, the Mualem, the Fatt and Dykstra and the Burdine equations. The Mualem, and Brooks-Corey relationships are the most consistent.

SIGNIFICANCE TO NRC WASTE MANAGEMENT PROGRAM:

This is one of the better papers to date which focuses on development of a theoretical equation to describe the flow in the matrix/fracture systems. The authors' assumptions are well justified and their theoretical development is easily followed. The development includes the compressibility of water, the matrix, and fractures, due to pressure changes. No field data are presented in the report. This report is a first step in developing capability for correctly modeling the unsaturated zone in Yucca Mountain.

PROBLEMS, DEFICIENCIES OR LIMITATIONS OF REPORT:

The main deficiency of the report under review is that variability of hydraulic properties within each unit is not considered. After a code is developed to handle variable hydraulic properties within each unit, it will be necessary to obtain some field verification of the code.

REFERENCES CITED:

Wang, J.S.Y., and Narasimhan, T.N., in press, Hydrologic Mechanisms Governing Partially Saturated Fluid Flow in Fractured Welded Units and Porous Non-welded Units at Yucca Mountain. Sandia National Laboratories, Albuquerque, NM, SAND85-7114.

Wang, J.S.Y., and Narasimhan, T.N., 1985, Hydrologic Mechanisms Governing Fluid Flow in Partially Saturated, Fractured, Porous Tuff at Yucca Mountain. Sandia National Laboratories, Albuquerque, NM, SAND84-7202.

Peters, R.R., Klavetter, E.A., Hall, I.J., Blair, S.C., Heller, P.R., and Gee, G.W., 1984, Fracture and Matrix Hydrologic Characteristics of Tuffaceous Material from Yucca Mountain, Nye County, Nevada. Sandia National Laboratories, Albuquerque, NM, SAND84-1471.

Travis, B.J., Hodson, S.W., Nuttal, H.E., Cook, T.L., and Rundberg, R.S., 1984, Preliminary Estimates of Water Flow and Radionuclide Transport in Yucca Mountain. Mat. Res. Soc. Symp. Proc., vol. 26, 1039-1047.

Martinez, M.J., in press, Capillary Driven Flow in a Fracture Located in a Porous Media. Sandia National Laboratory, Albuquerque, NM, SAND84-1697.