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UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

December 21, 1994

MEMORANDUM TO: John H. Austin, Chief
Performance Assessment and Hydrology Branch

THRU: David J. Brooks, Section Leader
Hydrologic Transport Section
Performance Assessment and Hydrology Branch

FROM: John Bradbury & Neil Coleman
Hydrologic Transport Section
Performance Assessment and Hydrology Branch

SUBJECT: TRIP REPORT ON THE ACNW MEETING ON GROUNDWATER DATING

We travelled to Las Vegas on October 20-21, 1994, to attend the ACNW meeting on groundwater dating (see attached agenda). This trip was very informative because much of what we saw and heard was new. The first day we visited the site and the second day was devoted to the meeting on recent progress in site characterization techniques. Only the highlights of the trip will be provided in this report.

Thursday, October 20, 1994

The purpose of the first stop on the field trip was to describe work that June Fabryka-Martin has been doing on the effects of the thickness of alluvium on infiltration. She described how the accumulation of chloride in the alluvium can be used to estimate infiltration. From average rainfall per year, concentration of chloride in rainwater, and age of the alluvium, as determined by a dating technique such as uranium-series disequilibrium, one can estimate the amount of chloride that should have accumulated in the soil. If the water does not infiltrate the bedrock, but just evaporates, chloride concentrations should be high; if, however, water passes through the alluvium and infiltrates the bedrock, chloride concentrations in the alluvium should be low. She found that thick deposits of alluvium have high concentrations of chloride, whereas thin cover has low concentrations. Thus, thick alluvial deposits can be effective at reducing infiltration.

This finding may have significance with regard to the extreme erosion Potentially Adverse Condition (PAC). For example, if the term "extreme erosion" is interpreted to mean removal of surface material to the extent where the performance of the repository is affected, then processes that reduce thick accumulations of alluvium could be viewed as cases of extreme erosion. Erosion of bedrock would not necessarily be required for the erosion to be "extreme." This is not the NRC's current interpretation of extreme erosion, which is defined in NUREG-0804 as the occurrence of substantial changes in landforms (as a result of erosion) over relatively short intervals of time.

The second stop was at an North Ramp Geology (NRG) well where air permeability tests were being performed. The person describing the work said that holes along the path of the Tunnel Boring Machine (TBM) (actually, offset some minimum distance) were being drilled and tested at an accelerated rate so that data could be collected prior to conjunction with the TBM. Data can then be

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compared before and after to determine the effect and extent of any disturbance by the TBM.

The third stop was the audit of the tunnel, 25 feet in diameter, with the tail end of the TBM sticking out. A concrete runway extends 200 feet out from the adit. The TBM was not operating during our visit. The working end of the machine was being modified because holes designed to pass drill cuttings were being clogged by large rocks. Progress would resume after the problem is solved.

The next stop was the exposure of the Ghost Dance fault where the cover has been meticulously removed and fractures and faults have been mapped on a scale of 1" = 40'. Mapping on this scale seemed excessive for determining the performance of the repository. Also, one wonders if all of the cover were removed from Yucca Mountain, would the area around the Ghost Dance fault look more highly fractured than other areas?

The fifth stop was the Sundance fault. To the untrained eye, the evidence for this fault was unspectacular. From the Sundance fault exposure, we walked to a trench dug in the bottom of a wash that should expose the trace of the Ghost Dance fault. The walls 15' high and floor of this trench were composed of a sand-gravel mix. The investigator noted that no trace of the fault was present in the trench. He then went on to say that this cover was dated at 10,000 years. Thus, he concluded the movement on the fault is old. However, the fact that this large volume of alluvium was only 10,000 years old could be viewed as evidence for significant erosion in a short period of time. To counter, he noted that the amount of material exposed in trench had collected in the bottom of the wash. A relatively small rate of erosion occurring in the upgradient area of the drainage basin could have accounted for the entire thickness of observed alluvium. He was probably correct, but this type of evaluation seems appropriate for addressing the extreme erosion issue.

We next went to the C-well complex. This set of three closely spaced holes, which are uncased in the saturated zone, will be used to test transport of reactive and unreactive constituents, and colloids and particulates. Of note was the cross-section they had constructed showing the flow directions between the wells. This was accomplished by packing off various intervals of the wells and injecting iodide or bromide in one well, and identifying its arrival in another well. What they found was that there are numerous transmissive intervals intersected by the wells and the flow is affected by the presence of the wells, i.e., water enters a well at one interval, travels either up or down the well to another interval, where it then exits. Additional work at the C-holes must await the purchase of a special, four-conductor cable for the large-capacity submersible pump that will be used in testing. The four-conductor cable is needed to meet specifications for electrical grounding. We also observed the plastic piping that will be used to transport groundwater from the C-hole site during pump testing. The water cannot be released at the site because its infiltration would cause test interference. The pumped groundwater will be piped miles to a spreading basin in Fortymile Wash, near well J-13.

The final stop was the site of the large block experiment. Here the hill side had been carved out leaving a rock pillar, covered with plastic, in the center of the excavation. This block will be heated and the effects on moisture distribution and temperature will be monitored. The person describing this experiment was considerably more reserved with regard to the expectations of the experiment than I have heard in the past from Tom Buscheck. Instead of demonstrating the effectiveness of all the important processes expected to occur in the repository, the purpose of the large block now is to help in designing the more important heater experiments in the ESF. Notably, the fractures exposed in the walls of the excavation appeared to contain calcite. This is important because the wetting characteristics of calcite may be different from the fracture material at the repository horizon.

Friday, October 21, 1994

The viewgraphs used in the presentations in the ACNW Workshop on Groundwater Age Dating are included in the Attachment. The meeting began with a presentation by Stan Davis, who pointed out that groundwater cannot be dated - only certain constituents dissolved in the water can be dated, i.e., the length of time since they have left the atmosphere. He described the difference between residence time and transit time. In the past DOE has suggested that residence time instead of travel time be used to describe water age. Residence time equals the flux divided by the volume through which the water flows. When applied to the unsaturated zone at Yucca Mountain, one would have to determine the volume involved in the flow system. Evidence is accumulating that there are parts of the Yucca Mountain system that are essentially isolated from faster flow paths. To downplay this evidence, DOE is beginning to suggest that more important than evidence for fast pathways is the volume of water that will flow through the repository in 10,000 years. Incorporation of the age of the old, isolated water in establishing the volume of water that would pass through the repository may be inappropriate. Techniques are not yet available to differentiate between old water and young water.

He listed some cosmogenic isotopes not mentioned in the site characterization plan. These are ^{85}Kr and ^{32}Si. The krypton isotope occurs as a gas, but its use has been limited to date because of analytical problems. The silicon isotope has not been used because of complex water rock interactions. However, it is not clear to me why ^{32}Si couldn't be used much the way bomb-pulse ^{36}Cl is used, namely, if one finds an elevated concentration at depth, one must conclude fast pathways.

Austin Long described the advantages and disadvantages to C-14 and tritium dating. He showed the effect of mixing of old waters and young waters. Small additions of young waters to old water can significantly reduce the age of resulting water calculated using C-14. Small additions of old water to young water, on the other hand, do not significantly increase the age of the water. He described global variations of these isotopes over the time they are effective. The changes due to natural processes such as sunspot flare-ups are insignificant, but changes due to nuclear testing are important. However, for tritium bomb pulse effects are quickly fading due to the short half-life. The

concentration of C-14 in the troposphere is still about 15% above prebomb-pulse levels.

Neil Plummer talked about the corrections needed for isotopic dating of groundwater by C-14. He pointed out that the corrections only make the age of the water younger. These corrections involve chemical changes affecting the initial C-14 activity of the infiltrating water such as carbonate dissolution, gypsum dissolution, etc., and chemical changes affecting C-14 activity as the water flows underground. He used NETPATH, a mass balance code to adjust the ages of groundwaters in the vicinity of Yucca Mountain. Using the model of Fontes and Garnier, which he prefers, he calculated an age for J-13 of 4955 years as opposed to the unadjusted age of 9900 years. It should be noted that the C-14 age of J-12 is 600 years younger than J-13. J-12 is to the south of J-13, presumably down stream based on head data. Thus, ages from C-14 don't agree with flow models where groundwater is moving to the south.

Following the discussion of C-14 dating, Plummer described the use of chlorofluorocarbons (CFCs), in dating groundwaters. The method is to analyze the water for CFCs, guess the recharge temperature, and calculate the atmospheric concentrations using Henry's law. The calculated atmospheric concentrations can then be compared with known concentrations versus years to get the time the water became isolated from the atmosphere.

The next speaker was Don Thorstenson who described the use of C-14 and CFCs to trace UZ gas transport at Yucca Mountain. The holes that are sampled are UZ1, UZ6 and UZ6S, and shallow neutron logging holes. Of note is the evidence from $\delta^{13}C$ suggesting little or no reactions between gas and porewaters or minerals. This is important because all performance assessment modeling to date has assumed the C-14 transport has involved equilibrium between gas and liquid. This evidence suggests the performance assessment modeling has been nonconservative.

Previous models had assumed diffusion was the only mechanism moving C-14 into the mountain. Consequently, travel times of C-14 into the deeper levels of the mountain were thousands of years. Now by combining the information from CFCs with the C-14 data, it has been recognized that mixing of air, near-surface gas, and deep rock gases is required to explain the data. Additional information suggesting the mixing of various CO_2 sources is apparent in UZ6 where the CO_2 concentration increases significantly at the deepest sampling port. Dead carbon from the rock is probably mixing with meteoric carbon to give an erroneously old age. The significance of this new conceptual model is that instead of a quiescent mountain in which gas constituents slowly diffuse, Yucca Mountain may breathe deeply and efficiently mix the gas constituents. This finding may also play a role in the pneumatic pathways issue, i.e., the effects of the ESF may be extend far from the workings because the deep system has high gas permeability.

There is an alternate way of looking at the gas analyses described at this meeting. These analyses were from open boreholes which have been described as blowing and sucking, depending on the season. One could imagine the short travel times of gas constituents to be a result of the mixing in the borehole alone and not characteristic of the mountain. Consequently, all the gas

analyses from open boreholes would be suspect. Notably UZ-1 and UZ-14 are very close to one another. UZ-1 is a stemmed hole but UZ-14 is currently open. Might the open hole interfere with analyses from the stemmed hole?

John Stuckless described more examples of problems associated with collecting precise chemical information from imprecise drill holes. In the past, a common method to determine depth to the water table was to coat a steel tape with salt and lower it into the hole. The salt would dissolve to the height of the water table. It is now recognized that adding salt to the water may interfere with ^{36}Cl data. Another problem was the use of pipe dope on drill stems and casing joints. The dope contains molybdenum and other constituents which could interfere with analyses. These procedures have been dropped.

The DOE does not have a compendium of human-induced phenomena at the site that could influence hydrochemical dating methods. This would include volumes of drilling fluid losses in boreholes, tracers used in drilling fluids, use of salt on well tapes, composition of drilling foams for "dry" drilling, composition of pipe lubricants, well zones influenced by cement injection, etc. A representative of the M&O said that a proposal for such a compendium had been made, but no specific commitment yet exists.

Al Yang described comparisons between H-3, C-14, and C-13 in both liquid and gas in the unsaturated zone. He pointed out that gas collected from a borehole such as the stemmed UZ-1 is sampling fracture gases. Gases and liquids from squeezed core are samples of matrix fluids. Thus, inconsistencies between fluid compositions may be a result of the isolation of one flow regime from the other. (Marty Mifflin stated that CFCs are not reported in UZ-1 because the hole is contaminated with them or their concentrations are unexplainable.)

Of particular note, is the description of drilling UZ-14. We have told DOE in the past that they must sample water from as close to the water table as possible to get water that will be part of the flow path instead of deep in the saturated zone. At UZ-14 they drilled to 1965' where the water table should be, but no water was observed. Drilling was continued another 240' to 2206' at which point the hole began to fill with water. In three days the water level had reached 1965'. It is most likely that fractures carry water in the saturated zone and no fractures were intersected for 240'. The composition of this water may be different from water in fractures at the water table. Thus, it may not be possible to always collect water at the water table itself, due to rocks of low hydraulic conductivity in some areas.

June Fabryka-Martin described her work with ^{36}Cl in dating of water in the unsaturated zone. The two methods she uses are bomb-pulse ^{36}Cl, and $^{36}Cl/Cl$ ratio. The bomb-pulse method can show evidence for fast pathways on the order of 40 years; the ratio method can show travel times measured in thousands to hundreds of thousands of years. The bomb-pulse technique seems to be a viable approach to dating UZ water. One caveat we hear more and more is that even though there are indications of fast pathways, these probably don't amount to a significant proportion of all of the pathways. Of course, if one eliminates from consideration all pathways that are on time scales much greater than that

of the repository, then the fast paths may make up a significant proportion of those influencing the site performance.

The ratio method requires that the source of Cl is known. Thus, if the rock is a source of dead Cl, the ratio would be reduced, and old dates would be mistakenly calculated. In order to differentiate meteoric from rock Cl, June is measuring the Br/Cl ratio. She originally thought that the meteoric ratio was well defined, and thus could be used to subtract out the rock source of Cl. Now she is not so sure. More variability occurs than she once thought would be present. What is confusing is, if the rocks of the unsaturated zone are 10 million years old, hasn't it been raining Br on them for that long? What does the Br/Cl ratio tell you?

Bo Bodvarsson described how before emplacement of wells, the Yucca Mountain system will be modelled. Then after wells are emplaced and more data is collected, modeling will be done again and the two models will be compared. He acknowledged that the presence of an impermeable cap would be important to site performance. Starting this year, Bodvarsson (LBL) will be using isotopic data from Yang, Fabryka-Martin, and others to constrain and calibrate his 3-D model of unsaturated flow.

Alan Flint briefly described his view of the unsaturated zone. He pointed out that for bomb-pulse dating techniques to work, i.e., ^{3}H or ^{36}Cl, you need rain along with high atmospheric concentrations to get these isotopes into the subsurface. We have had many dry years, with only a few wet years. Wet years lead to fracture flow. He went on to say we do not have a steady state system.

Discussions with Alan Flint suggest that perched zones at Yucca Mountain can exist based on matrix flux alone. If so, some perched zones should have ancient isotopic ages. Isotopic analyses of perched water should resolve this issue, and demonstrate whether some perched zones exist due to recharge from fast flow paths.

Zell Peterman used $\delta^{87}Sr$ to suggest that perched water of UZ-14 is from water percolating down, and is not a remnant from an earlier rise of the regional water table.

In the wrap-up it was agreed that much work remains to be done. Coordination between investigators was of prime concern. Multiple techniques will be used on the same sample to provide supporting evidence. A pledge toward improved coordination among researchers was made - Al Yang (USGS) and June Fabryka-Martin (Los Alamos) plan to analyze differing isotopes at the same intervals in wells. This would help confirm post-bomb recharge if separate isotopes (i.e., ^{3}H and ^{36}Cl) are elevated in the same zones.

For further information (including viewgraphs of presentations), please call John Bradbury at 415-6597 or Neil Coleman at 415-6615.

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Attachment: Final Agenda

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JOHN BRADBURY
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October 3, 1994

FINAL AGENDA

ADVISORY COMMITTEE ON NUCLEAR WASTE
WORKING GROUP MEETING
OCTOBER 21, 1994
SAN REMO HOTEL, LAS VEGAS, NV

USES AND LIMITATIONS OF GROUNDWATER DATING METHODS

Groundwater Dating Methods

8:30 - 8:45 a.m.	Opening remarks by Working Group Chairman and Consultants
8:45 - 9:30 a.m.	Overview of Groundwater Age Dating Methods- Applications, Reliabilities, and Uncertainties Stan Davis, University of Arizona
9:30 -10:15 a.m.	C-14 and Tritium Dating Methods, Applications, Reliabilities and Uncertainties Austin Long, University of Arizona
10:15- 10:30 a.m.	* * * BREAK * * *
10:30 -11:15 a.m.	Netpath Code for C-14 Modeling and Use of Chlorofluorocarbons to Date Groundwater Niel Plummer, USGS
11:15 - 11:45 p.m.	Use of C-14 and Chloroflurocarbons to trace UZ Gas Transport at the Proposed Yucca Mountain Site Don Thorstenson, USGS
11:45 - 1:00 p.m.	LUNCH (1 hour and 15 minutes)

Results of Isotopic Dating in the Unsaturated Zone at Proposed Site

1:00 - 1:30 p.m.	Overview of Status of Groundwater Age Dating Studies at the Proposed Yucca Mountain Site and Regulatory Significance of Age Dating John Stuckless, USGS
1:30 - 2:00 p.m.	Status of H-3, C-14 and Stable Isotope Studies to Date Groundwater in the Unsaturated Zone at the Proposed Yucca Mountain Site --Results and Interpretations Al Yang, USGS
2:00 - 2:30 p.m.	Status of Cl-36 Studies to Date Groundwater in the Unsaturated Zone at the Proposed Yucca Mountain Site--Results and Interpretations June Fabrika-Martin, LANL

Attachment

2:30 - 2:45 p.m.	* * * BREAK * * *
2:45 - 3:15 p.m.	Comparison of H-3 Cl-36 and C-14 Age Dating Results to Preliminary Modeling of Groundwater Flow Rates through the Unsaturated Zone, B. Bodvarsson, LBL
3:15 - 3:45 p.m.	Use of Strontium and Uranium to Date Fracture Fillings and Perched Water at UZ-14 Zell Peterman, USGS
3:45 - 4:45	Roundtable Discussion
4:45 p.m.	Adjourn