CENTER FOR NUCLEAR WASTE REGULATORY ANALYSES

TRIP REPORT

SUBJECT: ACNW Working Group Meeting on Uses and Limitations of Groundwater Dating Methods (20-5702-442 and 20-5704-175)

DATE/PLACE: October 21, 1994
Las Vegas, Nevada

AUTHOR(S): David Pickett (CNWRA)
David Turner (CNWRA)

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PERSONS PRESENT:

CNWRA	NRC
David Pickett	John Bradbury
David Turner	Neil Coleman

The ACNW working group on groundwater dating was comprised of M. Steindler, W. Hinze, J. Garrick, and P. Pomeroy; ACNW staff and consultants present included S. Conrad, K. Foland, P. Davis, D. Leap, and L. Deering. Total number of attendees was around 50.

BACKGROUND AND PURPOSE OF TRIP:

A working group of the Advisory Committee on Nuclear Waste (ACNW) of the Nuclear Regulatory Commission (NRC) met to hear presentations on the principles of groundwater dating, the uncertainties and limitations of its application, and its uses at Yucca Mountain (YM). Understanding of these methods is important in assessing conceptual models of groundwater flow at YM.

SUMMARY OF PERTINENT POINTS:

Introductory comments from the working group and its consultants, were followed by presentations and by experts on fundamental aspects of the methods, talks covering applications of ^{14}C, chlorofluorocarbon (CFC), tritium, and ^{36}Cl dating at YM and vicinity, a talk on U and Sr isotopic tracers at YM, and a comparison of isotopic data with modeling results. A notable feature of the meeting was the presentation of a significant amount of relatively new data from the unsaturated zone (UZ) at YM. The meeting agenda is attached, but note that agenda titles did not always match actual presentation titles. Copies of overhead figures from the talks are available from the authors of this report.

SUMMARY OF ACTIVITIES:

Members of the working group (most notably M. Steindler and W. Hinze) and their consultants (K. Foland, S. Conrad, P. Davis, and D. Leap) opened by relating their objectives in calling the meeting. Chiefly, they wished to better understand the uncertainties and limitations of groundwater dating and its uses in performance assessment (e.g., GWTT) and in constraining conceptual models.

S. Davis (University of Arizona) made the first presentation, entitled "Overview of Groundwater Dating Methods - Applications, Reliabilities, and Uncertainties." A key point was that these methods do not actually date water; typically, an atmospherically-derived component of water (e.g., C, Cl) is "dated" based on a series of assumptions. Factors which must be considered include open-system water-rock interaction which can change isotopic abundances, variable initial conditions, and the possibility of subsurface production of isotopes. Examples emphasized the ^{36}Cl method (half-life = 301 ka), with discussion of possible dilution by rock Cl and the use of the pulse in environmental ^{36}Cl produced by atmospheric nuclear weapons testing. Davis noted that the ^{81}Kr method (half-life = 210 ka) is quite promising due to the lack of subsurface production and reactivity, but it is analytically challenging.

A. Long (also of the University of Arizona) then discussed in more detail the use of the ^{14}C and tritium (^{3}H) methods. Included was a useful outline of attributes and drawbacks for each method. He examined in some detail the effects on ^{14}C (half-life = 5700 years) dates of contamination by modern or "dead" carbon, improvements in analytical tools, and the use of the "bomb pulse" in observing very young water. Tritium is useful on a much shorter time scale (half-life = 12 years) and its input function has also been greatly perturbed by atmospheric weapons testing (an advantage that is now, of course, diminishing).

N. Plummer of the United States Geological Survey (USGS) gave a talk on the use of the NETPATH code to correct aquifer ^{14}C ages for water-rock-gas interaction. This provided a vivid demonstration of the sensitivity of groundwater ages to variable environmental effects; in an extreme case, a 20 ka age was adjusted to zero. Plummer then described the use of chlorofluorocarbons for dating. This method takes advantage of the time-dependent global production of synthetic CFCs, and attendant increase in atmospheric concentration, over the past 50 years. Atmospheric CFC concentrations as a function of time are reasonably well constrained; by defining a temperature dependent distribution content between air and water, CFC groundwater concentration can thus be used to theoretically define the atmospheric concentration, and pinpoint the time of recharge. He outlined the various sources of possible error in age estimation, including recharge temperature and sources of excess CFC contamination.

D. Thorstenson (USGS) discussed the use of ^{14}C and CFCs to characterize gas transport in the UZ at YM (from the regulatory standpoint of gaseous radionuclide transport). Borehole gas ^{14}C measurements (which are not new) reveal post-bomb gas in the top 100 m of the Tiva Canyon. In general, there is a steady increase in ^{14}C age with depth, but in some boreholes (e.g., UZ-6) there are anomalously young measurements that are insensitive to sample depth ($\sim$85 PMC from near the surface to approximately 400 m). However, gas samples indicate that the Paintbrush nonwelded tuffs are a barrier to ^{14}C transport, and samples from the Topopah Spring suggest that transport occurs at much slower rates at depth. These data can be enhanced by comparison with travel times and gas-water interaction parameters imposed by CFC data. In general, ages calculated using two different CFCs are very young (up to an order of magnitude younger than ^{14}C dates) and agree within a year of one another. Additional calculations suggest that there is little interaction between the gas phase and the pore waters for some wells. Other wells (the N70 series) suggest that there is nearly complete interaction between gas and water.

J. Stuckless (USGS) began the afternoon session with an "Overview of the Status of Groundwater Age Dating at the Proposed Yucca Mountain Site and Regulatory Significance of Age Dating." The two key regulatory issues addressed were groundwater travel time (GWTT) and hydrologic response to climate change. The talk began with a caveat regarding the quality of much of the groundwater isotopic data from earlier samples because of serious potential contamination problems. A summary of saturated zone water ^{14}C results stated that apparent travel times are greater than 1000 years but that these may be too old due to interaction with "dead" carbon. Uranium-series and ^{14}C ages of borehole calcites suggest UZ water movement over the past 400 ka up to as recently as 20 ka ago. Other isotopic and age data indicate water movement and discharge at levels about 100 m above present water table within the past 15-20 ka. This talk emphasized indirect isotopic means of estimating groundwater histories, rather than actual groundwater dating.

A. Yang (USGS) then presented data on extracted UZ pore waters, with emphasis on ^{14}C and ^{3}H profiles. His approach to the numbers was significant in that he did not interpret data directly in terms of "ages," but rather used the isotopes as tracers of flow. The profiles feature abrupt changes in isotopic character which preclude a well-mixed flow system with a dominant vertical component. Rather, flow is localized in small zones of rapid transport with a significant lateral component, most significantly within the bedded and Calico Hills units (e.g., very high ^{3}H measured in the Calico Hills). UZ gas ^{14}C data were also presented; they are most consistent with diffusion as the dominant gas transport mechanism. Notably, Yang also reported that perched water samples had been obtained recently from the UZ; no data from them were reported.

J. Fabryka-Martin (Los Alamos National Laboratory) spoke on ^{36}Cl work in the UZ of Yucca Mountain. She presented the results of three approaches to utilizing ^{36}Cl and chloride data for characterizing groundwater flow. In the first, Cl concentrations were used to estimate downward fluxes; these were quite low in deep alluvium profiles (<0.8 mm/yr) but, in the Paintbrush and Calico Hills, fluxes were higher than expected from permeability of overlying strata. Second, Fabryka-Martin used the presence of bomb-pulse ^{36}Cl in borehole cuttings to deduce localized rapid transport, indicative of a highly heterogeneous flow system. Third, she calculated maximum water residence times from ^{36}Cl of 100-300 ka in the nonwelded Paintbrush and Calico Hills and 500-700 ka in the welded Topopah Spring.

Z. Peterman (USGS) discussed Sr and U isotopic data on perched water samples from borehole UZ-14 (referred to above in the summary of Yang's talk). He related difficulties in interpretation brought about by the possibilities of: (i) migration of drilling fluids from nearby earlier boreholes, (ii) inadvertent introduction of J-13 water into UZ-14, and (iii) contamination by drilling and cementing materials. With reasonable allowance for these possible contaminants (better for Sr than U), it appears that the UZ-14 perched water is isotopically distinct from saturated zone water. Peterman concludes that the water accumulated from downward flow, acquiring its Sr isotopic signature from interaction with soil-zone calcite. This talk did not address dating.

In the final scheduled presentation, G. Bodvarsson (Lawrence Berkeley Laboratory) gave a talk entitled "Use of Environmental Isotopes in the Modeling of Moisture and Gas Flow at Yucca Mountain," in which he addressed the issue of GWTT and comparison of model results and isotopic dating. The relatively limited amount of comparison suggests broadly consistent model predictions at the scale of an order of magnitude, but this work appears to be too preliminary from which to draw firm conclusions. Typically, modeled vertical moisture flow is highest to the north of Yucca Mountain, consistent with higher infiltration rates proposed for these areas. The gathering of new data is required to provide additional constraints to further calibrate the model. Inconsistent age dates calculated using different

radioisotopes is a problem. Additional work in the near future will focus on incorporating new geochemical data, and expanding the domain of the model to include additional faults. There is an ongoing effort to predict the conditions for new wells and the ESF as data become available.

A. Flint (USGS) gave a brief, unscheduled talk relating isotopic data to some of his results in studies of soil-zone infiltration at YM. An interesting point he made was that downward flux estimates based on tritium may be underestimated because of relatively low precipitation during the years of the "bomb pulse." He also pointed out that, matrix flux alone is sufficient for creating the observed perched water zones in many areas of YM. Also, the perched zones that have been encountered to date are typically in the northern part of Yucca Mountain, where infiltration is higher.

In the concluding roundtable discussion, M. Steindler outlined three areas of uncertainty that he felt were not adequately addressed by the day's presentations: (i) analytical uncertainty and quality of data, (ii) sensitivity of Cl and C isotopic systematics to the effects of surface processes, and (iii) the role of colloids and bio-organics in ^{14}C transport. In response to the first concern, R. Barnard (DOE), A. Yang (USGS), and others pointed out that error bars on the "ages" were not critical because: (i) TSPA models use conservative uncertainty distribution functions and (ii) the uncertainties in interpretation of the ages far exceeds any analytical error (e.g., error bars on an age do not mean much if you are not even sure it is an age).

IMPRESSIONS/CONCLUSIONS:

The session made it clear that, strictly speaking, groundwater dating is a daunting task. Interpretation of these isotopic data is a complex effort that combines considerations of hydrologic, geochemical, and environmental conditions. This was evidenced by the common lack, in the day's talks, of actual age information, However, many indirect ways of deducing GWTT were discussed. Nevertheless, these studies are valuable in providing *tracers* of site-specific processes critical to repository performance; for example, confirmed presence of "bomb-pulse" nuclides is powerful evidence for recent flow. While laboratory analytical uncertainties do not appear to limit application of these systems, sampling conditions must be considered; examples of potential sources of erroneous results include drilling fluid from older boreholes and anomalous environmental isotopic sources from the adjacent Nevada Test Site. Despite these caveats, isotopic studies of this type can be expected to continue to provide constraining information on hydrologic/geochemical processes. Particularly promising are ongoing perched water studies.

PROBLEMS ENCOUNTERED:

None.

PENDING ACTIONS:

None.

RECOMMENDATIONS:

None.

REFERENCES:

None.

SIGNATURES:

David A. Pickett
Research Scientist

11/10/94
Date

David R. Turner
Senior Research Scientist

11/10/94
Date

CONCURRENCE SIGNATURES AND DATE:

H. Lawrence McKague - Manager
Geologic Setting

11/15/94
Date

Robert G. Baca - Manager
Performance Assessment
& Hydrologic Transport

11/16/94
Date

Budhi Sagar
Technical Director

11/18/94
Date

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attachments

FINAL AGENDA
ADVISORY COMMITTEE ON NUCLEAR WASTE
WORKING GROUP MEETING

UNITED STATES
NUCLEAR REGULATORY COMMISSION
ADVISORY COMMITTEE ON NUCLEAR WASTE
WASHINGTON, D.C. 20555

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

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