See Pocket 3 for encl.

OAK RIDGE NATIONAL LABORATORY
OPERATED BY MARTIN MARIETTA ENERGY SYSTEMS, INC.

POST OFFICE BOX X
OAK RIDGE, TENNESSEE 37831

August 23, 1984

Dr. D. J. Brooks
Geotechnical Branch
Office of Nuclear Materials Safety
and Safeguards
U.S. Nuclear Regulatory Commission
623-SS
Washington, D.C. 20555

Dear Dave:

Enclosed is a copy of Gary Jacobs trip report to ONWI on August 22, 1984, MR-3.4, along with copies of the vu-graphs presented.

Sincerely,

Susan

Susan K. Whatley, Manager
Engineering Analysis and Planning
Chemical Technology Division

SKW:kk

Enclosures

cc: G. K. Jacobs
SKW-File

1445

See folder for ltr. to D. J. Brooks frm. S. K. Whatley 8-23-84

MR-3.4
8/23/1984

TRIP REPORT

AUTHOR: Gary K. Jacobs

LOCATION: Battelle Project Management Division, Columbus, OH

DATE: August 22, 1984

PURPOSE: Attend Geochemistry Program Overview for ONWI

PROJECT TITLE: Technical Assistance in Geochemistry

PROJECT MANAGER: Susan K. Whatley

ACTIVITY NUMBER: ORNL #41 37 54 92 4 (189 # B0287)
NRC #50 19 03 01

PARTICIPANTS: List was not available at time of departure.

AGENDA: See attachment 1

MEETING OBJECTIVE:

The objective of the meeting was to have ONWI present an overview of their geochemistry program to the NRC. The meeting was not intended to provide indepth information or to discuss regulatory issues or concerns of the NRC in any detail, rather the information was to include what type of data is being collected and a few examples of the data. In this way the NRC would get a feeling for the emphasis ONWI is placing on geochemistry. Future meetings will probably focus on specific issues, sites, and data in more detail.

OBSERVATIONS AND COMMENTS:

The presentations by the staff of ONWI provided excellent summaries of the current status of geochemistry in the ONWI program. Copies of the vu-graphs presented are included as Attachment 2. Major areas which were covered included: (1) Site Characterization, (2) Waste Package Interactions, and (3) Performance Assessment. Because detailed discussions of the material presented were not encouraged, little insight could be gained in any of the areas discussed. However, a few general observations follow.

(1) ONWI is not placing any emphasis on radionuclide retardation in the far field because of the nature of salt deposits (i.e., the hydrologic conditions at the sites tend to isolate the repository horizons from the likely flow paths in the far field). However, ONWI is characterizing the geochemistry of these far field flow paths in great detail.

(2) ONWI is placing much emphasis on the geochemical conditions in the near field as they may affect the performance of the waste package. Although much work has been done on brine migration in the past, ONWI is continuing to address this mechanism in order to reduce the uncertainty in estimates of water accumulation around waste packages (most of this work is going on in the rock mechanics section of ONWI, although the nature and amount of inclusions in the salt is obviously a part of the geologic characterization effort).

(3) In general, ONWI is still in the early stages of data collection and has not made firm plans to address all the issues as yet. However, ONWI appears to be cognizant of the uncertainties involved and will probably begin to address more details of data collection in the future. It would probably be beneficial to the NRC and ONWI to have detailed discussions concerning plans for data collection and performance assessment early in this period of planning.

GEOCHEMISTRY OVERVIEW

- Salt Repository Project -

August 22, 1984

Conference Room "C"

8:30am	Introduction	J. Sherwin/SRPO
8:40am	Introductory Comments	R. Johnson/NRC
9:00am	Site Characterization	N. Hubbard/ONWI

- Geological and Hydrological Settings: Palo Duro, Paradox, Gulf Coast
  - location and sizes of aquifers
  - water chemistry
  - origin of water chemistry
  - residence time (groundwater age)
  - radionuclide retardation
- Chemical Composition and Amounts of Brine
  - fluid inclusion brines: Palo Duro, Paradox, Gulf Coast
  - brines produced should external ground water intrude the host rock: Palo Duro, Paradox, Gulf Coast

10:00am	Laboratory Testing of Waste Package Components and Radiation Effects	D. Clark/ONWI

- Corrosion Rates of Mild Cast Steel in brines, with and without radiation
- Effects of Radiolysis on Brines and Salt
- Radionuclide Release in the Brine - Overpack - Waste Form System

10:30am	Performance Assessment	J. Kircher/ONWI

- Waste Package Lifetimes
  - expected conditions
    - brine migration
    - brine chemistry
    - radiolysis
  - breached by groundwater external to the salt
    - brine chemistry
    - radiolysis

11:30am Natural Analogs — N. Hubbard/ONWI

- Salton Sea
- Oklo
- Morro to Ferro

11:35am Closing Summary — N. Hubbard/ONWI

Major Points:

- Amounts of brine that migrate to waste package are inadequate to breach it;
- Waste package dominates near-field chemistry;
- Brines resulting from breaching are less corrosive than fluid inclusion brines, except perhaps at Paradox;
- No exit from salt under expected conditions;
- Extremely long travel times outside salt, especially at Palo Duro.

12:00 Lunch

SITE CHARACTERIZATION

GEOCHEMISTRY

OVERVIEW MEETING
WITH
NUCLEAR REGULATORY COMMISSION

22 AUGUST 1984

PRESENTER: NORMAN HUBBARD

ONWI
Office of Nuclear Waste Isolation
BATTELLE Project Management Division

NH:8/22/84

SUMMARY OF GEOCHEMICAL INVESTIGATIONS

GEOHYDROLOGIC SYSTEM

- Hydrochemistry
  - Flow paths
  - Residence times (ages)
  - Interaquifer relationships
- Radionuclide Transport
  - Travel time
  - Retardation
- Baseline for Monitoring
  - Water quality
  - Natural and fallout radionuclides

HOST ROCK (SALT)

- Amount and Chemical Composition of Brine in Salt
  - Fluid inclusions
  - Inter-granular brine
- Source of Brines
  - Chemical data
  - Isotopic data

SHAFT AND SEALS

- Chemical Environment
  - Mineralogy of Rock
  - Chemical composition of water

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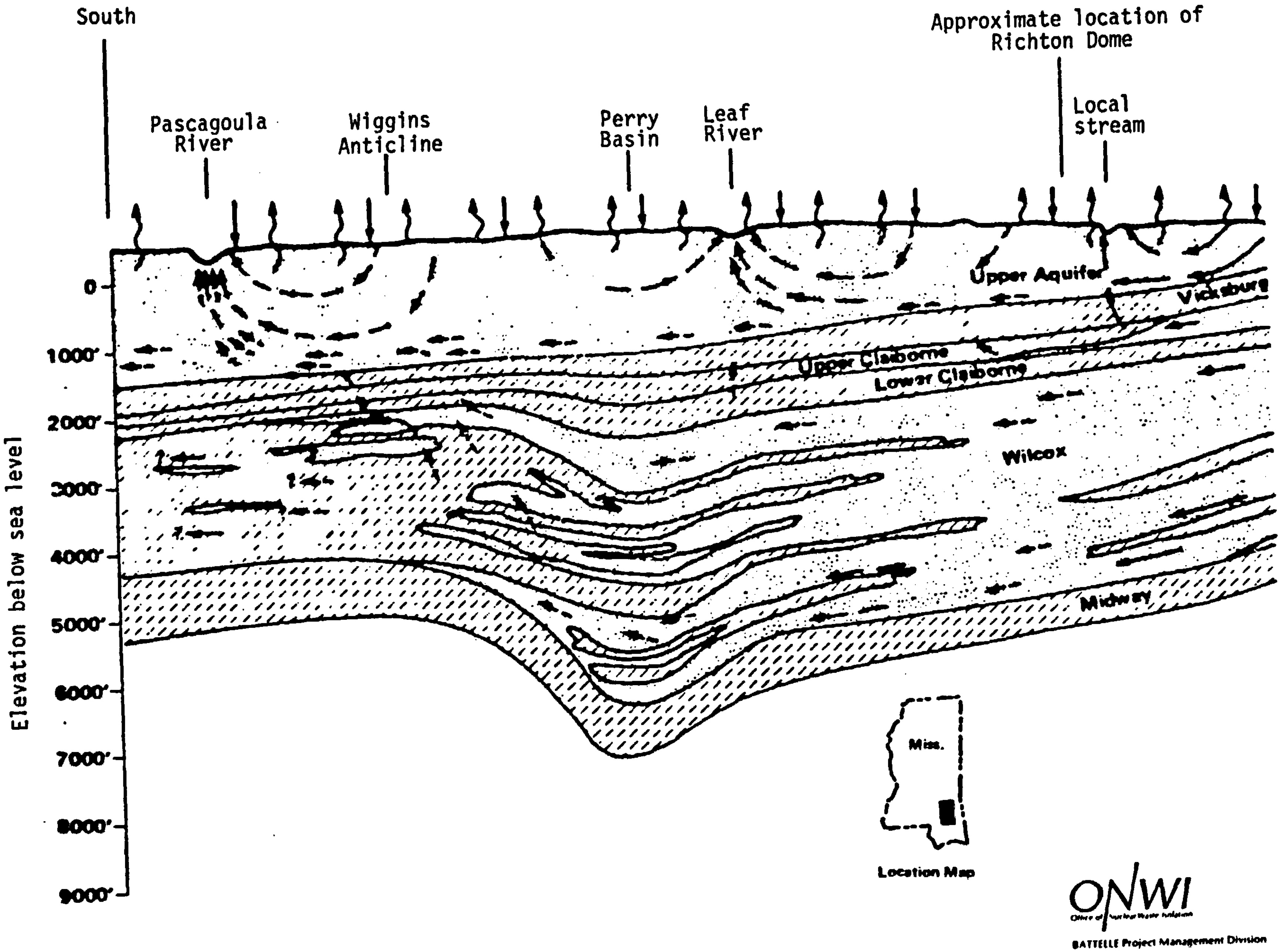
South
Pascagoula River
Wiggins Anticline
Perry Basin
Leaf River
Approximate location of Richton Dome
Local stream
Upper Aquifer
Vicksburg
Upper Claiborne
Lower Claiborne
Wilcox
Midway
Elevation below sea level
0
1000'
2000'
3000'
4000'
5000'
6000'
7000'
8000'
9000'
Miss.
Location Map
ONWI
BATTELLE Project Management Division

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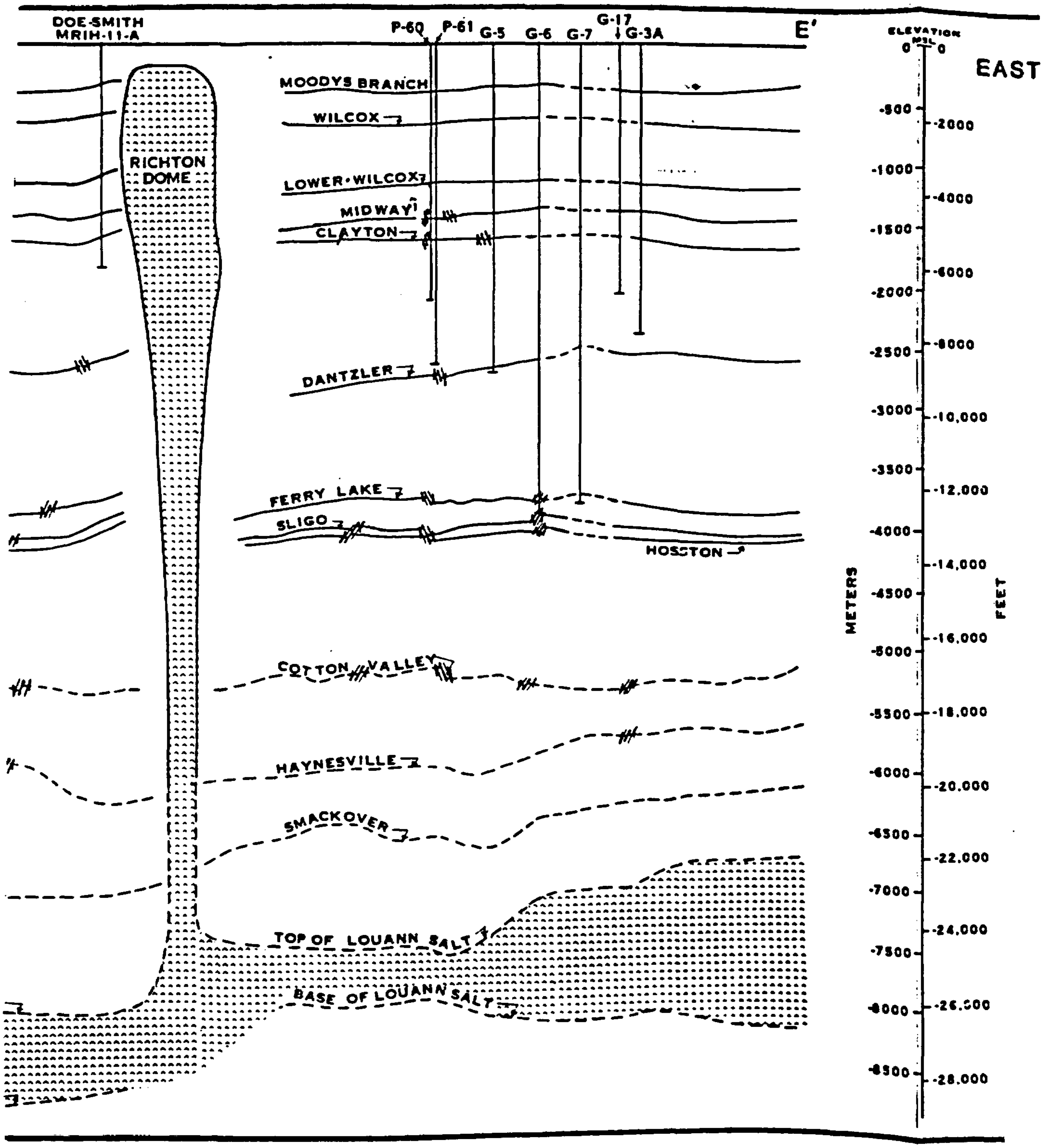

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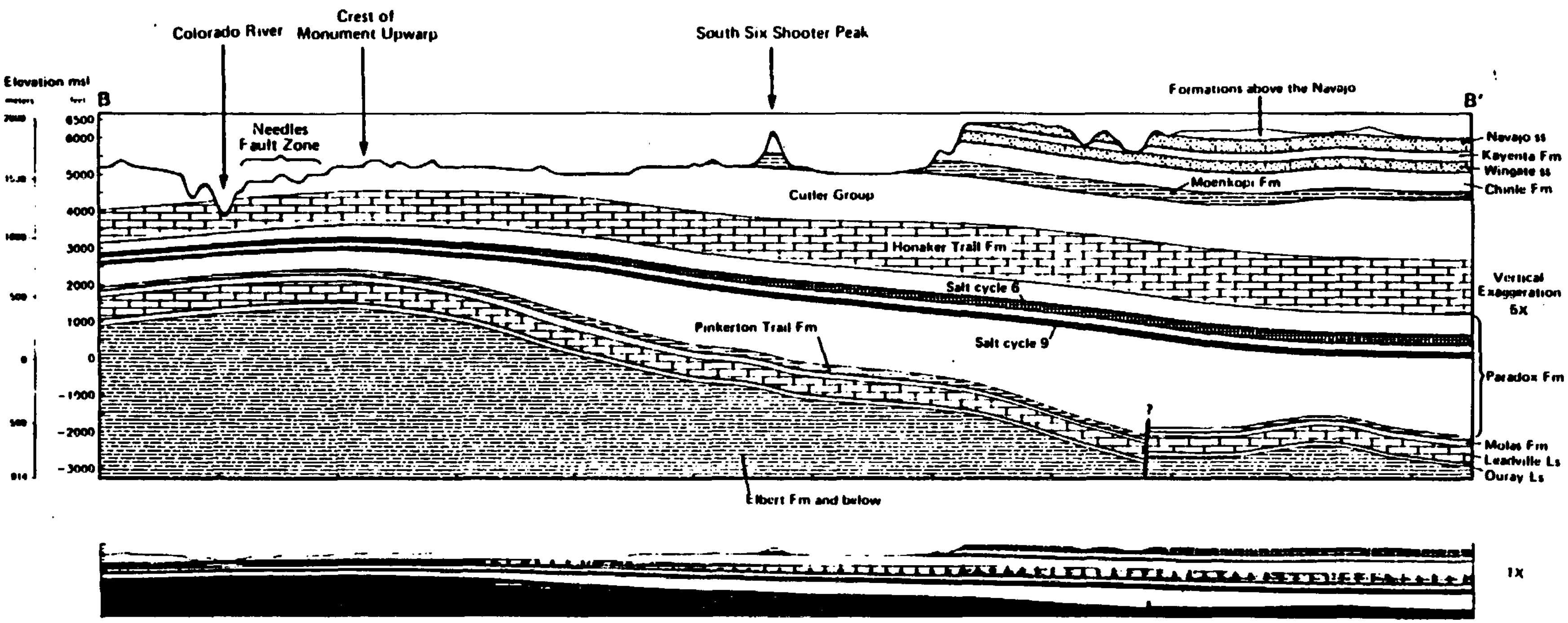
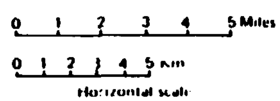


NOTE:
Refer to Figure 3-11 for location of cross section



East–West Computer-Generated Cross Section

Figure 3-12

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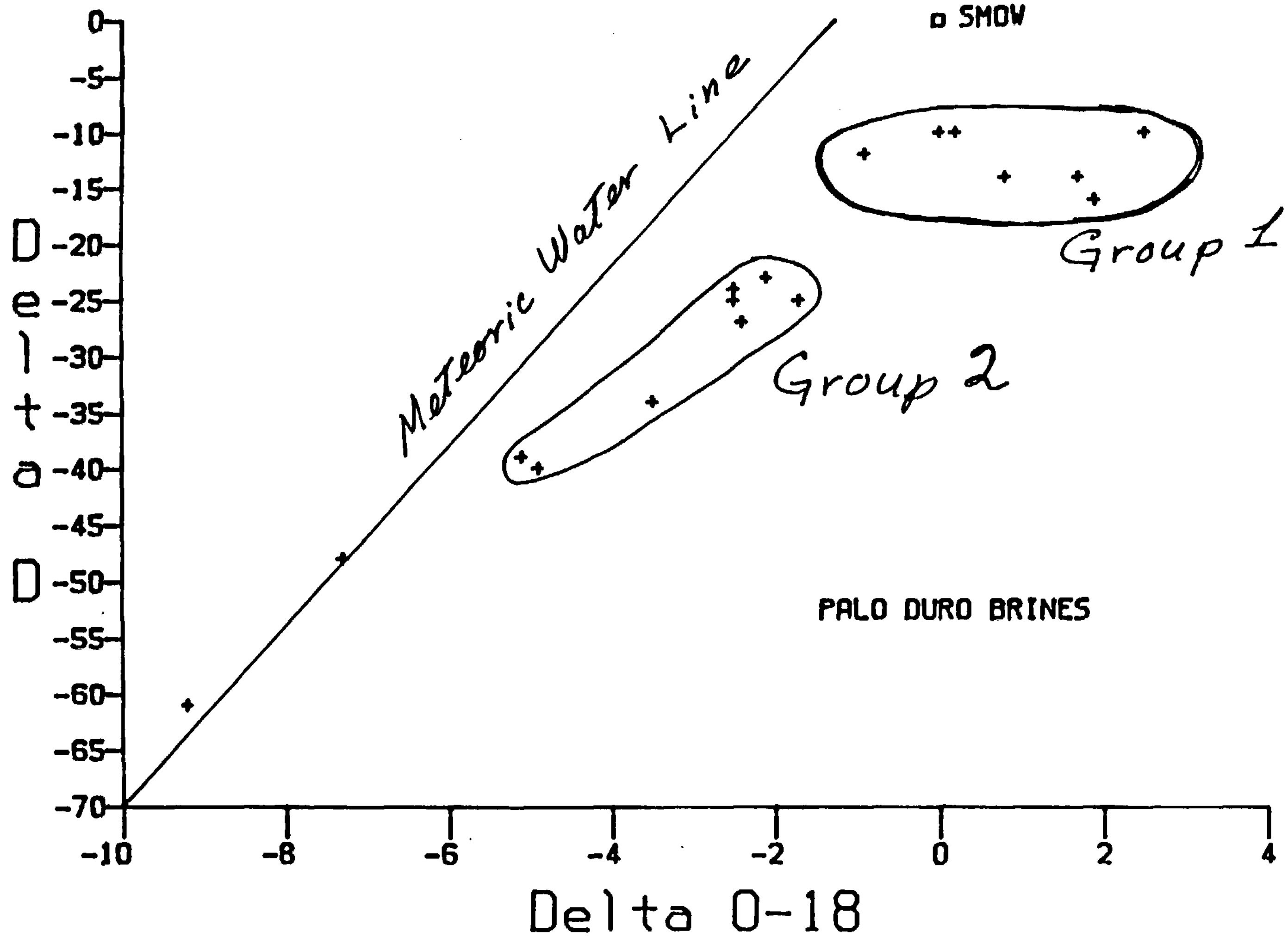

FIGURE 6

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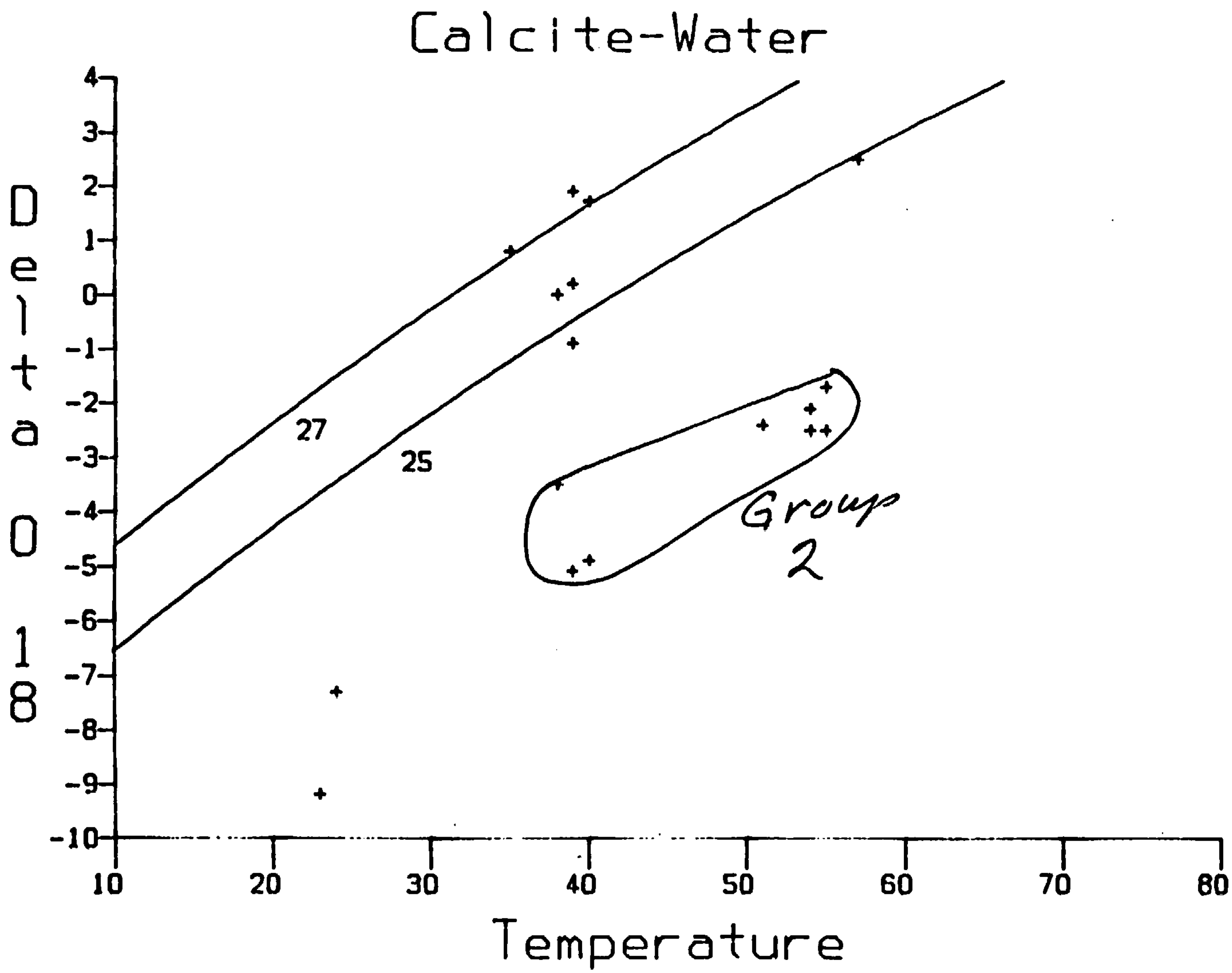

FIGURE 7A

NH:8/22/84

Table 5. Gas Analyses For Palo Duro Deep Basin Brines. Analyses Made By Bendix Field Engineering Corporation, Grand Junction, Colorado. Concentrations are In Volume Percent Gas At STP Per Volume Of Brine.

Well/Aquifer	N_2%	CH_4%	CO_2%
Sawyer/Granite Wash	4.4	3.5	0.68
" Wolfcamp	0.87	0.35	0.21
Mansfield/Wolfcamp	3.82	1.06	0.27
" Wolfcamp	7.59	0.75	0.04
Zeeck/Pennsylvanian Carbonate	0.74	0.34	0.03
" Wolfcamp	2.21	1.35	0.25
J. Friemel/Granite Wash			
" Granite Wash	5.44	1.47	0.10
" Pennsylvanian Carbonate	5.20	1.37	0.21
" Wolfcamp			

PALO DURO DEEP BASIN BRINES

Saturation with Gypsum (●) and Anhydrite (■)

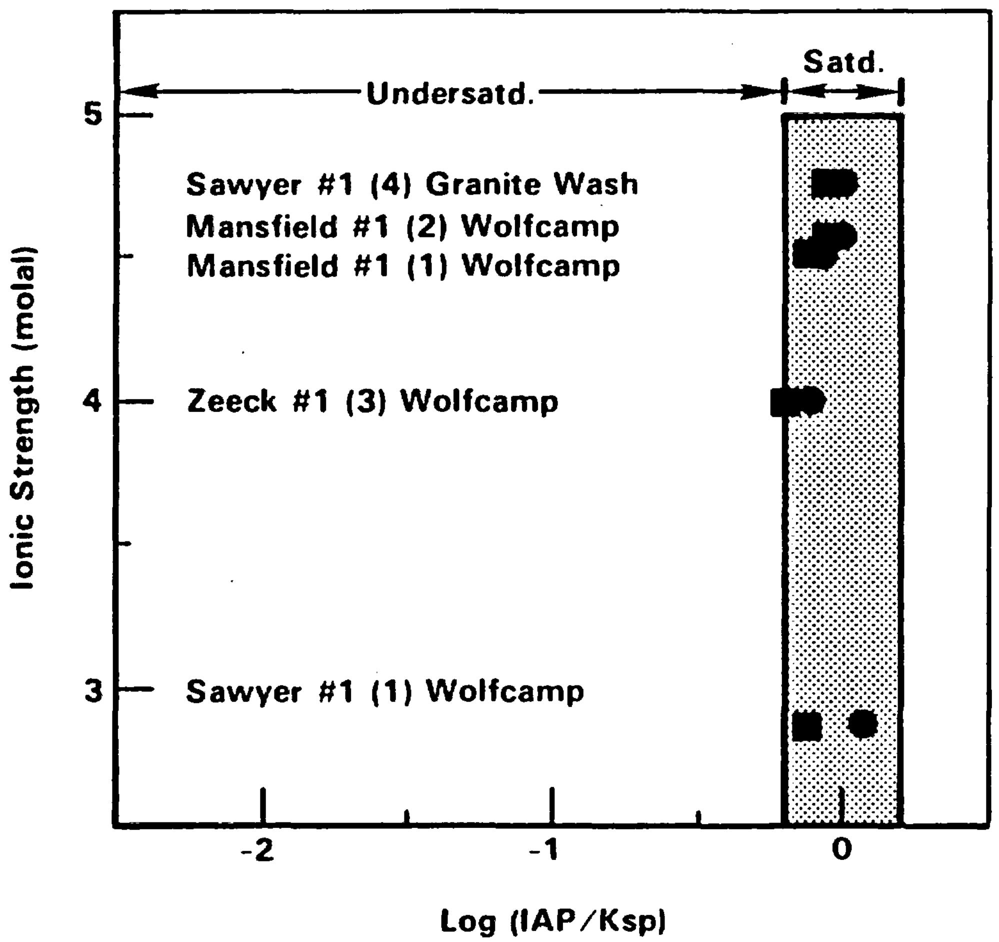

FIGURE 9

NH:8/22/84

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Table 2. $^{4}He/^{40}Ar$ Ratios for Deep Basin Brines, Palo Duro Basin, Texas Panhandle

Well and Aquifer	$^{4}He/^{40}Ar$*
Sawyer Granite Wash	4.8
Sawyer Wolfcamp	11.5
Mansfield Wolfcamp Zone 1	10.8
Mansfield Wolfcamp Zone 2	12.6
Zeeck Pennsylvania Carbonate	45.7
Zeeck Wolfcamp	23.1
J. Friemel Granite Wash Zone 1	8.4
J. Friemel Granite Wash Zone 4	6.6
J. Friemel Pennsylvania Carbonate	9.0
J. Friemel Wolfcamp	8.9

Table 4.

Noble Gas Composition and Ages of Wolfcamp Brine

Hydrologic Test Well (Formation)	$^4He \times 10^{-5} cm^3 STP / cm^3$ fluid	$^{40}Ar \times 10^{-5} cm$ STP / cm fluid	$^{40}Ar / Ar$	T_{He} MYBP	T_{AR} MYBP
Sawyer #1 Zone 5 (Wolfcamp)	224	19.4	433	100	162
Zeeck #1 Zone 3 (Wolfcamp)	295	16.0	518	132	133

In Table 1 noble gas abundances are in units of 10^{-} cm STP/cm of fluid and calculated ages are in millions of years before present (MYBP). For these calculations the following values were used in age equations: U_r = 3 ppm, Th_r = 3 ppm, K_r = 0.6% p = 0.05, ρ = 2.5 gm/cm and f_i = 1. See text and references for sources of data used in the calculations. For the fluid phase the abundances of U, Th and K are negligible relative to the rock.

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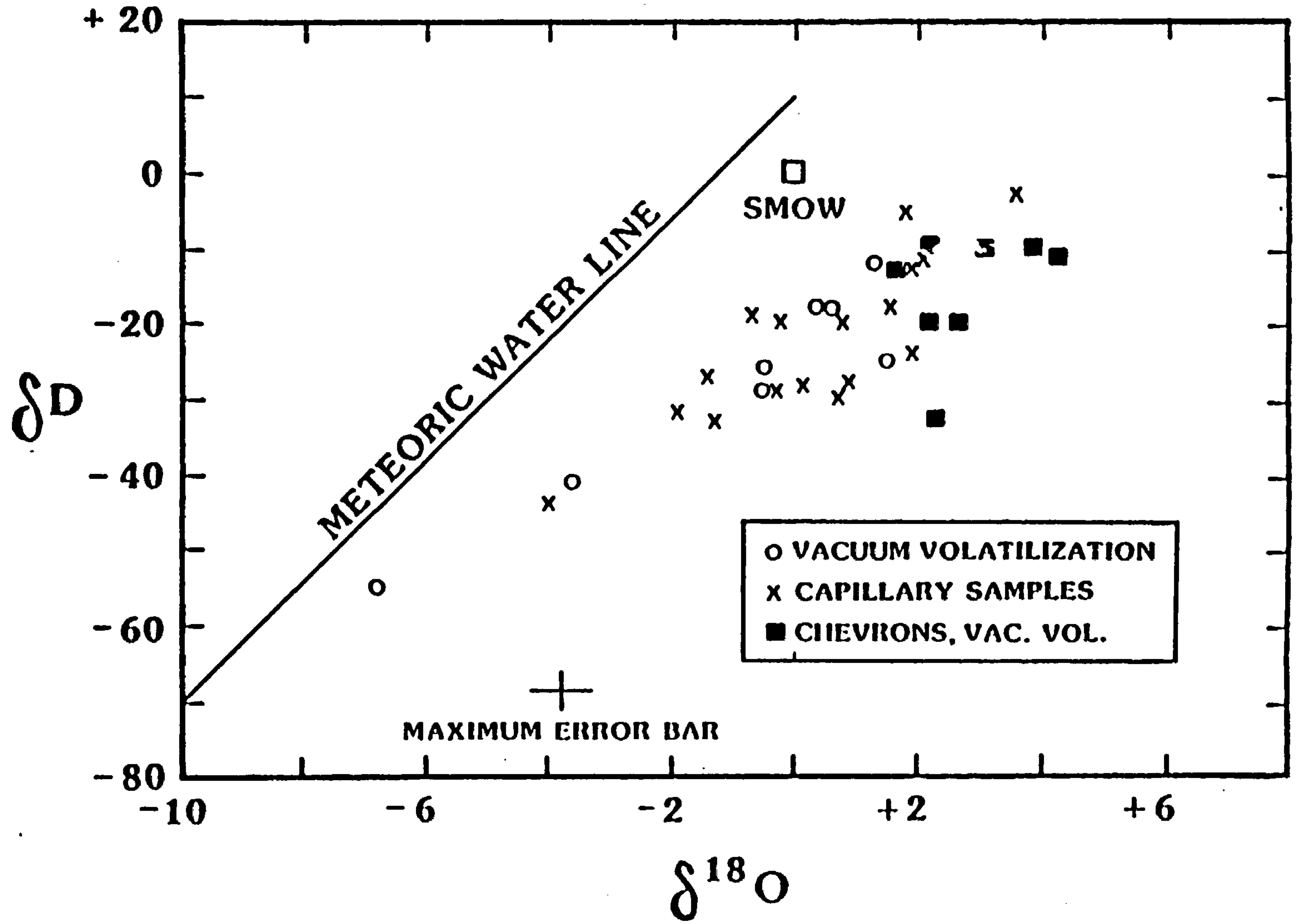

FIGURE 1 ISOTOPIC COMPOSITION OF FLUID INCLUSIONS IN THE PALO DURO SALT

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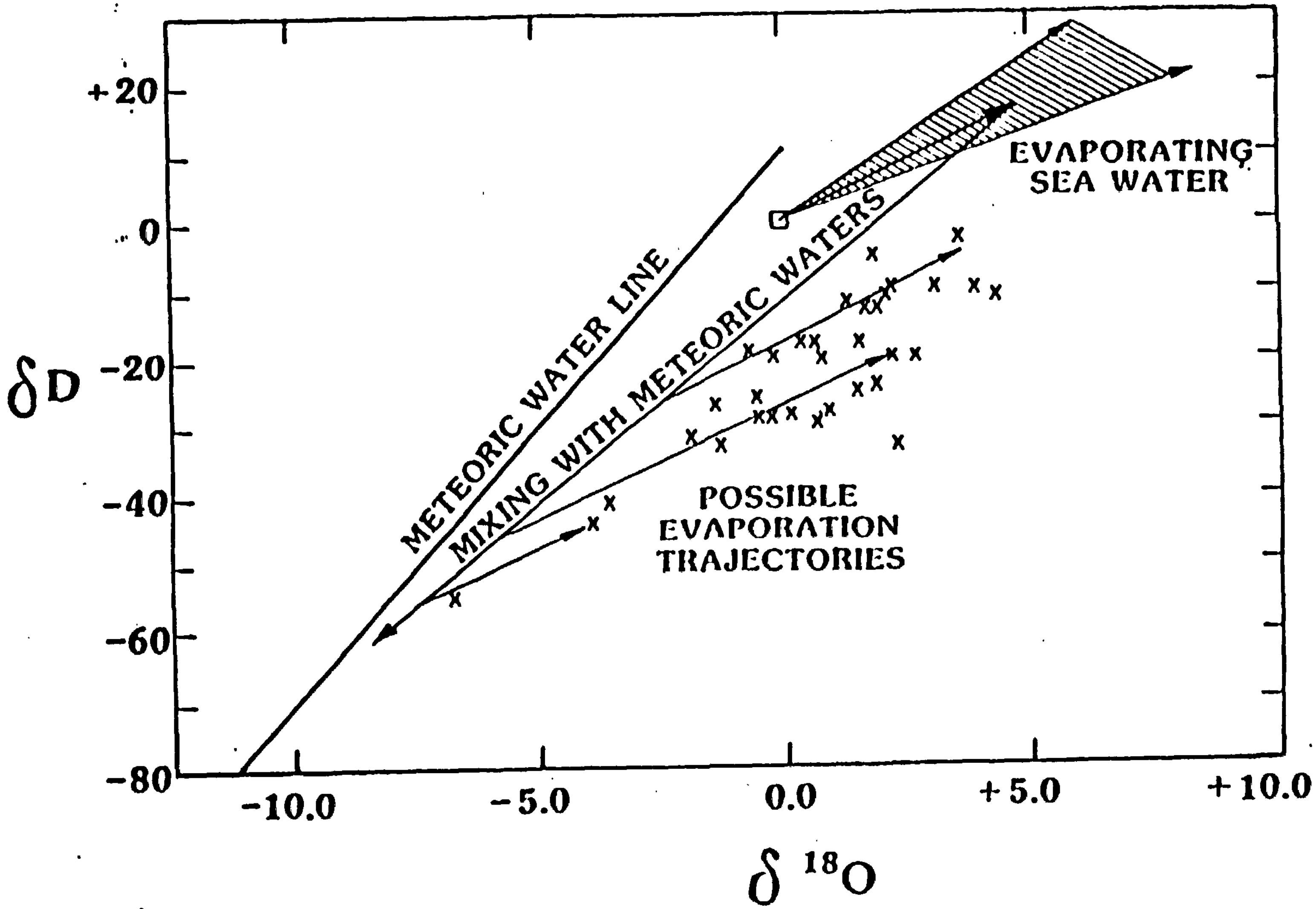

FIGURE 2. POSSIBLE EVAPORATION TRAJECTORIES THAT OVERLAP THE OBSERVED FLUID INCLUSION DATA

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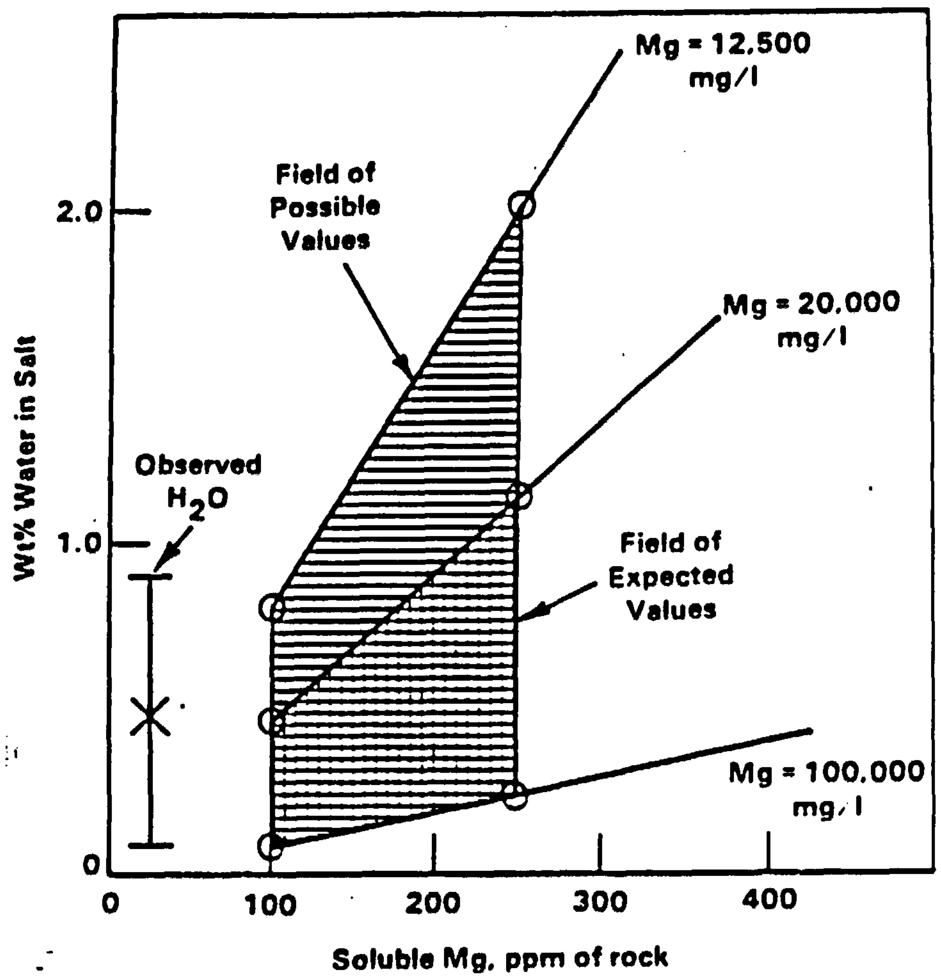

Figure 17. This figure shows the expected content and Mg concentration of fluid inclusions in the Lower San Andres salt beds in depositional cycle 4. The fields of possible and expected values are derived from a sample model of sea water evaporation discussed in the text.

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Table 6. Chemical Compositions of Fluid Inclusion Brines in Palo Duro Halite (Mg/L)

	1A(1)	1B(1)	2(2)	3(2)
Ca^{++}	---	---	12,630	15,600
Mg^{++}	50,000	50,500	18,810	25,000
Na^{+}	49,000	55,200	78,840	49,000
K^{+}	15,690	15,800	5,030	15,690
$SO_4^{=}$	61,450	76,200	470	200
Cl^{-}	191,000	187,900	200,900	191,000

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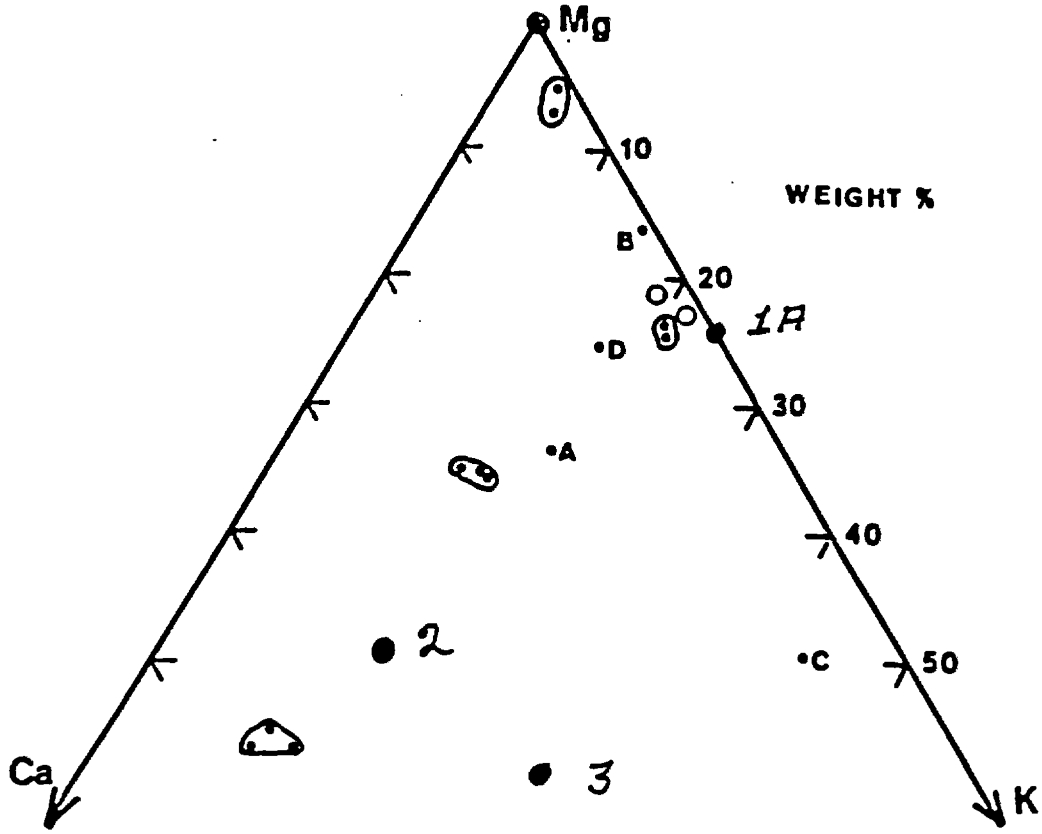

Fig. 17. Weight percent plot of ten analyses for Ca, Mg and K in 4 large ($\geq 10^{-4}$g) primary fluid inclusions in recrystallized bedded salt from Palo Duro basin, Texas (encircled dots), four from pairs of adjacent inclusions in two other similar samples (dots A and B; C and D), and two adjacent inclusions in a similar sample from Lyons, Kansas (circles). The encircled dots represent analyses of 2 or 3 duplicate samples, in each case extracted from the same inclusion. A series of 15 analyses of smaller inclusions ($<10^{-4}$g) showed a wider scatter.

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TABLE 1. Palo Duro Brine Compositions Compared with WIPP Brine Compositions (mg/L)

	Fluid[1] Inclusions		Fluid[2] Inclusions	(3) Dissolution Brine-PNL	Recommended Fluid Inclusion Brine[4]	WIPP Brine (3)		
	#1A	#1B	#2			Brine A	Fluid Inclusions (preliminary)	
Ca^{++}	---	---	12,630	1,560	1,336	600	210	150
Mg^{++}	50,000	50,500	18,810	134	50,000	35,000	23,000	40,000
Na^{++}	49,000	55,200	78,840	123,460	25,290	42,000	63,000	32,000
K^{+}	15,690	15,800	5,030	39	15,690	30,000	8,700	6,800
$SO_4^{=}$	61,450	76,200	470	3,197	3,200	3,500	13,200	13,200
Cl^{-}	191,000	187,900	200,900	191,380	200,000	190,000	160,000	160,000

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TABLE 1. Palo Duro Brine Compositions Compared with WIPP Brine Compositions (mg/L)

	Fluid Inclusions[1] #1A	Fluid Inclusions[1] #1B	Fluid Inclusions[2] #2	[3] Dissolution Brine-PNL	Recommended Fluid Inclusion Brine[4]	Dessication Brine (5) ($MgCl_2$ Brine)	WIPP Brine: Brine B Dissolution
Ca^{++}	---	---	12,630	1,560	1,336	---	900
Mg^{++}	50,000	50,500	18,810	134	50,000	138,720	10
Na^{++}	49,000	55,200	78,840	123,460	25,290	---	115,000
K^{+}	15,690	15,800	5,030	39	15,690	---	15
$SO_4^{=}$	61,450	76,200	470	3,197	3,200	---	3,500
Cl^{-}	191,000	187,900	200,900	191,380	200,000	406,260	175,000

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AMOUNTS OF BRINE IN HOST SALT (VOL %)

- Palo Duro/Lower San Andres

fluid inclusions	0.8:	range 0.1 - 1.5
clay-rich salt	<u>1.0</u>:	3.0 vol. % clay
Total	1.8	

- Paradox/Salt #6

"carnallite-marker" zone	$\sim$ 5.0
Lower $\sim$ 1/3 of bed	$<$ 0.5

- Gulf Coast Salt Domes

  $<$ 0.15: $<$0.05 perhaps more accurate value

- Used in P. A. calc.

Palo Duro and Paradox	5.0
Gulf Coast Salt Domes	0.5

- See E.A. Data Sheets for References

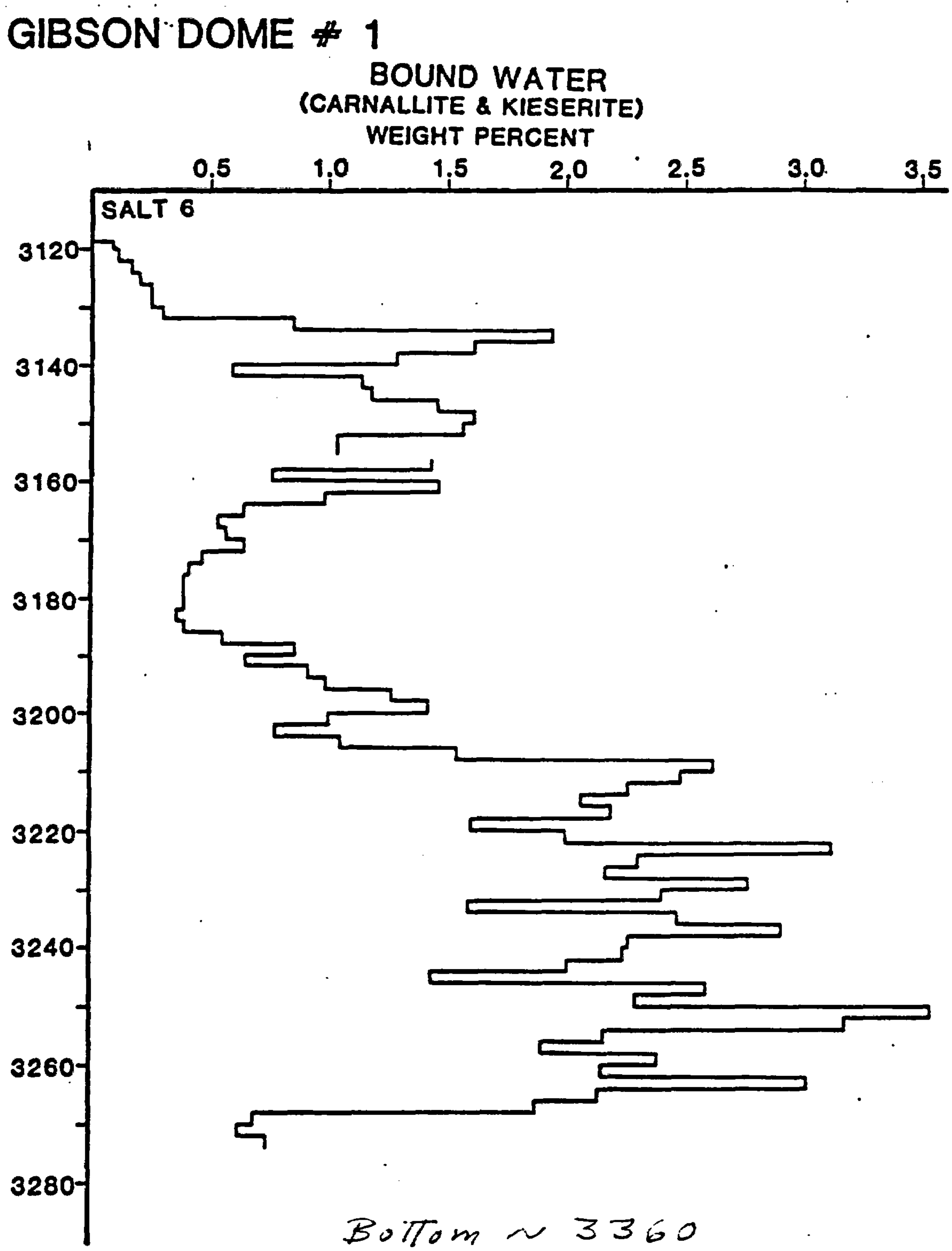


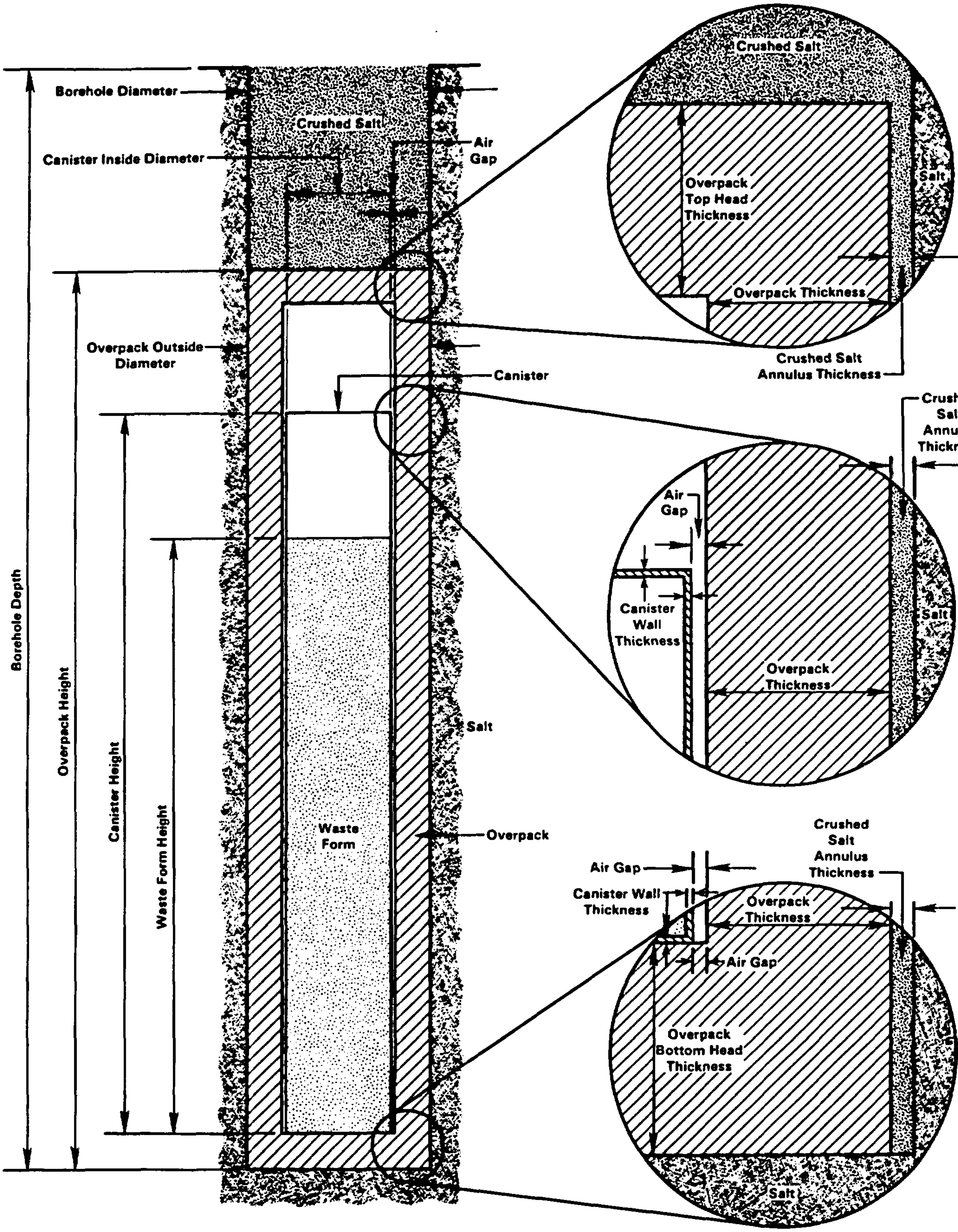
Figure 46.-- Total bound water in the "carnallite marker" of Salt 6 of the Paradox Member, GD-1 core hole. Includes water of crystallization from carnallite ($KCl \cdot MgCl_2 \cdot 6H_2O$) and kieserite ($MgSO_4 \cdot H_2O$).

DISCUSSION TOPICS
FOR
SRPO SALT GEOCHEMISTRY MEETING
AUGUST 22, 1984

1. CORROSION OF LOW-CARBON STEEL
2. RADIOLYSIS EFFECTS IN SALT AND BRINES
3. WASTE PACKAGE LEACHING TESTS

DON CLARK
ENGINEERING DEVELOPMENT SECTION

DEC: 08/22/84



SCHEMATIC DRAWING OF GENERIC WASTE PACKAGES
EMPLACED IN BOREHOLE IN A SALT REPOSITORY

MK
7/25/84
Rev. 1

Table 3. Concentrations of ^{4}He In Palo Duro Deep Basin Brines

Well/Aquifer	^{4}He Conc. $\frac{\text{CC Gas at STP}}{\text{CC Brine}} \times 10^{-5}$
Sawyer/Granite Wash	178
" Wolfcamp	228
Mansfield/Wolfcamp, lower zone	359
" Wolfcamp, upper zone	543
Zeeck/Pennsylvanian Carbonate	243
" Wolfcamp	360
J. Friemel/Granite Wash , lower zone	514
" Granite Wash , upper zone	589
" Pennsylvanian Carbonate	422
" Wolfcamp	472

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PALO DURO DEEP BASIN BRINES

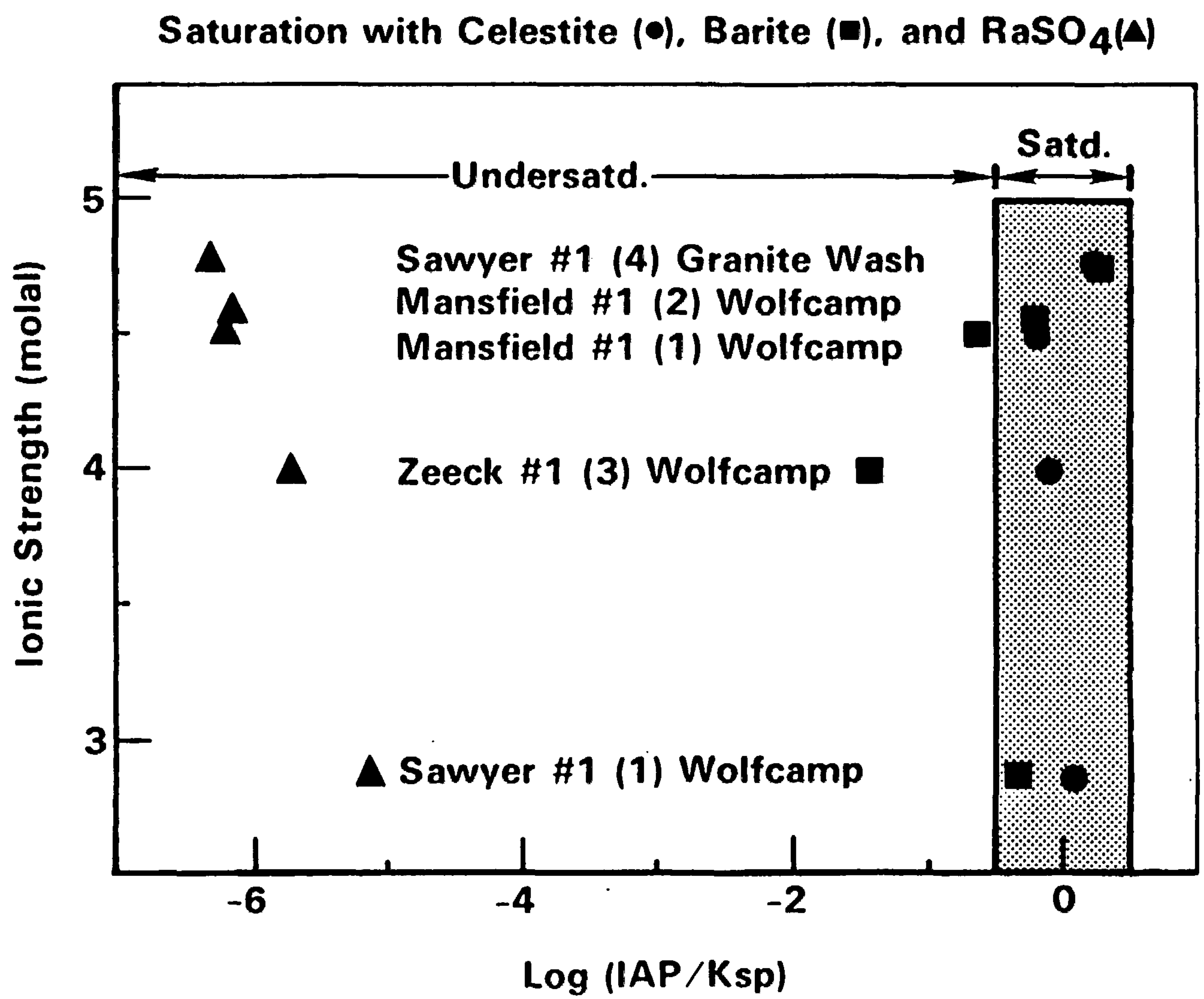

FIGURE 10

NH:8/22/84

Kieserite

$MgSO_4 \cdot H_2O_{(s)}$ + NaCl/$CaSO_4$ $\rightarrow$
sat. brine

$NaCl_{(s)}$ + $CaSO_{4(s)}$ + $MgCl_2$/NaCl
Mg enriched brine

Can produce $MgSO_4$/$MgCl_2$/NaCl
brine highly enriched in Mg

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Carnallite

$KMgCl_3 \cdot 6H_2O_{(s)}$ + NaCl sat. brine →

$KCl_{(s)}$ + $MgCl_2$/NaCl

Sylvite Mg enriched brine

Can produce nearly pure $MgCl_2$ brine

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IMPACT OF RADIATION ON THE PERFORMANCE OF WASTE PACKAGE MATERIALS

- SALT IRRADIATION EFFECTS (PRODUCTION OF COLLOIDAL, SODIUM, CHLORINE GAS)
- BRINE RADIOLYSIS EFFECTS
- BRINE MIGRATION
- RADIATION-ASSISTED CORROSION
- OTHER EFFECTS (CURRENTLY UNKNOWN)

DEC: 7/17/84

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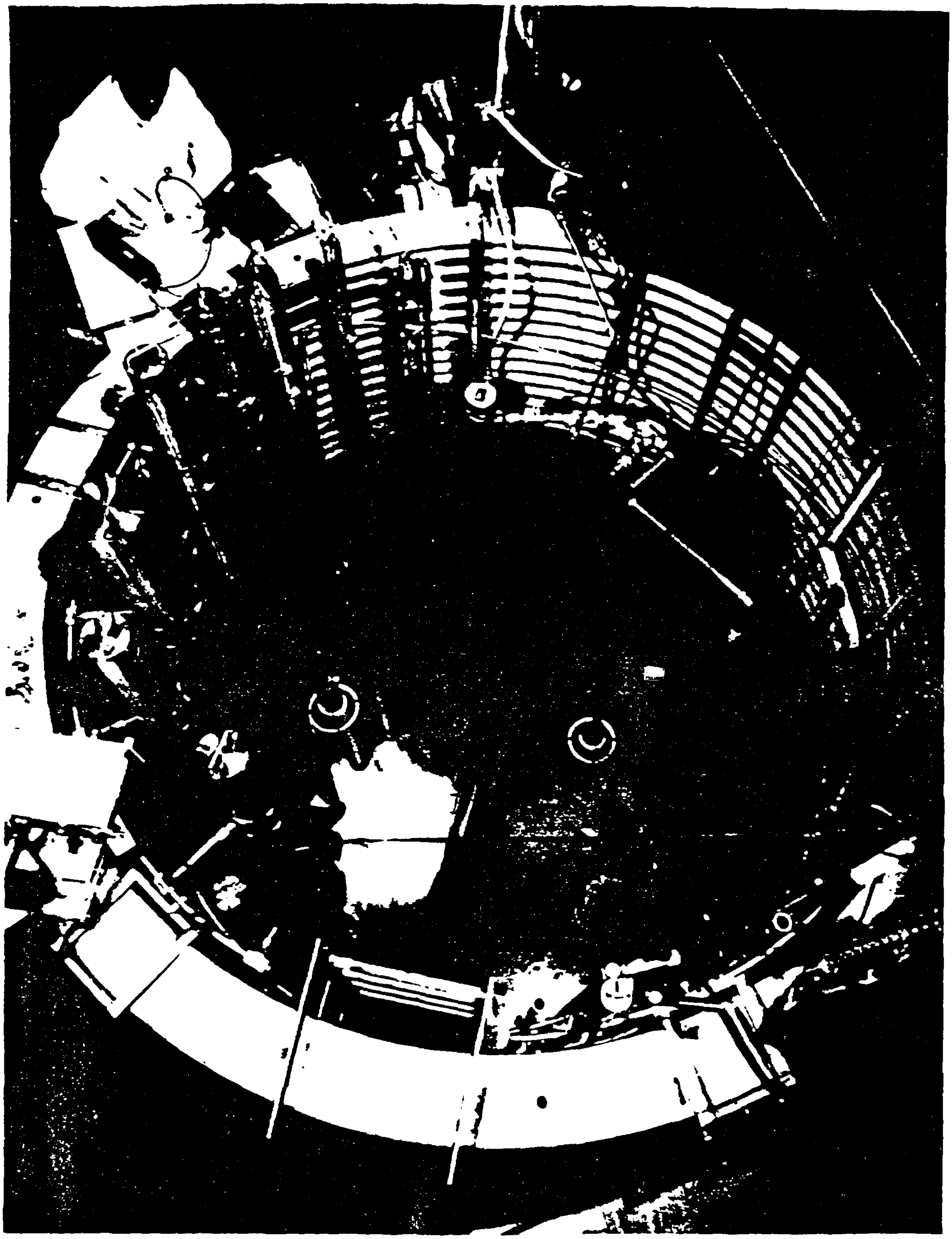
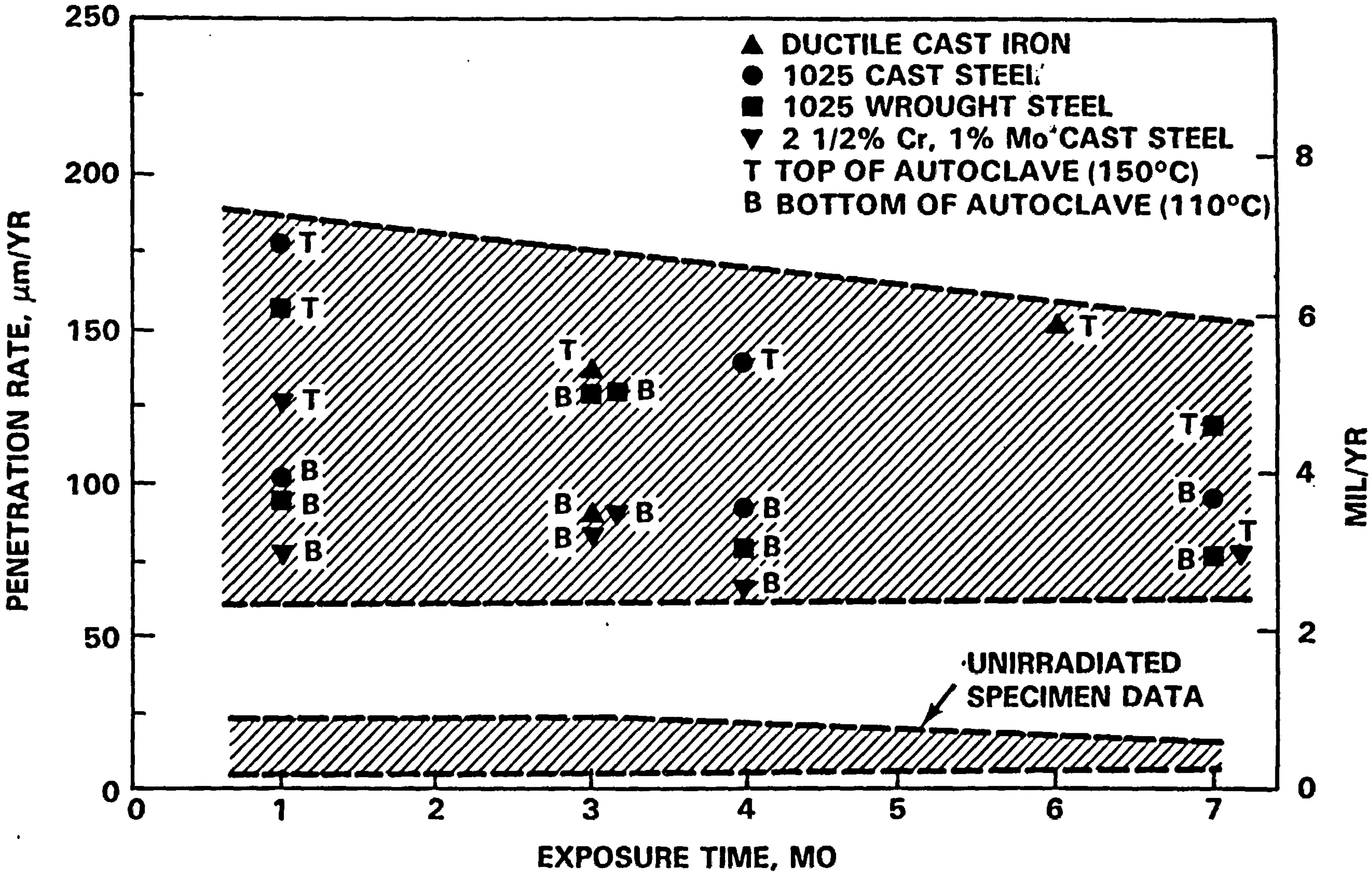
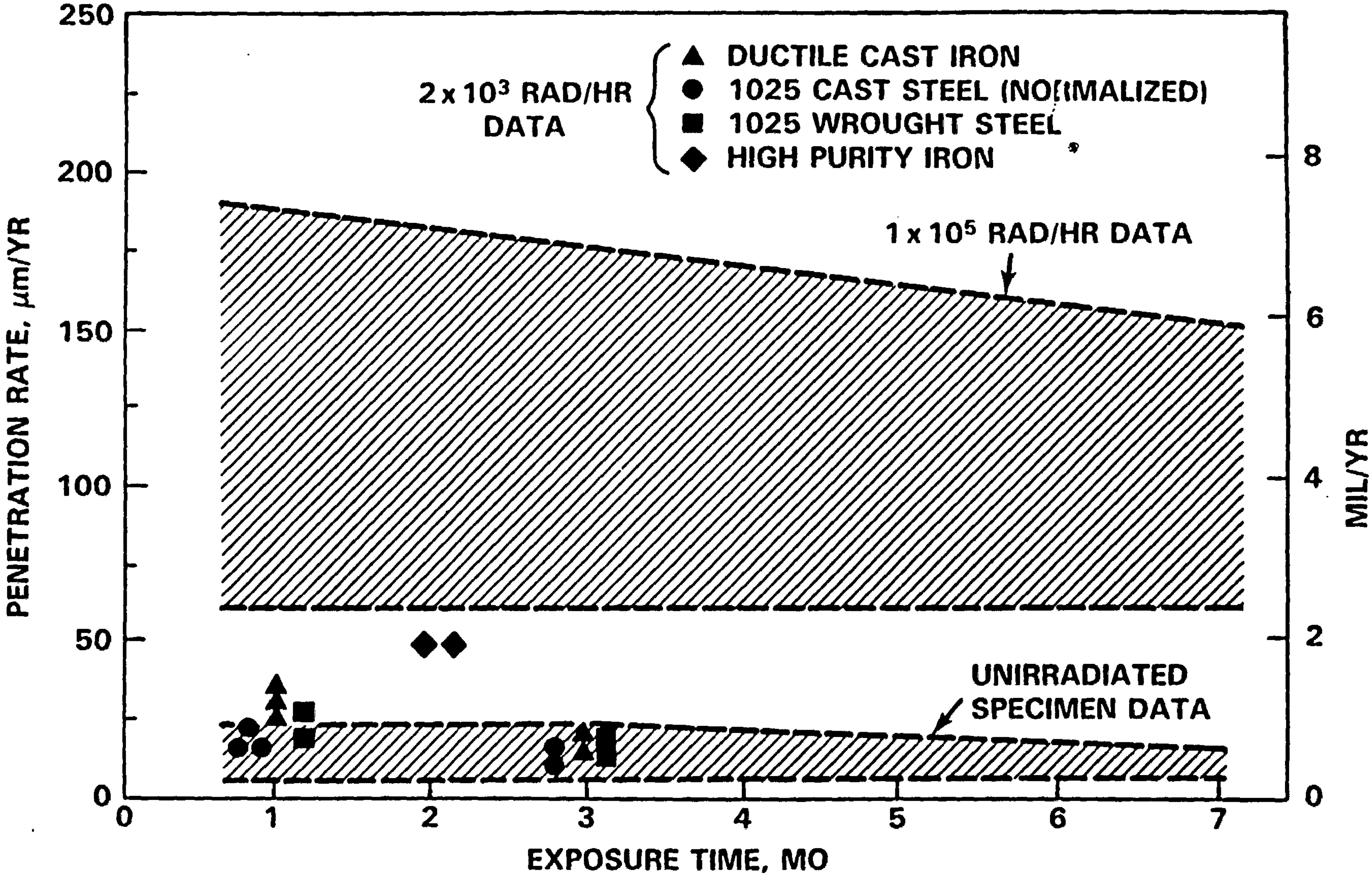
BATTELLE Project Management Division



Gamma Irradiation Facility (Cobalt-60) used for Waste Form, Corrosion, Slow Strain Rate, Solution and Salt Irradiation Studies



Irradiation-Corrosion of Ferrous Materials in Permian Basin Brine No. 2 at 1×10^5 rad/hr and a Maximum Temperature of 150°C



Irradiation-Corrosion of Ferrous Materials in Permian Basin Brine No. 2 at $2x10^3$ rad/hr and a Maximum Temperature of 150°C

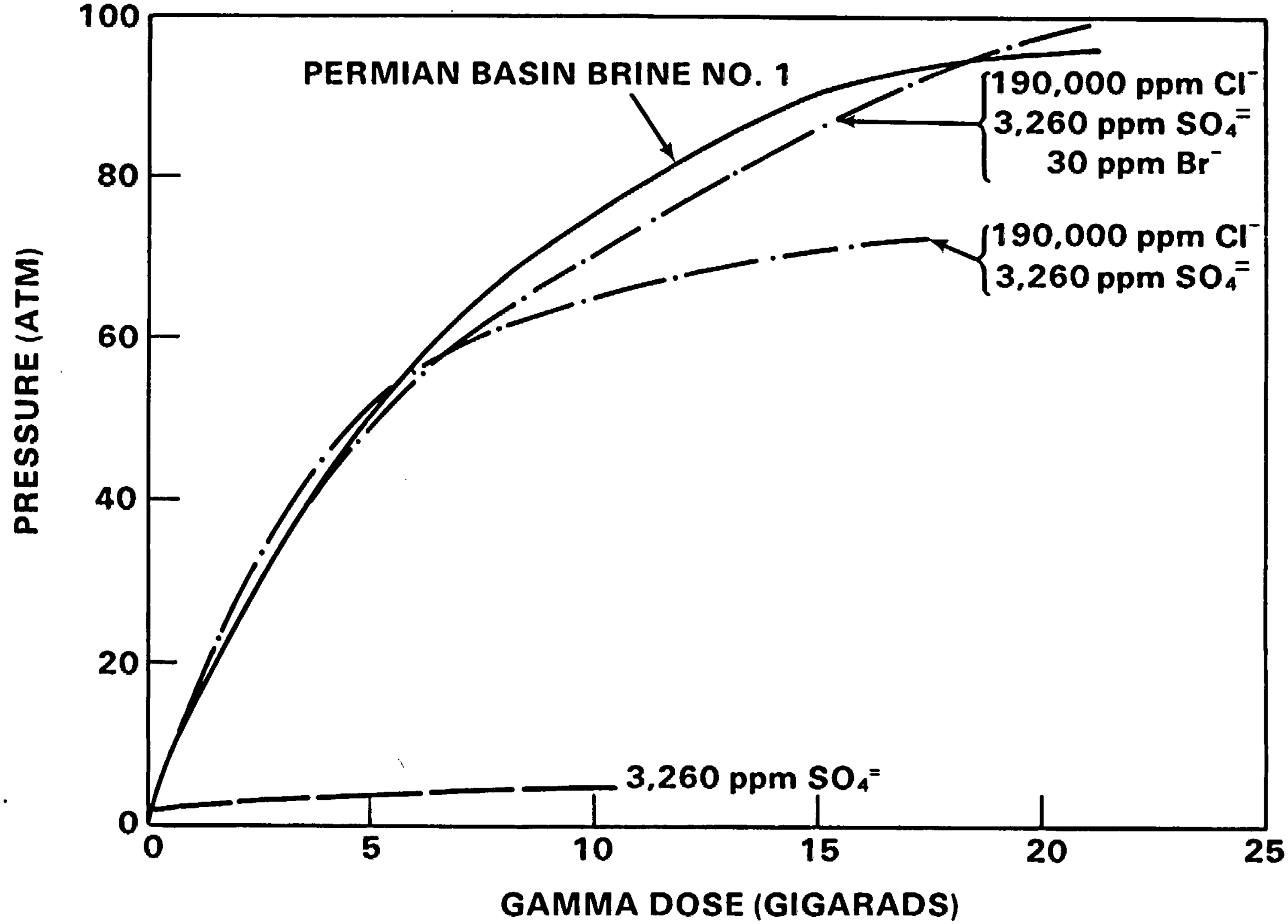
WASTE PACKAGE TESTING PROGRAM

STUDIES OF NEAR-FIELD ENVIRONENT - INTENDED TO PROVIDE DEFINITION OF THE ENVIRONMENTAL CONDITIONS TO WHICH WASTE PACKAGES WILL BE EXPOSED FOLLOWING EMPLACEMENT:

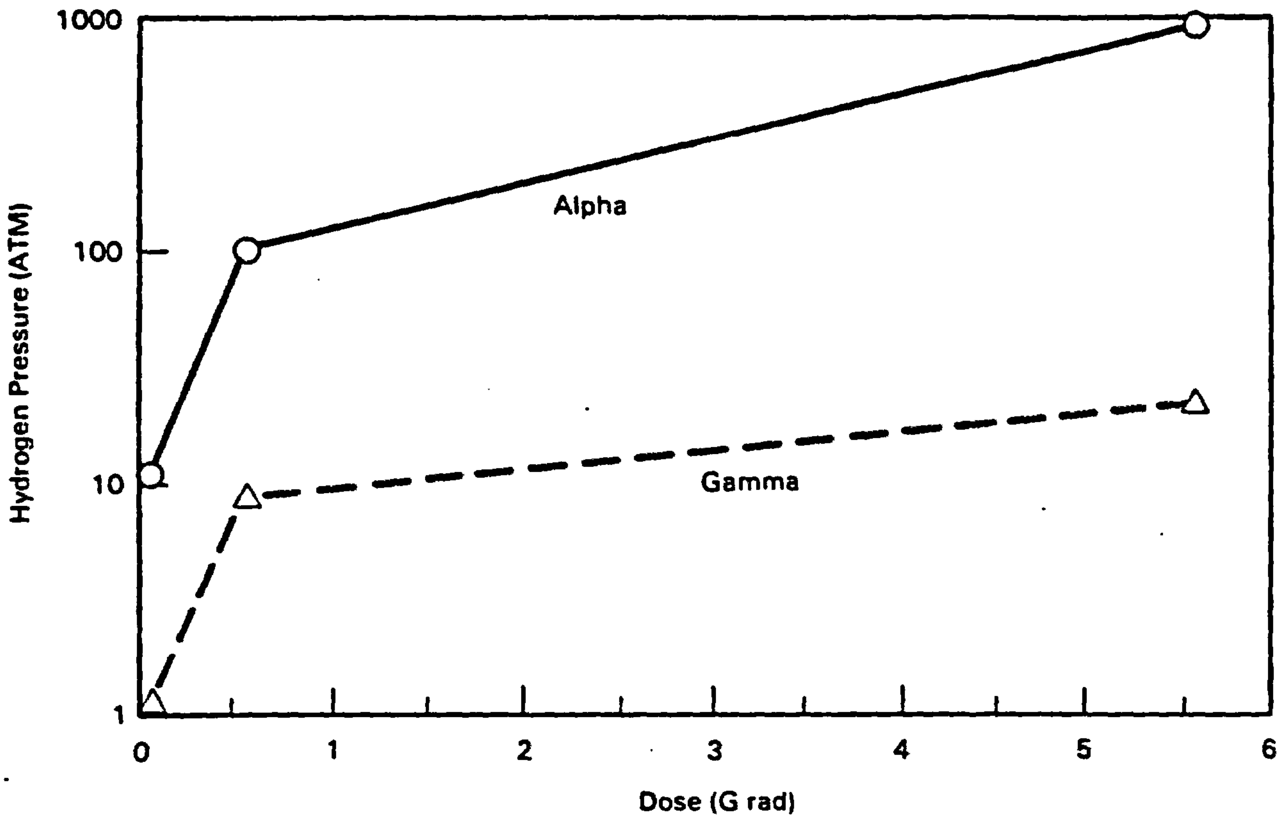
(A) SALT RADIOLYSIS EFFECTS

(B) BRINE RADIOLYSIS

(C) COMPOSITIONAL AND OTHER CHANGES IN HOST ROCK AND BRINES



Gamma Radiolysis Gas Pressure Generation From Various Salt Solutions as a Function of Dose



CALCULATED HYDROGEN PRESSURE GENERATED BY GAMMA OR ALPHA RADIOLYSIS OF NaCl BRINE

REACTION SCHEME FOR IRRADIATED SALT

$$Na^+Cl^- \xrightarrow{h\nu} Na^\circ + Cl^\circ \qquad (0)$$

$$Na^\circ + H_2O \longrightarrow 1/2\ H_2 + Na^+ + OH^- \qquad (1)$$

$$Cl^\circ + 1/2\ H_2O \longrightarrow 1/2\ Cl^- + 1/2\ H^+ + 1/2\ HOCl \qquad (2)$$

$$HOCl \rightleftharpoons H^+ + OCl^-\ (K=3x10^{-8}) \qquad (3)$$

$$3\ OCl^- \overset{k_1}{\rightleftharpoons} 2\ Cl^- + ClO_3^-\ \ (K=10^{27}) \qquad (4)$$

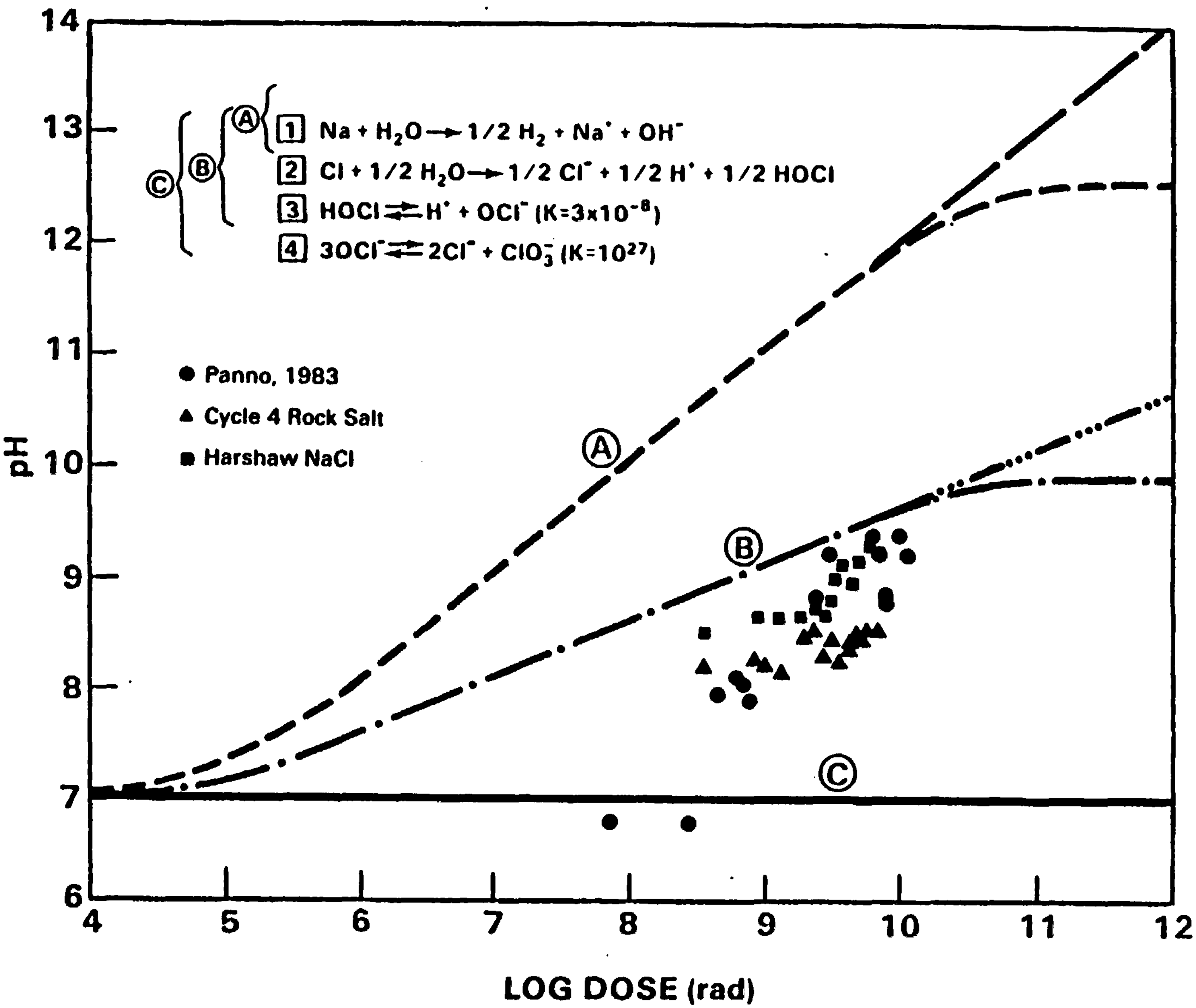
k_1(25°C) SLOW

k_1(75°C) MODERATE

$$4\ ClO_3^- \overset{k_1'}{\rightleftharpoons} Cl^- + 3\ ClO_4^-\ (K=10^{29}) \qquad (5)$$

k_1'(100°C) VERY SLOW

Solution pH vs Dose



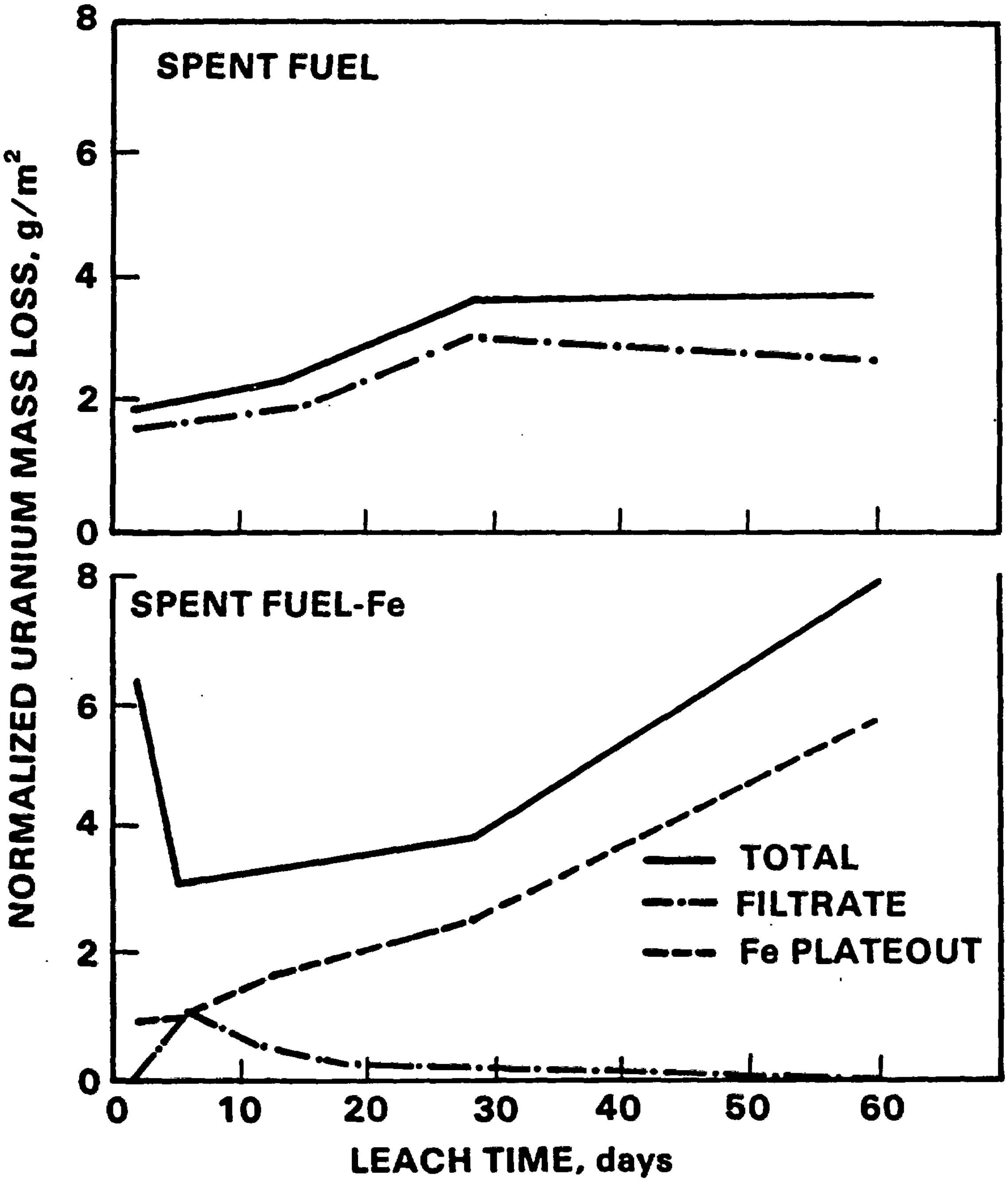
WASTE PACKAGE LEACHING TESTS

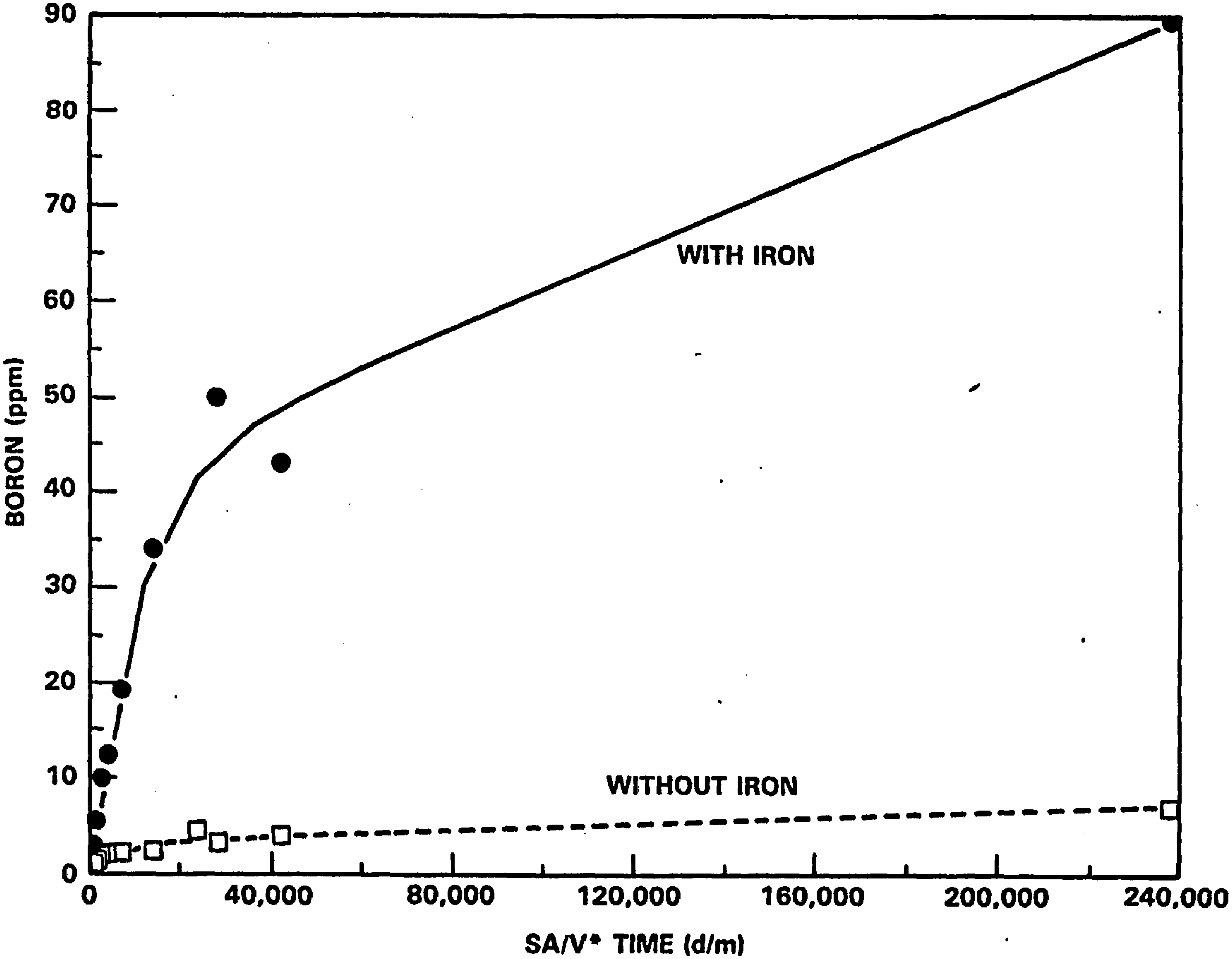
- ALPHA RADIOLYSIS RESULTS IN VERY OXIDIZING BRINE SOLUTIONS AND IN ENHANCED SOLUBILITIES OF MOST ACTINIDES

- THE PRESENCE OF IRON IN BRINES CAN RESULT IN REDUCING CONDITIONS THAT LOWER ACTINIDE SOLUBILITY

- SOLUTION EFFECTS (E.G., SOLUBILITIES) ARE CONTROLLING WITH RESPECT TO RADIONUCLIDE RELEASES FROM THE WASTE PACKAGE

COMPARISON OF URANIUM RELEASED IN SYSTEMS INCORPORATING SPENT FUEL AT 25 °C IN BRINE





Boron Release From 76-68 Glass vs. SA/V* Time in Permian Basin brine No. 1 at a Temperature of 70°C, With and Without Iron

WASTE PACKAGE TESTING

FOR PURPOSES OF QUALIFYING THE WASTE PACKAGE AND PREDICTING LONG-TERM PERFORMANCE, IT IS REQUIRED THAT WASTE PACKAGE TESTING BE DONE UNDER REPOSITORY-RELEVANT CONDITIONS. THUS, IT IS VITALLY IMPORTANT TO OBTAIN A PRECISE DEFINITION OF THE NEAR-FIELD ENVIRONMENT AND GEOCHEMICAL CONDITIONS TO WHICH EMPLACED WASTE PACKAGES WILL BE EXPOSED.

GEOCHEMISTRY OVERVIEW

PERFORMANCE ASSESSMENT

AUGUST 22, 1984

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Office of Nuclear Waste Isolation

BATTELLE Project Management Division

JFK/8/22/84

BRINE MIGRATION CODES

MIGRAIN - EMPIRICAL

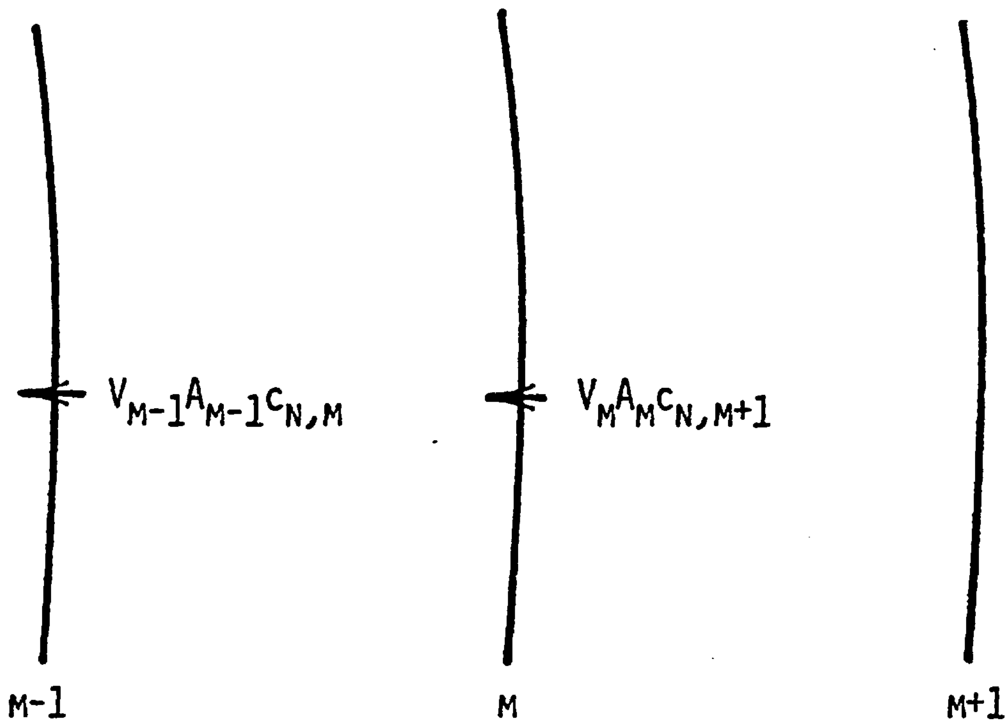
SPECTROM-58 - COMPREHENSIVE, THEORETICAL BASIS

BRINEMIG - EMPIRICAL; RESEMBLES MIGRAIN

BRINEMIG

FINITE DIFFERENCE CODE BASED ON RADIAL INCREMENTS AND TIME INCREMENTS.

- USES JENKS EQUATION TO CALCULATE VELOCITIES
- CALCULATES TEMPERATURES FROM TABLES SUPPLIED BY TEMPV5
  - --USES LARGEST TEMPERATURE GRADIENTS
  - --PERFORMS SEMILOGARITHMIC INTERPOLATIONS
  - --NEGLECTS END EFFECTS
- ALLOWS USE OF A THRESHOLD GRADIENT



IN = OUT + ACCUMULATION

$$V_M A_M c_{N,M+1} = V_{M-1}A_{M-1}c_{N,M} + (c_{N+1,M} - c_{N,M}) \frac{\Delta V_M}{\Delta T}$$

WHERE M = RADIAL INCREMENT NUMBER

N = TIME INCREMENT NUMBER

V = VELOCITY

A = AREA

c = CONCENTRATION

ΔV = VOLUME OF INCREMENT

ΔT = TIME INCREMENT

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JENKS EQUATION

$$\log (V/G) = 0.00656T - 0.6036$$

WHERE V = VELOCITY OF FLUID INCLUSION, CM/YR

G = TEMPERATURE GRADIENT IN SALT, $^{o}C/CM$

T = TEMPERATURE, ^{o}C

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Threshold Gradient

- Minimum temperature gradient which will give brine migration.
- Estimated in literature to equal 0.125°C/cm.

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SALT BLOCK II

THERMAL GRADIENTS APPLIED TO A SALT CYLINDER

- CYLINDER FROM A SALT BED

  OUTSIDE RADIUS = 0.5 M
  INSIDE RADIUS = 0.05 M
  HEIGHT = 1 M

- VARIABLE HEAT SOURCE INSIDE

- CONSTANT TEMPERATURE CONTROL OUTSIDE

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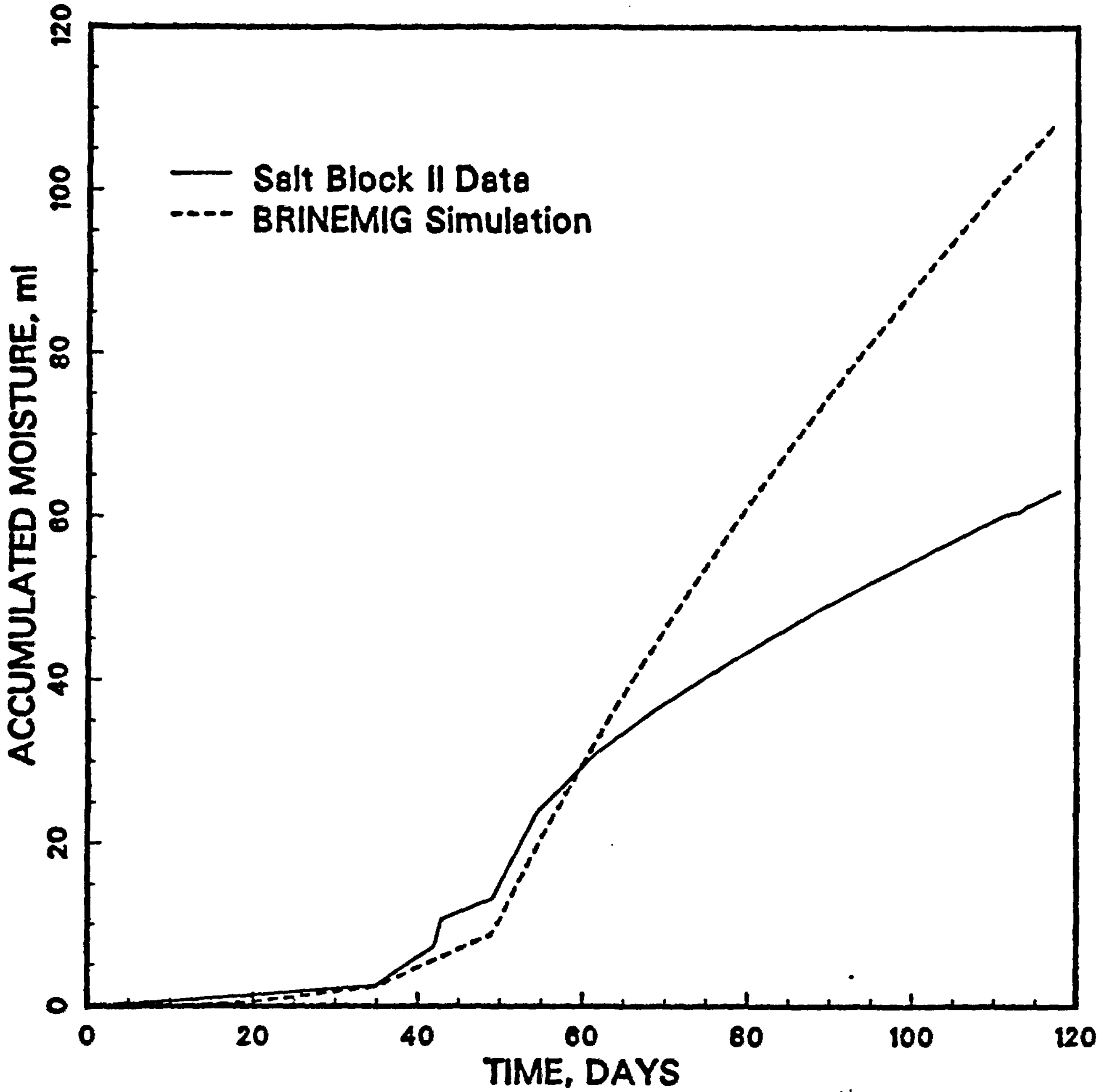
ASSUMPTIONS

- ALL MIGRATION WAS INTRACRYSTALLINE.
- MOST CONSERVATIVE TEMPERATURE PROFILE WAS APPLIED THROUGHOUT.
- END EFFECTS WERE CONSIDERED FOR SALT BLOCK II SIMULATION.
- END EFFECTS WERE NEGLECTED FOR WASTE PACKAGES.
- INITIAL MOISTURE CONTENT WAS 5 VOLUME PERCENT FOR BEDDED SALTS.
- INITIAL MOISTURE CONTENT WAS 0.5 VOLUME PERCENT FOR DOMAL SALT.



Accumulated Moisture vs. Time
Simulation of Salt Block II Data

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Input to BRINEMIG

Initial concentrations of brine in salt

- Bedded = 0.05 mL/cm^3
  - Gibson Dome
  - Palo Duro
- Dome = 0.005 mL/cm^3
  - Richton

Effective package length

- CHLW = 367.9 cm
- SF = 385.0 cm

Package radius

- CHLW = 44.5 cm
- SF = 41.7581 cm

Distance between packages

- CHLW = 1310 cm
- SF = 1005 cm

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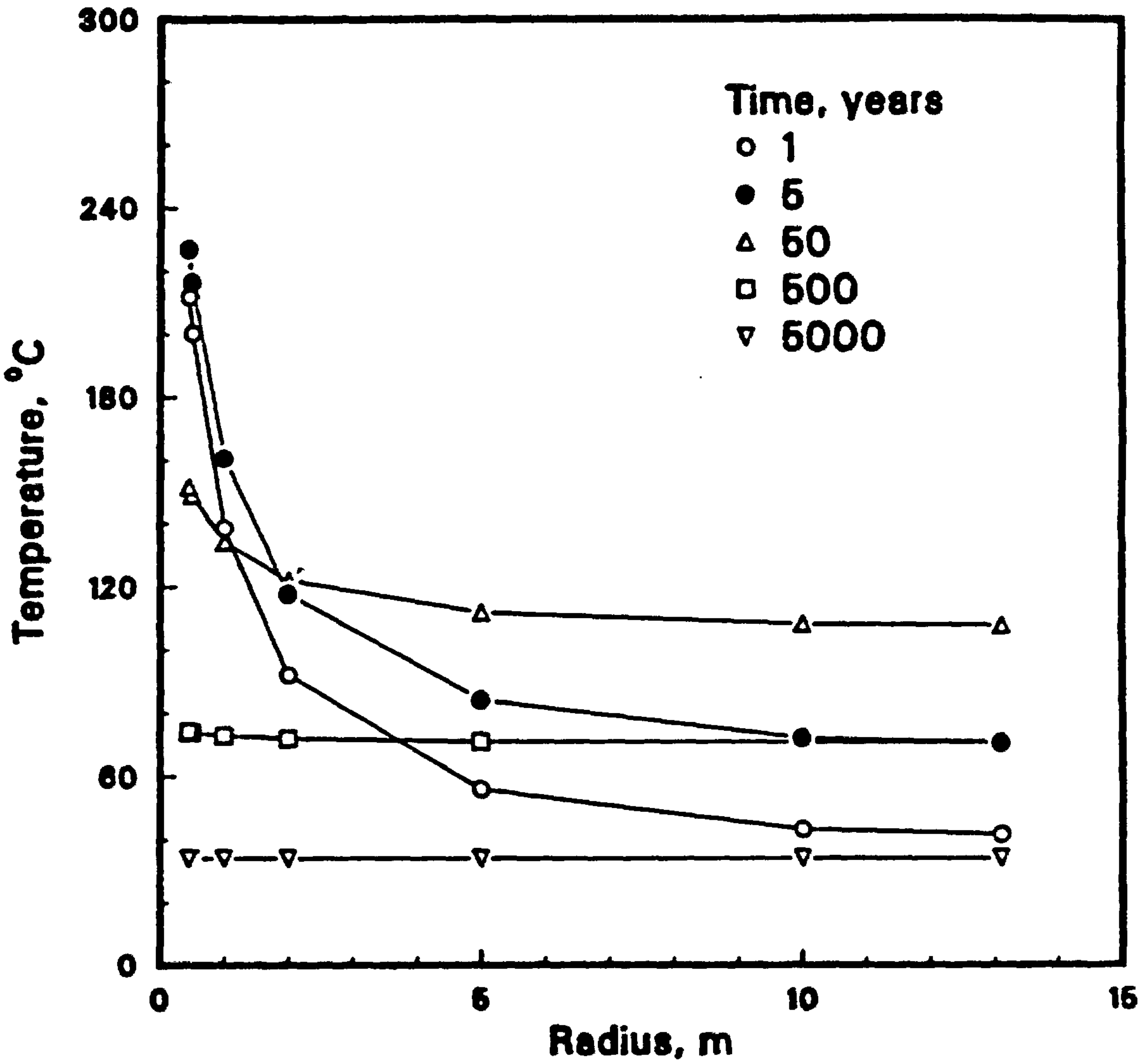

TEMPERATURES AROUND CHLW
WASTE PACKAGE AT DEAF SMITH

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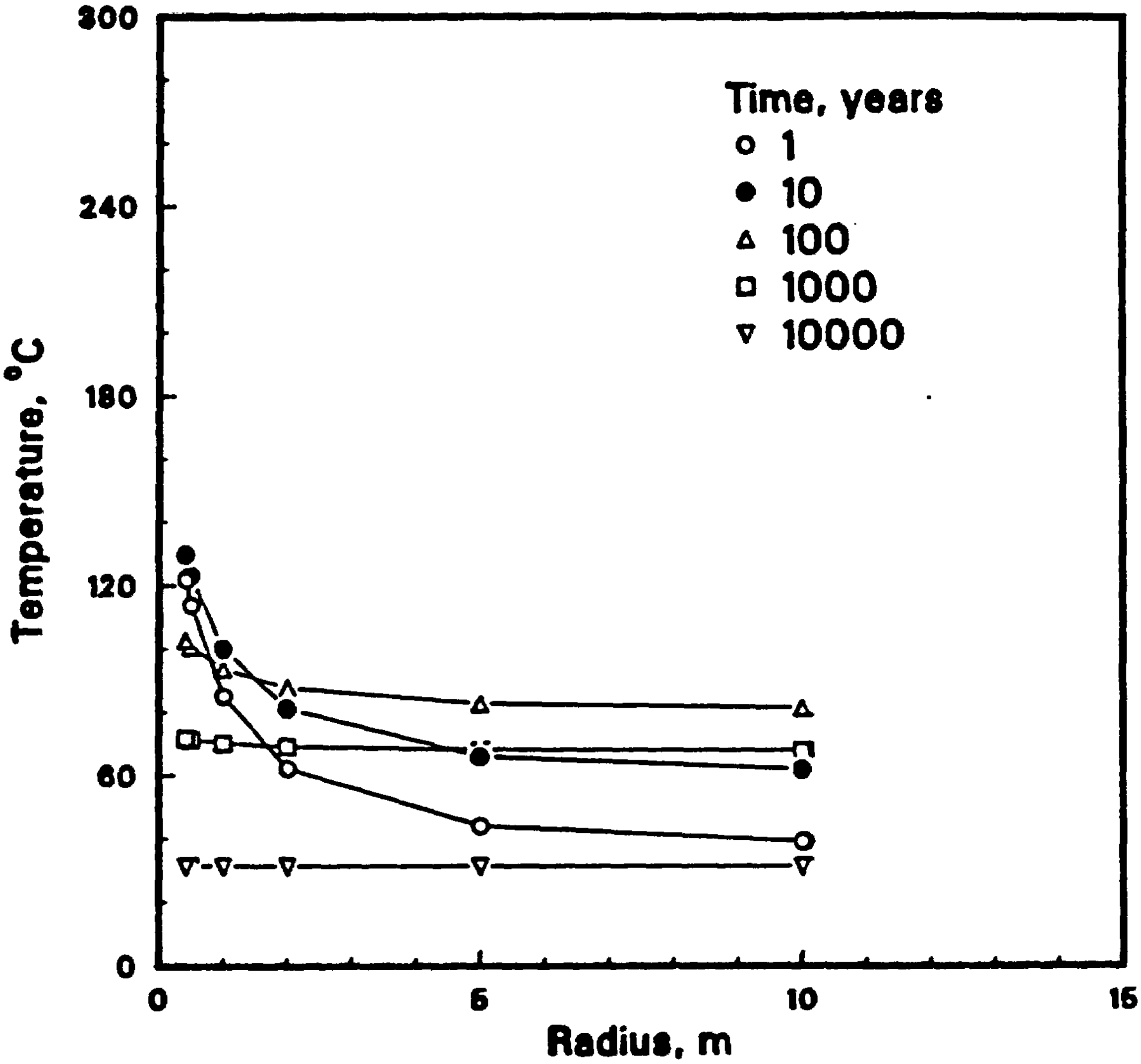

TEMPERATURES AROUND SFPWR
WASTE PACKAGE AT DEAF SMITH

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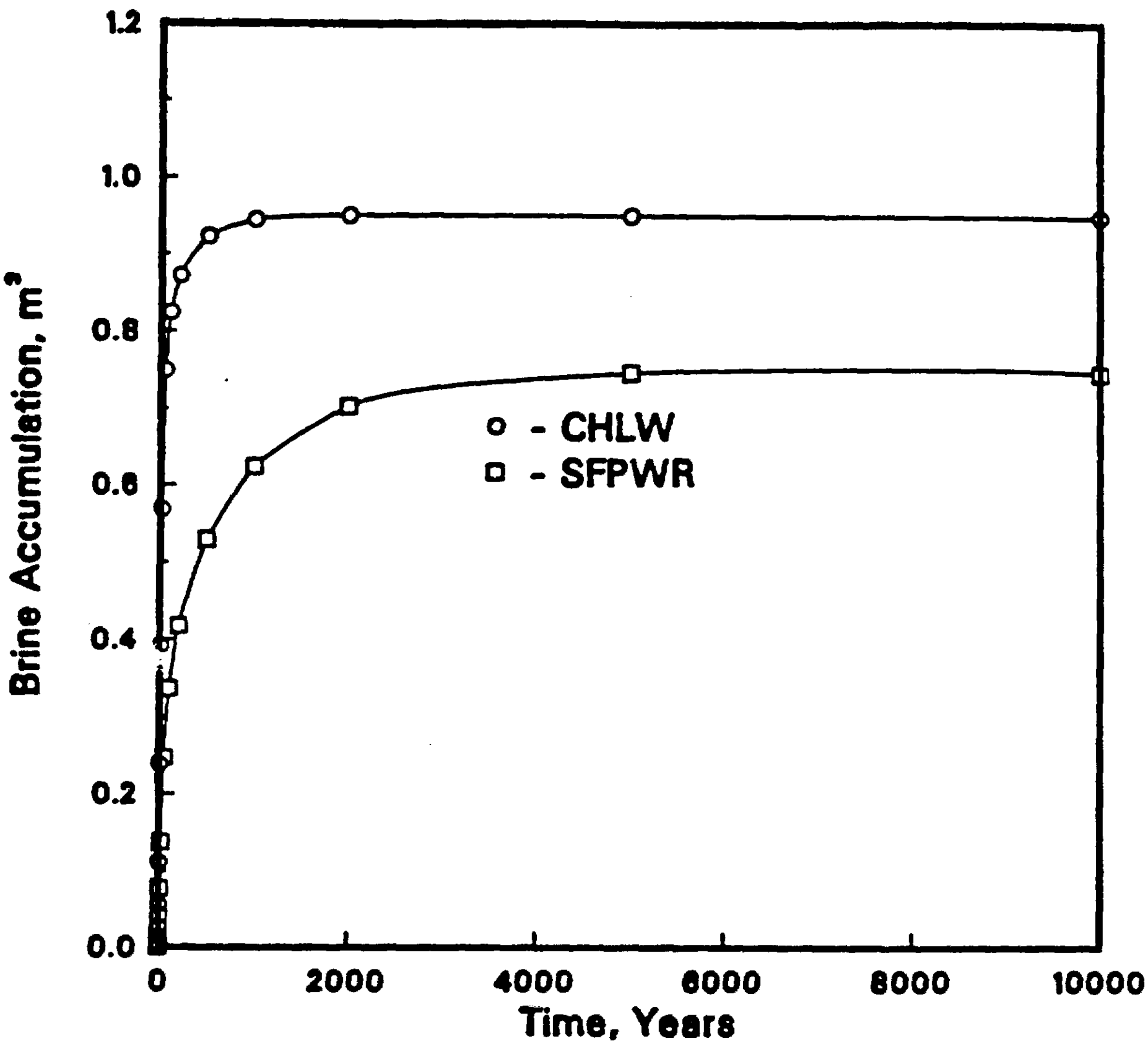
VSM:7-9-84



BRINE ACCUMULATION AT WASTE PACKAGE
WITH TIME AND ZERO THRESHOLD GRADIENT
FOR DEAF SMITH

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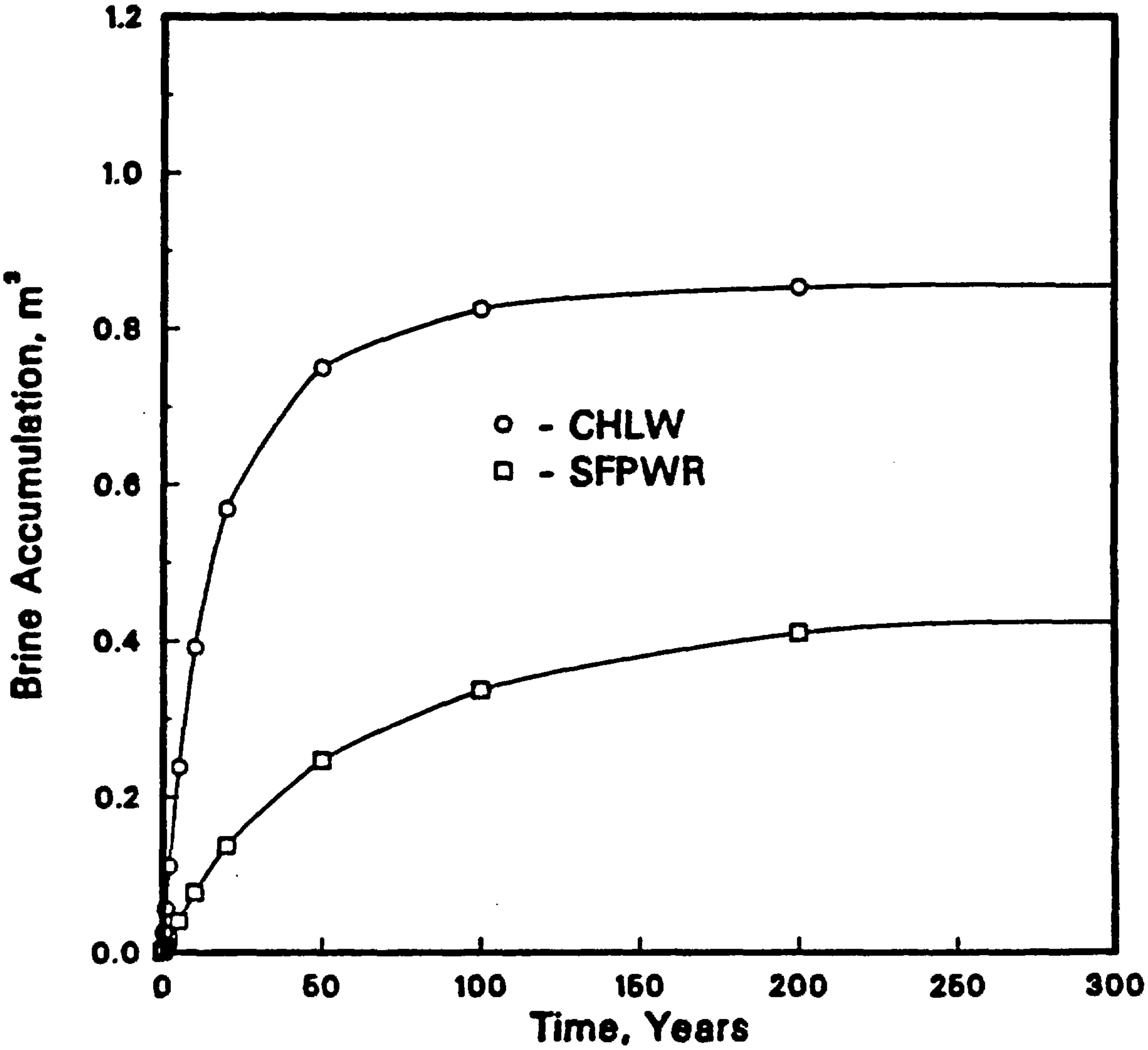

BRINE ACCUMULATION AT WASTE PACKAGE
WITH TIME AND THRESHOLD GRADIENT OF
0.125°C/CM FOR DEAF SMITH

ONWI

VSM:7-9-84

CONCLUSIONS

- ONLY A SMALL FRACTION OF THE AFFECTED MOISTURE LEAVES THE SALT.
- THE THRESHOLD GRADIENT HAS A SIGNIFICANT EFFECT ON THE RESULTS FOR SPENT FUEL.
- RICHTON DOME SHOWS THE SMALLEST BRINE ACCUMULATION.
- MORE WORK MUST BE DONE TO ESTABLISH CONSERVATISM.

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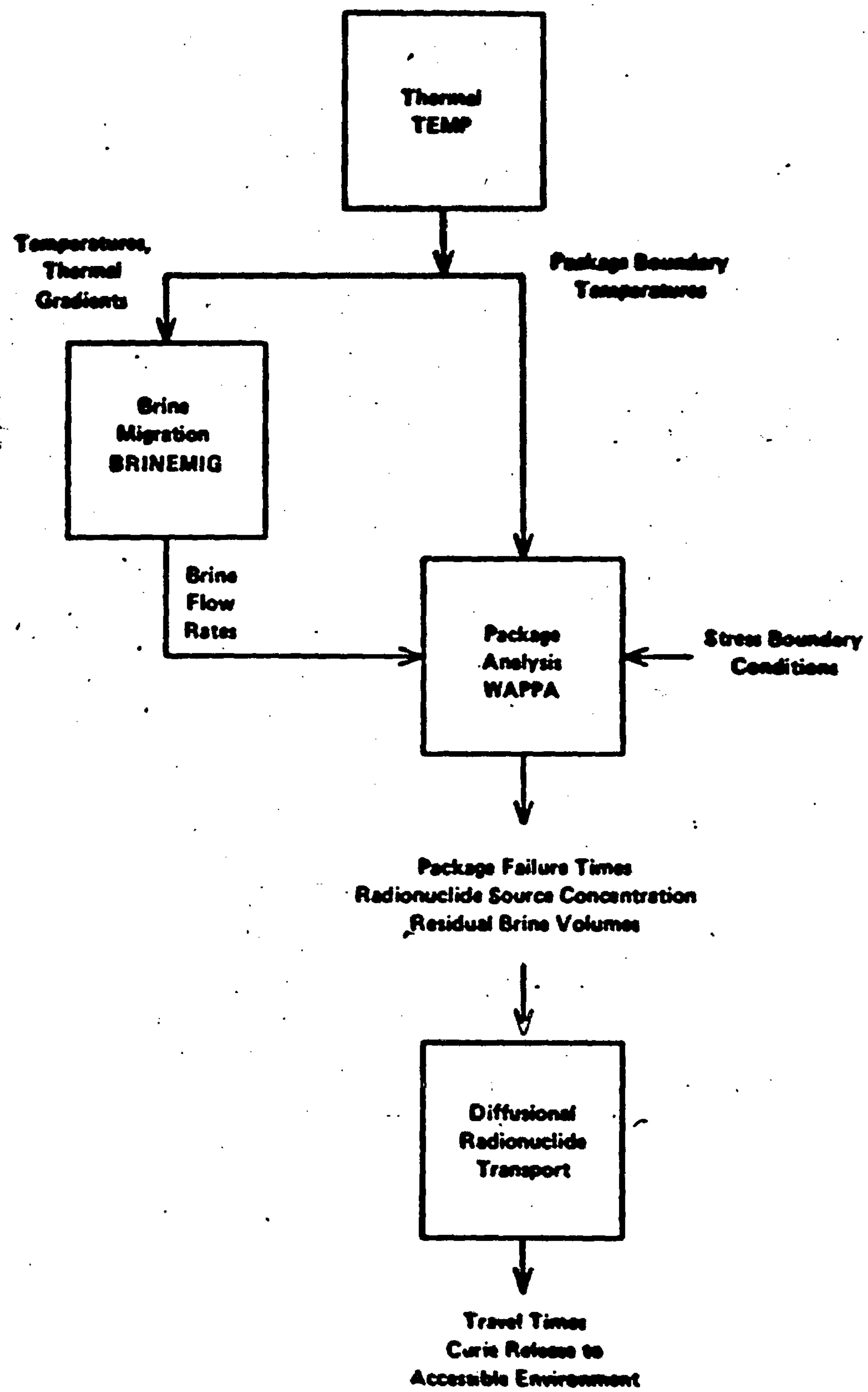

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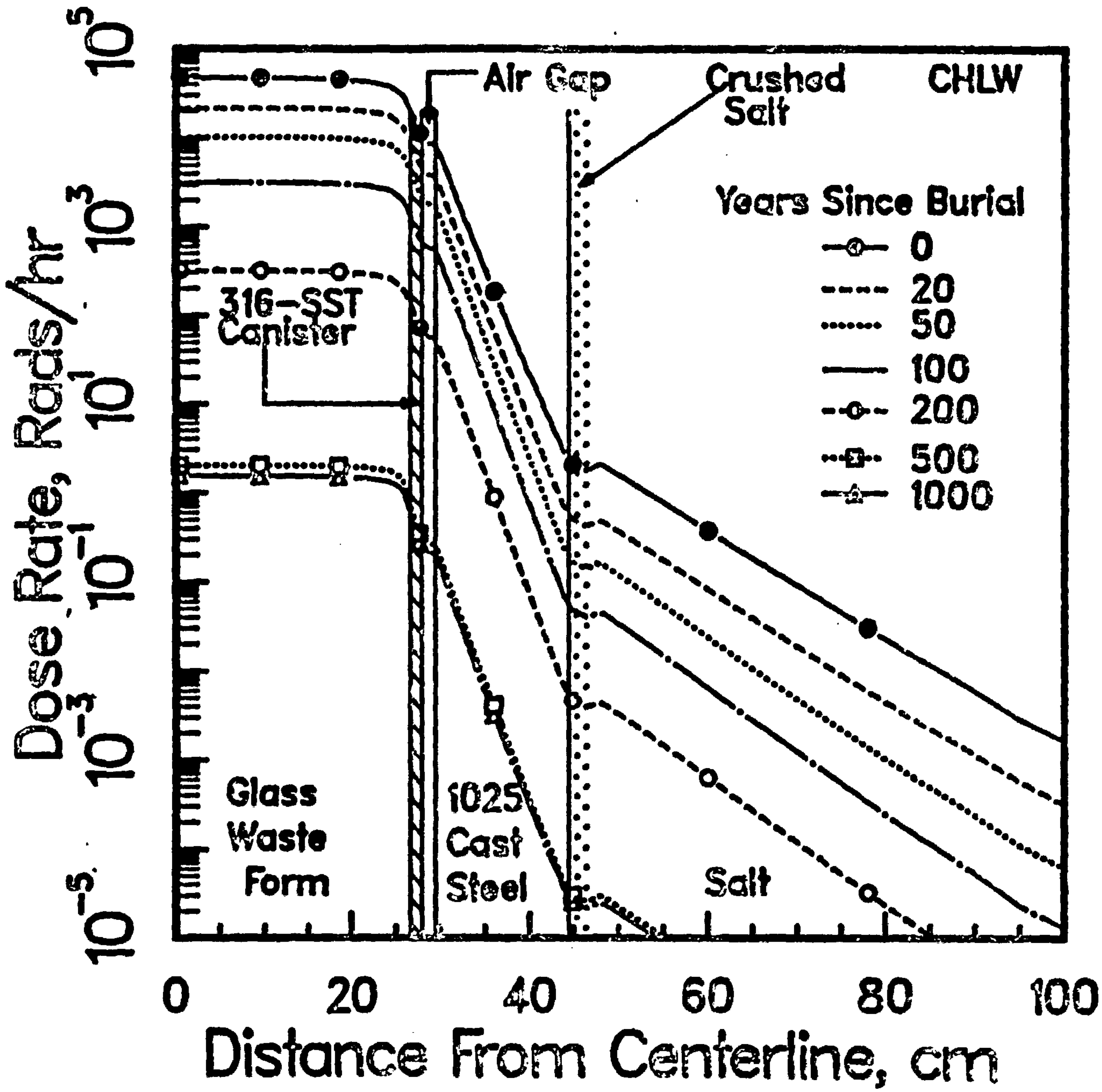
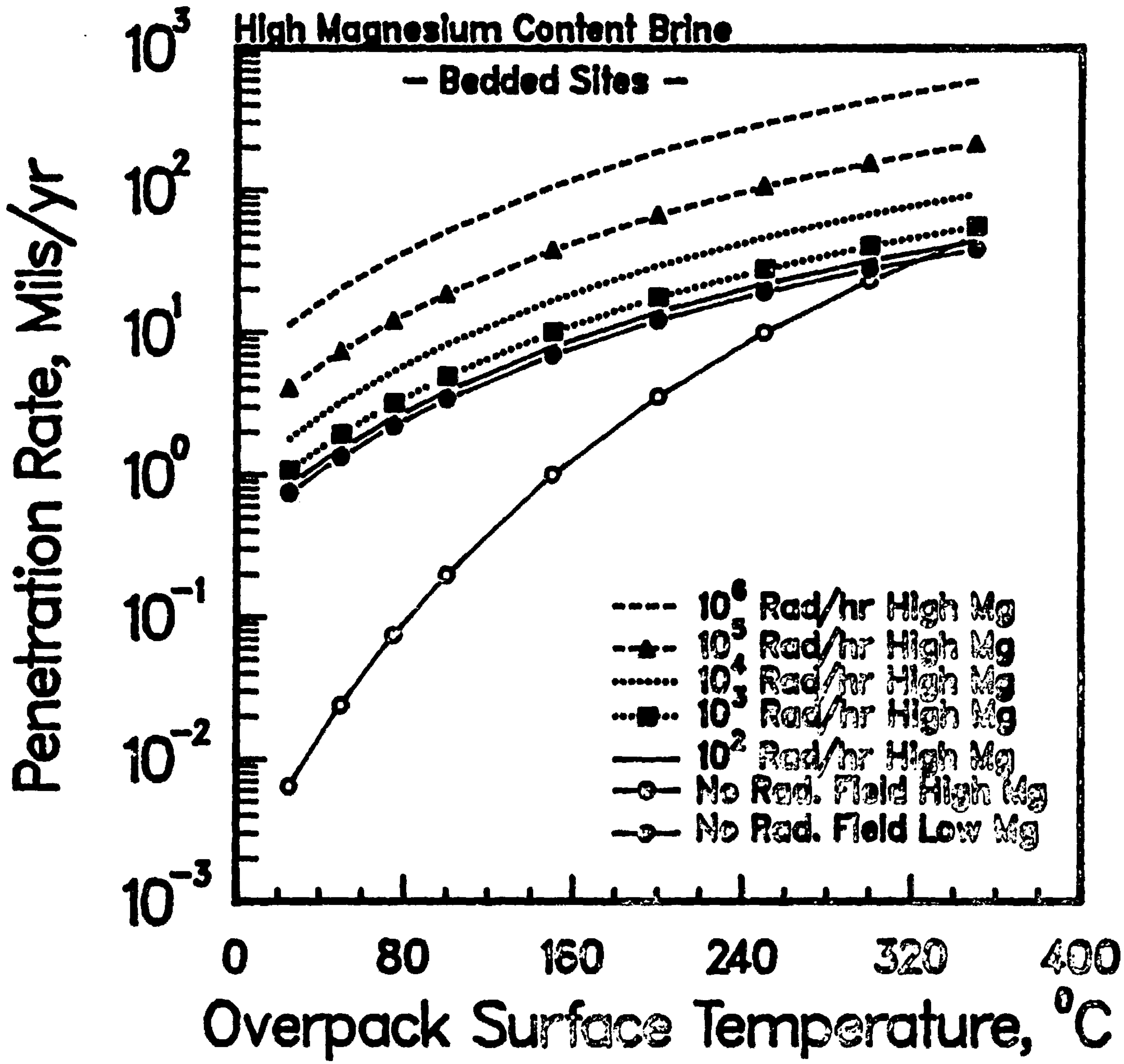
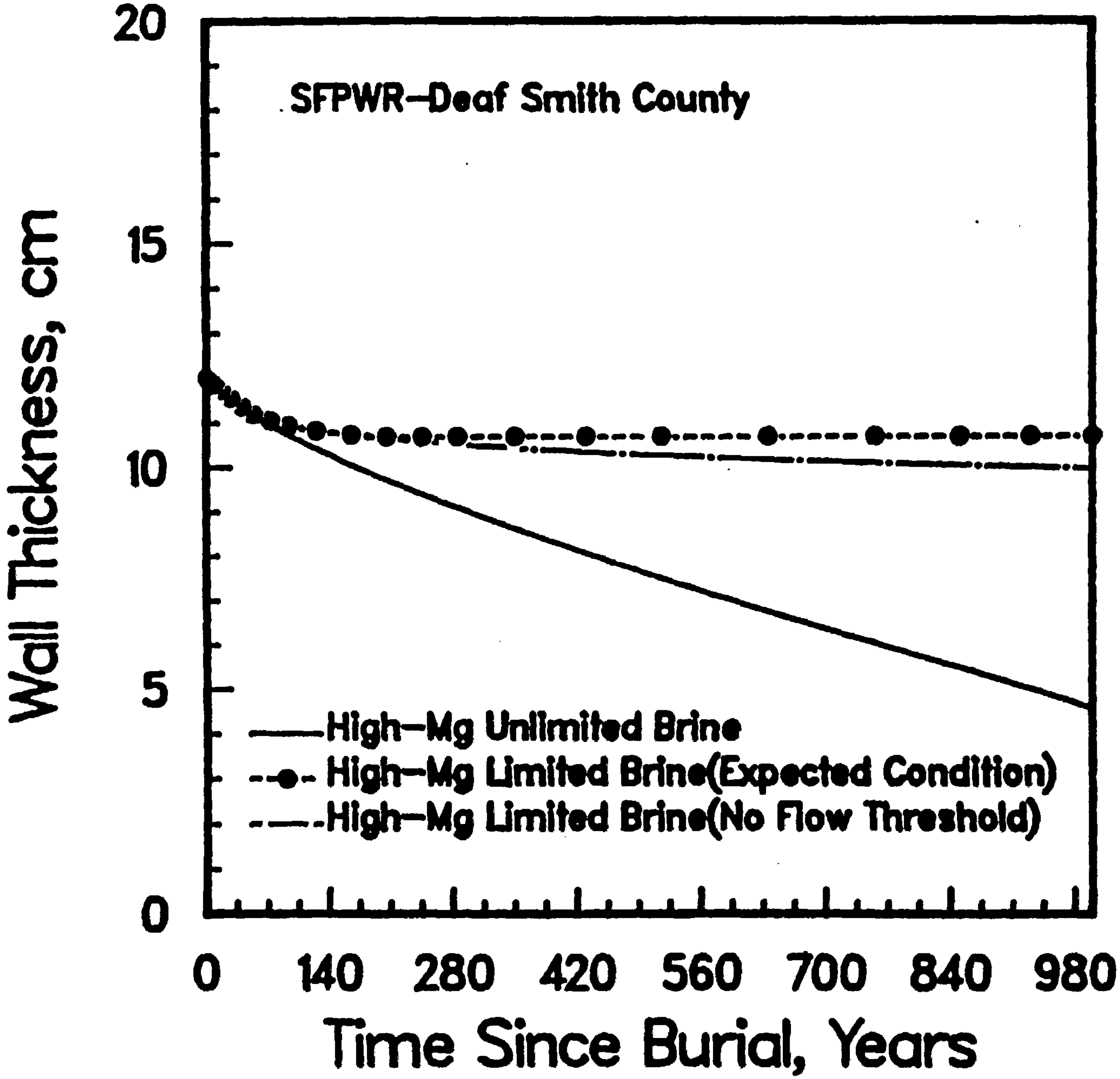
System Analyses for Assessment of Performance of Engineered Barriers



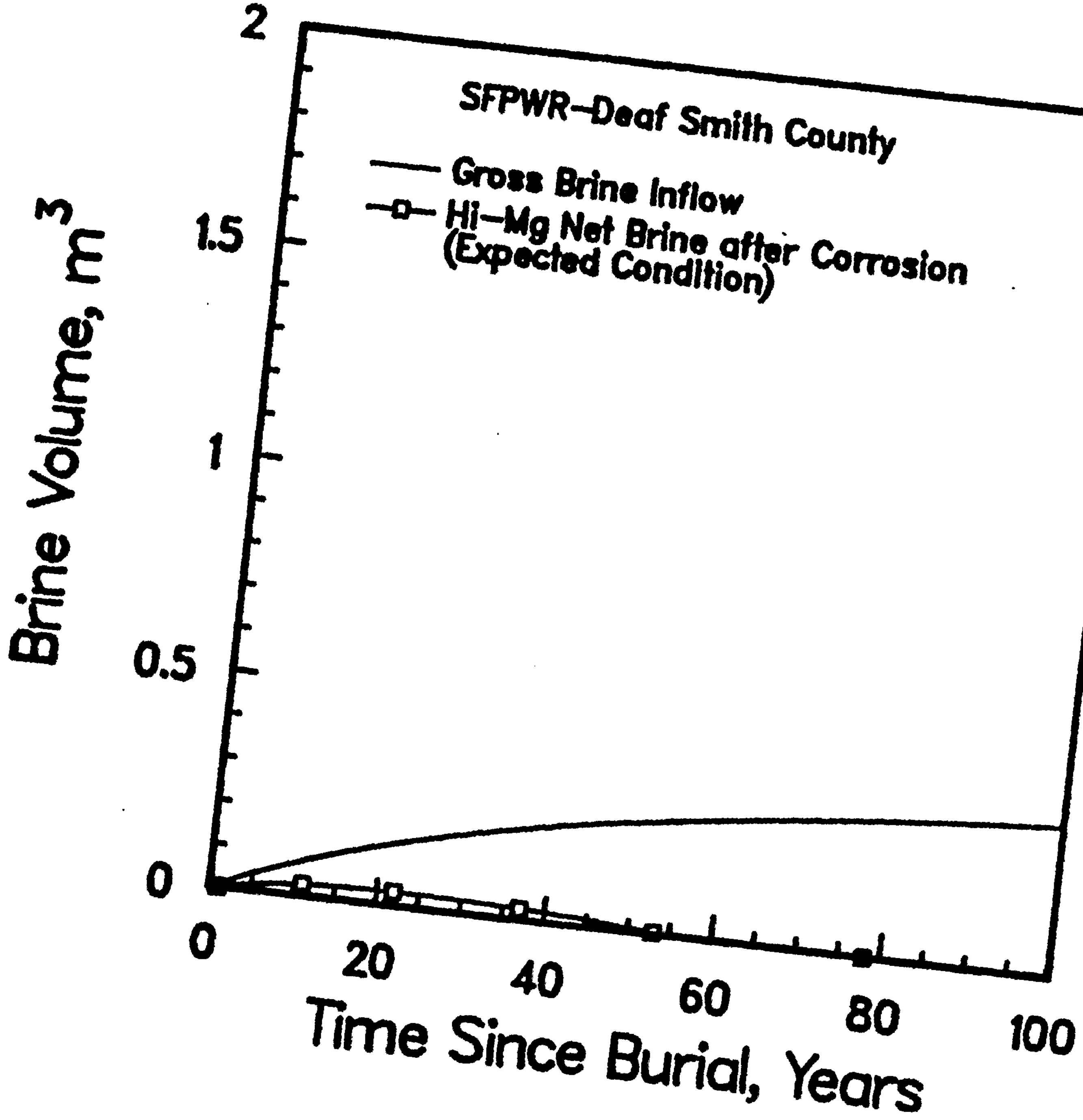
Air Gap
Crushed Salt
CHLW
Years Since Burial
0
20
50
100
200
500
1000
316-SST Canister
Glass Waste Form
1025 Cast Steel
Salt
Dose Rate, Rads/hr
10^5
10^3
10^1
10^{-1}
10^{-3}
10^{-5}
0
20
40
60
80
100
Distance From Centerline, cm

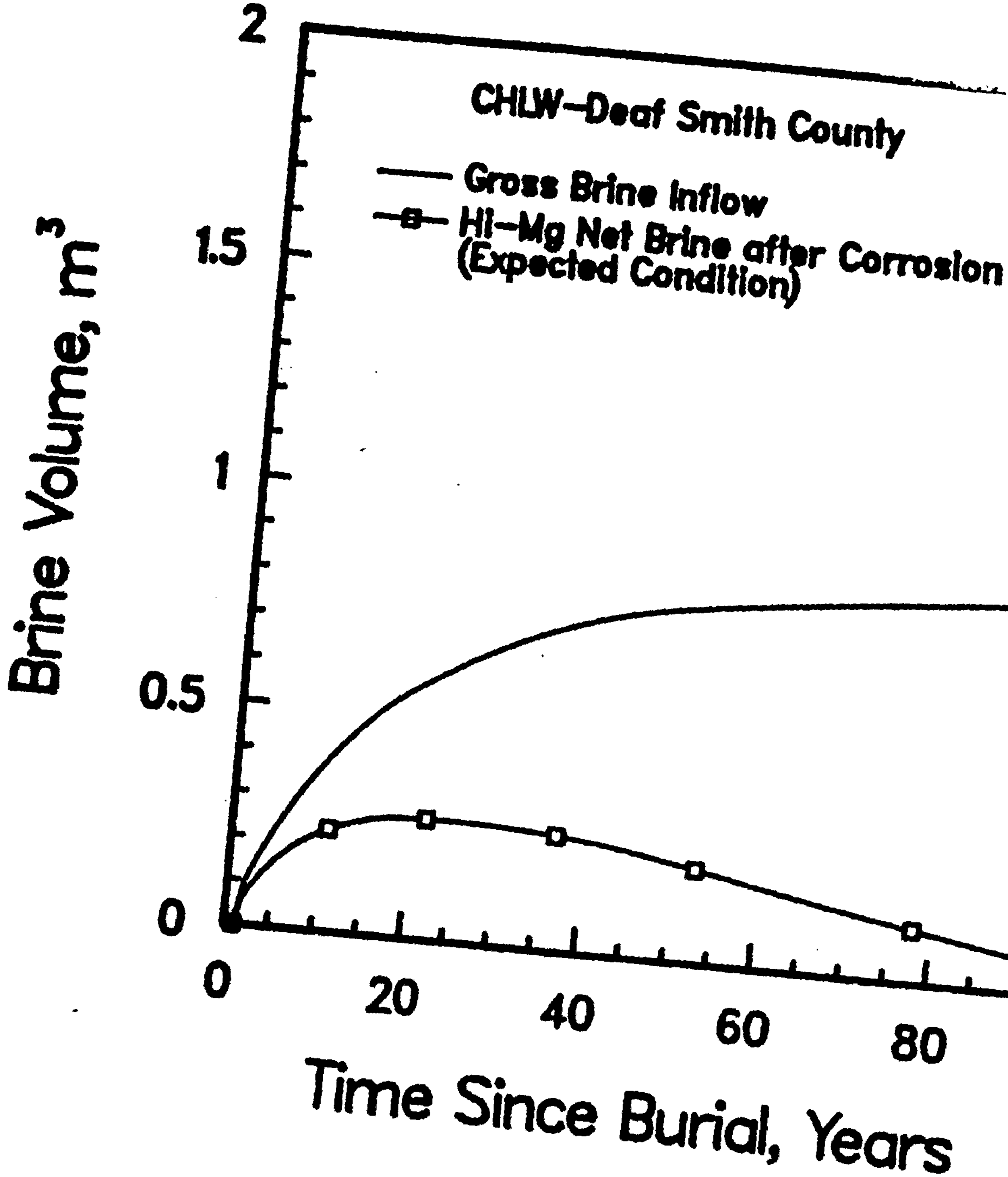


High Magnesium Content Brine
– Bedded Sites –
Penetration Rate, Mils/yr
10^3
10^2
10^1
10^0
10^{-1}
10^{-2}
10^{-3}
0
80
160
240
320
400
Overpack Surface Temperature, °C
10^6 Rad/hr High Mg
10^5 Rad/hr High Mg
10^4 Rad/hr High Mg
10^3 Rad/hr High Mg
10^2 Rad/hr High Mg
No Rad. Field High Mg
No Rad. Field Low Mg



SFPWR–Deaf Smith County
Wall Thickness, cm
20
15
10
5
0
High–Mg Unlimited Brine
High–Mg Limited Brine(Expected Condition)
High–Mg Limited Brine(No Flow Threshold)
0
140
280
420
560
700
840
980
Time Since Burial, Years


SFPWR–Deaf Smith County
Gross Brine Inflow
Hi–Mg Net Brine after Corrosion
(Expected Condition)
Brine Volume, m3
2
1.5
1
0.5
0
0
20
40
60
80
100
Time Since Burial, Years



CHLW–Deaf Smith County
Gross Brine Inflow
Hi–Mg Net Brine after Corrosion (Expected Condition)
Brine Volume, m3
2
1.5
1
0.5
0
0
20
40
60
80
100
Time Since Burial, Years

Deaf Smith County SFPWR Package. Comparison of Solubility and Maximum Brine Volume Limited Release at a Failed Waste Package Boundary with EPA Discharge Limits to the Accessible Environment

The volume of brine is 0.41 m^3 made available by brine thermal migration with a threshold thermal gradient.

Element	Solubility,[(a)] grams/m^3	Package Inventory,[(b)] grams	Dissolved in Brine, grams	Nuclide	EPA Limit,[(c)] Curies per 1000 MTIHM	Ratio of Radioactivity[(b)] in Brine to EPA Limit	Total Volume of Saturated Brine to Reach EPA Limit, m^3
Carbon	400.	831.	164.	C-14	200	1.2	0.35
Selenium	0.001	279.	4.1E-4	Se-79	500	0.12E-5	3.4E+5
Strontium	0.8	1,750.	0.33	Sr-90	80	0.11	3.9
Technetium	0.001	3,813.	4.1E-4	Tc-99	10,000	0.14E-6	2.9E+6
Tin	0.0001	6,752.	4.1E-5	Sn-126	80	0.58E-7	7.0E+6
Iodine	600,000.	1,157.	1,157.	I-129	500	0.063	Not saturated
Cesium	600,000.	7,077.	7,077.	Cs-135	2,000	0.17	Not saturated
				Cs-137	500	159. (meets limit by decay at 520 years)	
Radium	0.00042	0.67	1.7E-4	Ra-226	3	0.19E-4	2.1E+4
Thorium	0.001	50.	4.1E-4	Th-230	10	0.34E-5	1.2E+5
Uranium	0.001	4,800,000.	4.1E-4	U-234	10	0.16E-7	2.5E+7
Neptunium	0.001	8,245.	4.1E-4	Np-237	20	0.15E-5	2.7E+5
Plutonium	0.001	38,394.	4.1E-4	Pu-238	400	0.57E-5	7.2E+4
				Pu-239	100	0.33E-4	1.2E+4
				Pu-240	100	0.55E-4	7.5E+3
				Pu-241	500	0.41E-7	1.0E+7
				Pu-242	100	0.18E-06	2.3E+6
Americium	0.0001	4,304.	4.1E-5	Am-241	10	0.26E-2	1.6E+2
				Am-243	4	0.38E-4	1.1E+4
Curium	0.001	4.4	4.1E-4	Cm-244	10	0.13E-3	3.3E+3

(a) Various other solubility data exist, some with higher and some with lower values for various nuclides. These other data may be no more or no less applicable for this preliminary analyses.
(b) Maximum value during the period 300 years to 10,000 years.
(c) U.S. EPA, 1982, p. 58206.

Deaf Smith County SFPWR Package. Comparison of Package Release Rates to Saturate Incoming Brine at 300 Years at the Waste Package Boundary with NRC Engineered System Release Rate Limits in 10 CFR 60

The final gross volume of incoming brine will be 0.75 m^3, made available by brine migration without a threshold thermal gradient.

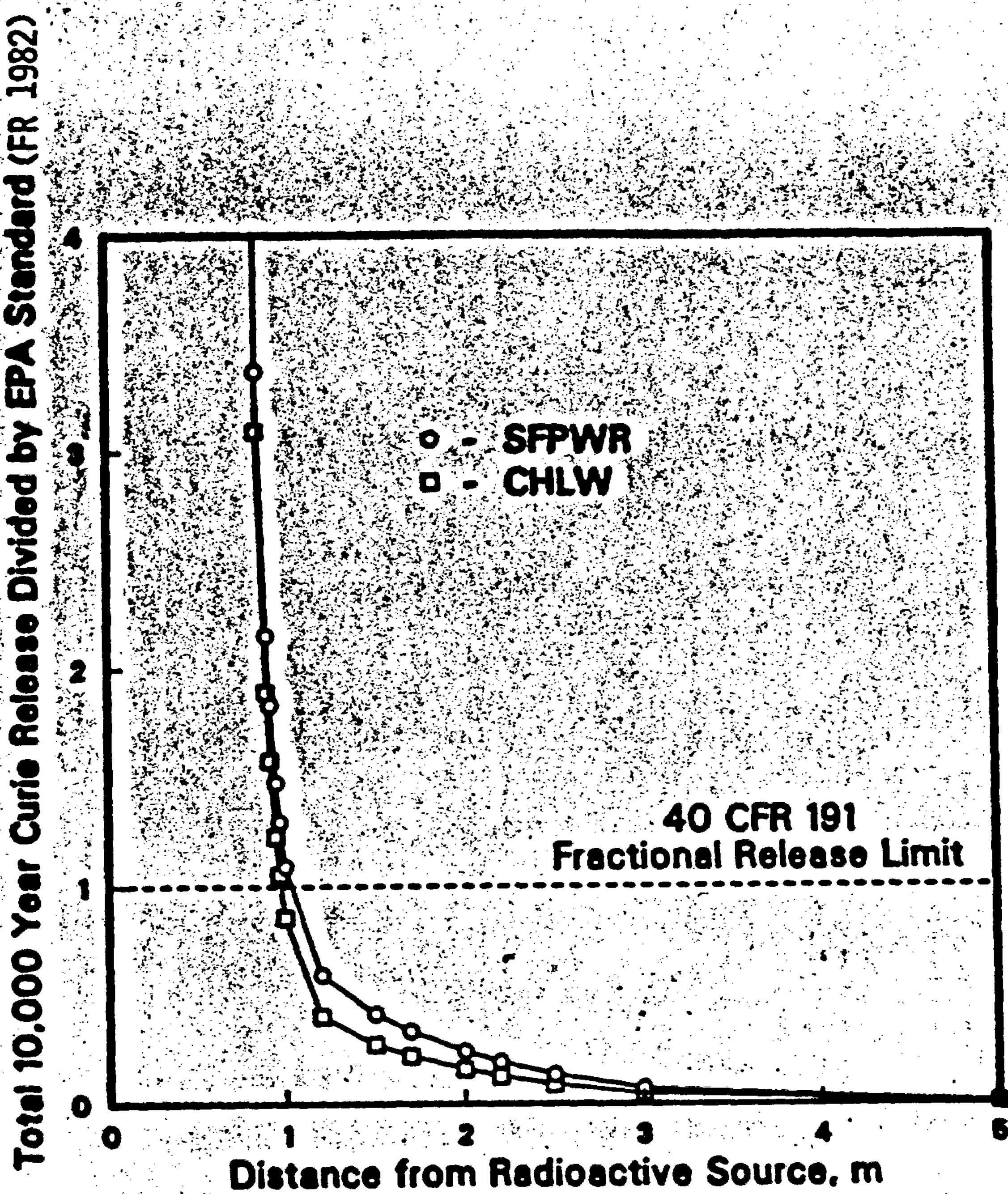
The gross brine inflow rate is 4.2E-4 m^3 per year at 300 years after burial.

Element	Solubility,[(a)] grams/m^3	300 yr Package Inventory,[(b)] grams	Quantity Required to Saturate Incoming Brines, grams/yr	Nuclide	Activity From Package to Brine, Curies/yr	Ratio to 1000yr Nuclide Activity/ (1E-5 per yr)	Ratio to 1000yr Total Activity/ (1E-8 per yr)
Carbon	400.	831.	0.17	C-14	0.0012	22.	14.
Selenium	0.001	279.	4.2E-07	Se-79	3.0E-9	1.5E-04	(c)
Strontium	0.8	1,750.	3.4E-04	Sr-90	4.3E-5	330,000.	0.52
Technetium	0.001	3,813.	4.2E-07	Tc-99	7.1E-09	1.1E-5	(c)
Tin	0.0001	6,752.	4.2E-08	Sn-126	2.4E-11	6.3E-7	(c)
Iodine	600,000.	1,157.	250.	I-129	0.034	22,000.	410.
Cesium	600,000.	7,077.	250.	Cs-135	0.060	3,600.	710.
				Cs-137	14.	3.8E+10	170,000.
Radium	0.00042	1.1E-03	1.8E-7	Ra-226	1.7E-07	1.1	0.0021
Thorium	0.001	1.2	4.2E-7	Th-230	7.3E-09	0.086	(c)
Uranium	0.001	4,800,000.	4.2E-7	U-234	8.3E-13	8.3E-9	(c)
Neptunium	0.001	4,250.	4.2E-7	Np-237	3.0E-10	6.0E-6	(c)
Plutonium	0.001	38,394.	4.2E-7	Pu-238	1.2E-8	2.4E-4	(c)
				Pu-239	1.7E-08	1.1E-6	(c)
				Pu-240	2.8E-8	1.2E-6	(c)
				Pu-241	1.0E-10	1.6E-5	(c)
				Pu-242	9.3E-11	1.1E-6	(c)
Americium	0.0001	4,304.	4.2E-08	Am-241	1.3E-7	3.0E-6	(c)
				Am-243	7.8E-10	1.0E-6	(c)
Curium	0.001	4.4	4.2E-07	Cm-244	6.4E-09	3.1E+06	7.7E-05

(a) Various other solubility data exist, some with higher and some with lower values for various nuclides. These other data may be no more or no less applicable for this preliminary analyses.

(b) The radium, thorium, and neptunium grow larger with time, so that at 10,000 years these inventories are 6.7E-01, 49.5, and 8,243 grams per package, respectively.

(c) This value is not computed unless the primary (10^{-5}) standard is not met indicated by a value greater than one in the preceding column.



TOTAL 10,000 YEAR CURIE RELEASE DIVIDED BY EPA STANDARD FOR VARIOUS DISTANCES TO HYPOTHETICAL ACCESSIBLE ENVIRONMENT FOR DEAF SMITH

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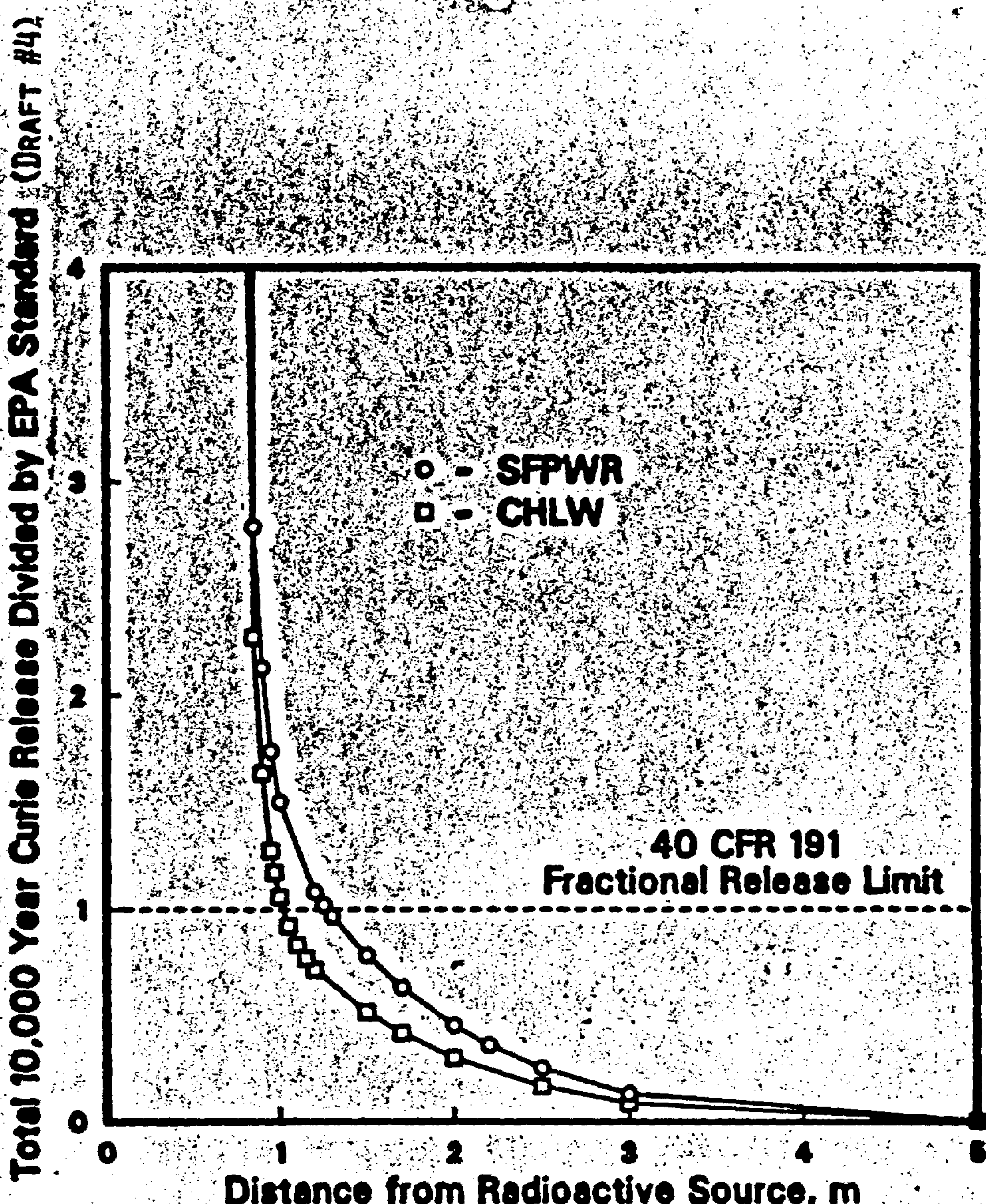
SB:7-9-84



Total 10,000 Year Curie Release Divided by EPA Standard for Various Distances to Hypothetical Accessible Environment for Deaf Smith

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SB:7-9-84

SUMMARY COMMENTS

GEOCHEMISTRY OVERVIEW MEETING
WITH
NUCLEAR REGULATORY COMMISSION

22 AUGUST 1984

PRESENTER: NORMAN HUBBARD

ONWI

BATTELLE Project Management Division

NH:8/22/84

WASTE PACKAGE DOMINATES NEAR-FIELD CHEMISTRY

- source of heat and radiation
- insufficient brine
  - corrosion rate not important
  - radiolysis not important
- virtually no redox controlling minerals in salt
  - Fe metal and radiolysis are controlling

NH:8/22/84

ONWI Office of Nuclear Waste Isolation Battelle

BRINE AMOUNTS INADEQUATE TO
BREACH WASTE PACKAGE
- expected conditions -

- performance assessment calc. assume 2x to 10x more brine in salt than found
- all brine is reacted
  - no dependence on corrosion rate date
- more than 10cm of Fe overpack mutual remains
- overpack lifetimes always greater than 1,000 years

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NO EXIT FROM SALT

- expected conditions -

- No known natural exits
- Very slow flow/diffussion rates in salt
- impermeable rocks protecting salt

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BRINES RESULTING FROM

BREACHING REPOSITORY

- unexpected conditions -

- potentially unlimited volume of brine
- NaCl brines, sat. with $CaSO_4$, at Palo Duro and Gulf, rather than Mg-rich brines
- potentially large volumes of high-Mg brine at Paradox
- corrosion rate and radionuclide solubility data are more crutial

NH:8/22/84

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TRAVEL TIMES IN FAR-FIELD AQUIFERS

Site	Outside Host Rock to 10km
Richton	>100,000 years
Palo Duro (Wolfcamp)	>500,000 years
Paradox (interbed below salt 6)	>1,000,000 years

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