Preliminary Analysis of Some Waters From the Confined Aquifers Underlying the Hanford Site

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MASTER

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PRELIMINARY REPORT

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PRELIMINARY ANALYSIS OF SOME WATERS
FROM THE CONFINED AQUIFERS UNDERLYING
THE HANFORD SITE

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Program Director
Basalt Waste Isolation Program

September 1978

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A B S T R A C T

This report presents results of analyses available at this point in time from waters from some wells sampled in or near the Hanford Site. The analyses of these wells were done for various purposes and are consolidated to help us define the nature of the waters found within the Columbia Plateau basaltic sequence. Results of the analyses show the waters from the unconfined aquifers underlying the Hanford Site are characterized by a high calcium-magnesium content. These waters can be described as calcium-magnesium-bicarbonate-type. Waters from deeper basaltic confined aquifers are primarily of the sodium bicarbonate type. Two waters sampled from the Grande Ronde Formation from Rattlesnake Hills Exploratory Well Number 1 are slightly different and can be described as sodium-calcium-bicarbonate-sulfate-chloride-type. Age-dating results for these water samples lead to the conclusions that waters from the confined aquifers were entrapped 15,000 to 23,000 years ago.

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SUMMARY

This report presents results of analyses available at this point in time from waters from some wells sampled in or near the Hanford Site. The analyses of these wells were done for various purposes and are consolidated to help us define the nature of the waters found within the Columbia Plateau basaltic sequence. Results of the analyses show the waters from the unconfined aquifers underlying the Hanford Site are characterized by a high calcium-magnesium content. These waters can be described as calcium-magnesium-bicarbonate-type. Waters from deeper basaltic confined aquifers are primarily of the sodium bicarbonate type. Two waters sampled from the Grande Ronde Formation from Rattlesnake Hills Exploratory Well Number 1 (RSH-1) are slightly different and can be described as sodium-calcium-bicarbonate-sulfate-chloride-type. Age-dating results for these water samples lead to the conclusions that waters from the confined aquifers were entrapped 15,000 to 23,000 years ago.

INTRODUCTION

The geology and hydrology of the Hanford Site have been extensively studied since nuclear operations were started over 30 years ago. Numerous papers and reports detail salient features of the aquifers underlying the Hanford area.^(1, 2, 3) In addition, the stratigraphy of the underlying strata has been summarized recently⁽⁴⁾ as shown in Figure 1.

Complete chemical analyses are available for many wells penetrating the unconfined aquifer* underlying the Hanford Site. These analyses have been reported previously.^(1, 2, 3) A more limited number of analyses exist for the uppermost confined aquifers.^(1, 2)** Table I depicts the typical composition of both the unconfined and uppermost confined aquifers. Table II shows results of analyses of one of the uppermost confined aquifers. Since

*Unconfined Aquifer - A water table aquifer in the unconsolidated and semi-consolidated sediment overlying the basalts.

**Uppermost Confined Aquifer - Waters obtained from or stratigraphically above the Mabton Member⁽⁴⁾ and strata between it and the uppermost surface of the Columbia River basalts.

FIGURE 1
STRATIGRAPHY OF THE PASCO BASIN

V7808-6

TABLE IAVERAGE COMPOSITION OF WATERS FROM AQUIFERS
UNDERLYING THE HANFORD RESERVATION

(Numbers in parentheses denote the range of values found.)

<u>CONSTITUENTS</u>	<u>UNCONFINED AQUIFER</u>	<u>UPPERMOST CONFINED AQUIFERS</u>
Sodium (mg/liter)	29 (16-64)	40 (4.1-122)
Calcium (mg/liter)	48 (31-72)	15 (1-18)
Magnesium (mg/liter)	12 (7.1-14)	7 (0-11)
Chloride (mg/liter)	13 (3.1-24)	16 (3.8-81)
Sulfate (mg/liter)	58 (20-150)	9 (0-29)
Bicarbonate (mg/liter)	172 (115-315)	152 (93-180)
Carbonate (mg/liter)	0 (0)	3 (0-15)
Hardness, total (mg/liter)	170 (110-220)	66 (3-96)
Potassium (mg/liter)	6.8 (4.6-13)	9.0 (4.5-17)
pH	8.0 (7.5-8.1)	8.0 (7.2-8.7)

TABLE II

RESULTS OF ANALYSIS OF THE INTERVAL 540-620-FOOT DEPTH
OF ARH-DC-1 (UPPER CONFINED AQUIFER) DURING CONSTRUCTION OF THE WELL

<u>CONSTITUENT</u>	<u>AMOUNT</u>	<u>QUANTITY</u>
SiO ₂	46	mg/liter
Na	79	mg/liter
K	7.8	mg/liter
Ca	2.1	mg/liter
Mg	0.3	mg/liter
Fe	0.10	mg/liter
HCO ₃	199	mg/liter as CaCO ₃
CO ₃	10	mg/liter as CaCO ₃
SO ₄	0	mg/liter
Cl	4.2	mg/liter
F	1.0	mg/liter
NO ₃	0.1	mg/liter
B	0.06	mg/liter
T.D.S.	250	mg/liter
Conductivity	344	micromhos/cm at 25°C.
pH	8.46	-

this sample was taken from an upper confined aquifer at the interval 540-620 feet during construction of Well ARH-DC-1, results should reflect a representative sample uncontaminated from any lower waters. Representative samples from the Vantage Sandstone Member and below have been heretofore nonexistent.

This report summarizes results of analyses conducted during the past two years in some wells within or near the Hanford Site. Sampled intervals range from the uppermost confined aquifers to horizons nearly 3,000 feet below the land surface. These investigations were not totally part of the Basalt Waste Isolation Program.

SAMPLING

A number of wells (DB-1, DB-2, DB-4, DB-7, DDH-3, 699-53-103, and 699-52-52) were sampled by Battelle, Pacific Northwest Laboratories for the Atlantic Richfield Hanford Company during the month of August 1976. Complete chemical analyses were obtained for Wells DB-1, DB-2, DB-7, and DDH-3. Carbon-14 age dates were determined for all wells, and O^{18}/O^{16} ratios were measured for all except Well DB-4. Tritium-3 analyses were obtained for DB-1, DB-2, DB-7, DDH-3, and 699-53-103. In addition, RSH-1 was sampled in May 1977 by Atlantic Richfield Hanford Company and a complete chemical analysis was obtained. No age-dating data are available for Well RSH-1. The locations of all wells sampled are shown in Figure 2.

All sampling was done by the Water and Land Resources Section of Battelle, Pacific Northwest Laboratories, except for Well RSH-1 which was sampled by Atlantic Richfield Hanford Company. Well DB-1 has a water level within a few meters of the ground surface. A conventional centrifugal pump was used to both flush the well and subsequently sample it. Well 699-53-103 is artesian and a water sample was directly obtained. For all other wells sampled, the water levels in the wells were below the capabilities for a centrifugal pump and, therefore, an air lift method was employed. The method entails the use of a long sampling tube being lowered into the well and air pressure from an air compressor used as the driving force to bring the water to the surface. All wells were sampled until a reasonably clean sample was obtained. In the case of DDH-3, diesel oil and drilling mud contamination was detected and could not be removed even after

FIGURE 2

HANFORD AREA MAP SHOWING LOCATION OF WELLS SAMPLED

extensive well clean out. Thus, DDH-3 results are not representative of aquifer water and are simply given for completeness. For all other water samples obtained, the air lift method provided reproducible results. Well RSH-1 was sampled using a swab unit while testing for hydraulic conductivity in selected zones of the Grande Ronde Formation.

Duplicate samples for chemical composition were taken in all wells sampled and are reported in Tables III and IV.

ANALYSES

The chemical analyses were done by various laboratories under quality assurance procedures prepared jointly by Atlantic Richfield Hanford Company and Battelle, Pacific Northwest Laboratories. The project was under the direction of Dr. M. W. Grutzeck of Atlantic Richfield Hanford Company. The analytical work was divided as follows:

Major Constituents - United States Testing Company, Richland, Washington;

Trace Constituents - United States Testing Company, Richland, Washington;

C^{14} - Washington State University, Pullman, Washington;

O^{18}/O^{16} - Teledyne Isotopes, Westwood, New Jersey;

3H - University of Miami, Miami, Florida.

Laboratories were provided with blind samples. Duplicate samples were provided in all cases. Standard samples and blanks were also included in the suites to be analyzed.

RESULTS

Results of the analyses are reported in Tables III-VI. Table III shows the major constituents, while Table IV summarizes the trace constituents. Results of the C^{14} and O^{18} analysis are summarized in Table V. Table VI summarizes the results of the 3H analyses.

INTERPRETATION

Waters from the unconfined aquifer underlying the Hanford Site are characterized by a high calcium and magnesium content (Table I). They can basically be described as calcium-magnesium-sulfate-bicarbonate waters. On

TABLE III

MAJOR CONSTITUENTS: ANALYTICAL RESULTS

(Sampling dates are in parentheses.)

Constituent	DB-1 (8-9-76)		DB-2 (8-17-76)		DB-7 (8-11-76)		DDH-3* (8-11-76)		RSH-1 (5-11-77)		Units
SiO ₂	27.8	28.8	31.6	31.8	36.4	36.4	29.0	29.0	22.5	22.5	ppm
Na	75.0	75.0	150.0	150.0	106.0	117.0	166.6	172.3	30.0	25.0	ppm
K	14.0	14.0	12.5	12.5	12.5	12.5	23.0	22.0	9.0	7.7	ppm
Ca	3.5	8.0	4.2	4.5	2.5	2.5	10.5	8.0	6.5	8.5	ppm
Mg	0.70	0.90	0.18	0.20	0.50	0.50	1.40	1.20	1.0	2.2	ppm
Fe	.155	.105	0.53	0.63	2.72	3.82	3.8	4.0	.08	<.02	ppm
HCO ₃	208.8	219.6	196.4	192.8	135.7	121.4	192.8	191.0	42.8	67.3	mg/l CaCO ₃
CO ₃	0	0	21.4	21.4	35.7	50.0	99.9	114.2	0	0	mg/l CaCO ₃
SO ₄	<.5	<.5	.5	.5	1.0	.5	1.0	1.0	23.0	15.0	ppm
Cl	12.2	11.8	134.5	117.5	53.0	52.0	83.5	82.5	16.2	8.8	ppm
F	3.0	3.5	2	<1	7.0	8.7	15.0	18.0	0.7	0.7	ppm
NO ₃	.5	.5	<.5	<.5	.5	.5	<.5	<.5	<.05	.20	ppm
B	.25	.25	.6	.6	.8	.7	.5	.4	<.05	<.05	ppm
T.D.S.	345	307	430	417	531	505	861	914	118	112	mg/liter
TOC	29	28	14	16	27	28	160	160	9	9	mg/liter
Cond.	400	430	430	440	450	475	460	560	250	250	micromhos/cm
pH	8.2	8.3	8.6	8.6	9.0	9.0	9.1	9.1	7.3	7.4	
	Water from Mabton Inter-bed sampled with centrifugal pump.		Water from Mabton Inter-bed sampled with air-lift device and air compressor.		Water from Mabton Inter-bed sampled with air-lift device and air compressor.		Water from Lower Frenchman Springs and Vantage members sampled with air-lift device and air compressor.		Water from Grande Ronde Formation sampled by swabbing.		

*Anomalously high metal ion content confirmed sampling of stagnant water containing diesel oil and drilling muc.

TABLE IV

TRACE CONSTITUENTS: ANALYTICAL RESULTS

(Sampling dates are in parentheses.)

Trace Constituent	DB-1 (8-9-76)		DB-2 (8-17-76)		DB-7 (8-11-76)		DDH-3 (8-11-76)		RSH-1 (5-11-77)	
Zn	24	16	14	15	600	655	790	750	2,560	39,000
Cu	15	15	10	12	15	19	30	25	20	50
Hg	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05	<.05
Sb	10	<8	<8	<8	10	15	70	55	<3	<3
Ba	22	30	39	35	43	42	74	53	140	50
Be	.8	.9	1.3	1.2	.8	1.2	.8	1.1	NA	NA
Cd	<.5	<.5	<.5	<.5	1.0	1.5	1.5	1.5	.2	.6
Cr	2	<1	<1	<1	14	33	750	480	<25	<25
Co	6	7	7	5	6	5	8	5	2	2
Pb	19	17	15	13	31	41	38	15	7	12
Mo	67	20	<1	<1	40	15	107	120	2	2
Ni	7	10	8	11	15	13	19	11	NA	NA
Ag	1.5	1.0	1.0	1.5	0.8	0.8	1.5	0.5	<2.5	<2.5
Sr	7	5	2	3	4	3	8	5	NA	NA
Sn	14	17	14	14	5	5	6	10	NA	NA
Tl	11	11	12	15	11	13	7	8	NA	NA
V	<2	<2	8	9	13	14	22	19	NA	NA
Unit Sampled	Mabton Member		Mabton Member		Mabton Member		Lower Frenchman Springs/Vantage Member		Grande Ronde Formation	

NA = Not analyzed for.

* = All constituents are expressed in parts per billion.

TABLE V
C¹⁴ AND O¹⁸ ANALYSES

<u>WELL</u>	<u>C¹⁴ AGES (YEARS)</u>	<u>δ¹⁸O VERSUS SMOW*</u>
DB-1	20,500 ± 500	-17.6
DB-2	23,000 ± 500	-17.6
DB-7	15,400 ± 500	-17.4
DDH-3	4,200 ± 140**	-15.2**
699-53-103	16,800 ± 250	-18.0***
DB-4	15,400 ± 250	NA†
699-52-52	19,900 ± 500	-18.0††

*Standard Mean Ocean Water.

**Anomalously high metal ion content indicates sampling of stagnant water containing diesel oil and drilling mud.

***Mixed water from several confined aquifers.

NA=Not Analyzed

† Water from between the Mabton and Vantage.

†† Water from the uppermost confined aquifer.

TABLE VI
RESULTS OF ^3H ANALYSES

<u>WELL</u>	<u>^3H RANGES</u>
DB-1	Below Detection
DB-2	Below Detection
DB-7	Below Detection
DDH-3	46-53 pCi/l*
699-53-103	Below Detection
Upper Confined Aquifers Range	500-4,000 pCi/l
Unconfined Aquifer	10^3 pCi/l - 3×10^6 pCi/l
Concentration Guide USDOE Manual Chapter 0524	3×10^6 pCi/l
Level of Detection	1 pCi/l

*Contaminated sample.

the other hand, the waters in the uppermost confined aquifers are primarily sodium-bicarbonate (Table I).

Generally, waters from basaltic aquifers are characterized by high ratios of calcium to sodium and of magnesium to calcium, a relatively high silica content, and a relatively high fluoride content.⁽⁵⁾ The waters in the uppermost confined aquifers (Table I) and those values reported in Table III for the uppermost confined aquifer are atypical basalt waters and appear to be influenced by the sedimentary interbeds and not the basalt proper. The water from Well RSH-1, obtained from the Grande Ronde Formation, is slightly different and can be described as a sodium-calcium-bicarbonate sulfate-chloride water; however, its composition is also atypical of basalt waters.

LaSala and Doty⁽⁶⁾ have examined numerous water analyses of Columbia Plateau basaltic aquifers. They concluded that the waters were typical of those found in sedimentary aquifers. The silica content of these waters indicates near-equilibrium with a silica phase having properties similar to those of chalcedony or cristobalite. The silica probably comes into solution from feldspars and other minerals, but at a concentration higher than that at which it would be in equilibrium with quartz.^(7, 8) The solubility of quartz is particularly low and would account for only 5 to 15 parts per million SiO_2 in the water. Other silicate minerals, however, have solubilities intermediate between quartz and amorphous silica (40 parts per million).

The major constituents of the waters obtained from Wells DB-1, DB-2, DB-7, and RSH-1 are depicted in semi-logarithmic diagrams in Figures 3 through 6, respectively. The equilibrium pH with respect to CaCO_3 of all these waters is higher than the actual pH. The results from the analyses are also fairly close in the duplicate samples.

Application of the Palmer classification⁽⁹⁾ to the waters from DB-1, DB-2, DB-7, and RSH-1* shows that all the waters are Class I waters and, in the bulk of the samples, the primary alkalinity is dominant, indicating waters in contact with sedimentary strata. Well DB-7 shows also a high primary salinity, probably due to the basaltic influence on the water composition.

*Well DDH-3 water was not further studied, since the sample appeared to be contaminated.

FIGURE 3

MAJOR CONSTITUENTS IN DB-1 (DUPLICATE SAMPLES) WATER FROM THE MABTON MEMBER

FIGURE 4

MAJOR CONSTITUENTS IN DB-2 (DUPLICATE SAMPLES) WATER FROM THE MABTON MEMBER

FIGURE 5

MAJOR CONSTITUENTS IN DB-7 (DUPLICATE SAMPLES) WATER FROM THE MABTON MEMBER

FIGURE 6

MAJOR CONSTITUENTS IN RSH-1 (DUPLICATE SAMPLES) WATER FROM THE
GRANDE RONDE FORMATION

In the waters depicted in Figure 3 through 6, sodium is the predominant cation present. These waters appear to be in equilibrium with a feldspar of about equal calcium and sodium content.

The cation-anion balances of the waters from DB-1, DB-2, DB-7, and RSH-1 are within 0.8 to 14.8 percent, averaging 5.5 percent. In over 60 percent of the samples, the balance is within 2 percent.

The main trace constituents are Zn, Cu, Ba, Pb, and Mo. Zinc is present in concentrations as high as 39 parts per million (RSH-1 sample; Table IV). Well water from DDH-3 shows anomalously high Cr and Mo. Potential sources of contamination in DDH-3 are diesel fuel and molybdenum disulfide grease, which were probably used during drilling operations.

The U. S. Geological Survey⁽⁶⁾ analyzed the C^{14} content of the bicarbonate dissolved in water from the uppermost confined aquifers in Well ARH-DC-1 within the Hanford Site. Their measured C^{14} content was then adjusted for the dilution effects of carbonate mineral solution, using the C^{13} value of bicarbonate.⁽¹⁰⁾ They found an adjusted age of about 13,000 years before present. The same procedure was followed for the wells in Figure 2 whose dates are reported in Table V. Adjusted ages range from 15,400 to 23,000 years before present. Results for DDH-3 denote some contamination.

The $\delta^{18}O$ versus standard mean ocean water values reported in Table V are representative of waters recharged during a glacial stage when a colder climate prevailed. Results for DDH-3 reflect some contamination.

Further, the 3H results (Table VI) show very low 3H in the confined aquifer system sampled, probably due to lack of interconnection between these and aquifers closer to the land surface. The results for DDH-3 reflect some contamination.

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