Underground nuclear explosion test locations as analogs for a high level waste repository

A presentation to the Nuclear Waste Technical Review Board

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Summary and Conclusions

- Data from the Radionuclide Migration (RNM) program can support bounding risk assessments for a Yucca Mountain repository
  - confirm theories about equilibrium radioactivity levels in water when bare vitrified waste is submersed in ground water
  - confirm theories about retardation of radionuclides during flow through saturated tuffaceous rock.
- The opportunity exists for field studies of colloidal migration.
- The opportunity exists for field studies of migration of radionuclides from an existing source vertically downward through unsaturated rock.

Outline of presentation

- Background
  - Phenomenology and history of underground nuclear testing
  - General information about RNM program
- The Cambric experiment and other results
- Relevance of nuclear test data to repository assessment
- Summary and Conclusions

Purpose of Radionuclide Migration (RNM) Program

- Prior to RNM, there were some theoretical risk assessments based on geologic and hydrologic data for the Nevada Test Site (NTS)

- However, there was little information on distribution of radioactivity and its availability to ground water

- The RNM Program was started in 1973 to address the relation between the radionuclide inventory and the ground water source term for transport calculations

- If very little radioactivity gets into ground water at the source, the potential for migration is limited

- Ultimate aim was to evaluate potential for offsite migration of radionuclides at levels above Radiation Concentration Guides

History of underground nuclear testing at NTS

- First contained underground test: Rainier, Sept 1957
- Since July 1962, all NTS tests have been underground
- Distribution of tests and radioactivity in this talk summarized as of June 1975 (1)

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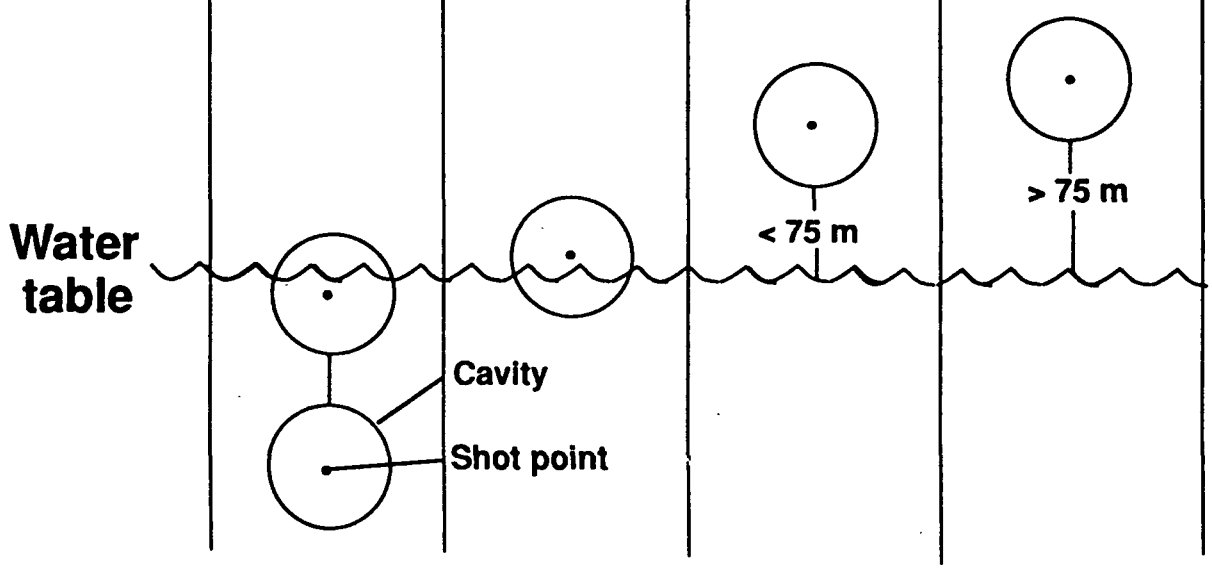
(1) I. Borg, R. Stone, H. Levy, and L. Ramspott: "Information Pertinent to the Migration of Radionuclides in Ground Water at the Nevada Test Site, Part 1: Review and Analysis of Existing Information", Lawrence Livermore National Laboratory Rept. UCRL-52078 Pt.1, May 1976, 216 p.

Location of nuclear tests with respect to the water table through 1975

					Total
Yucca Flat (1958-1975)	36	17	30	168	251
Frenchman Flat (1965-1975)	1	2	7	-	10
Pahute Mesa (1965-1975)	18	4	1	4	27
SUM	55	23	38	172	288



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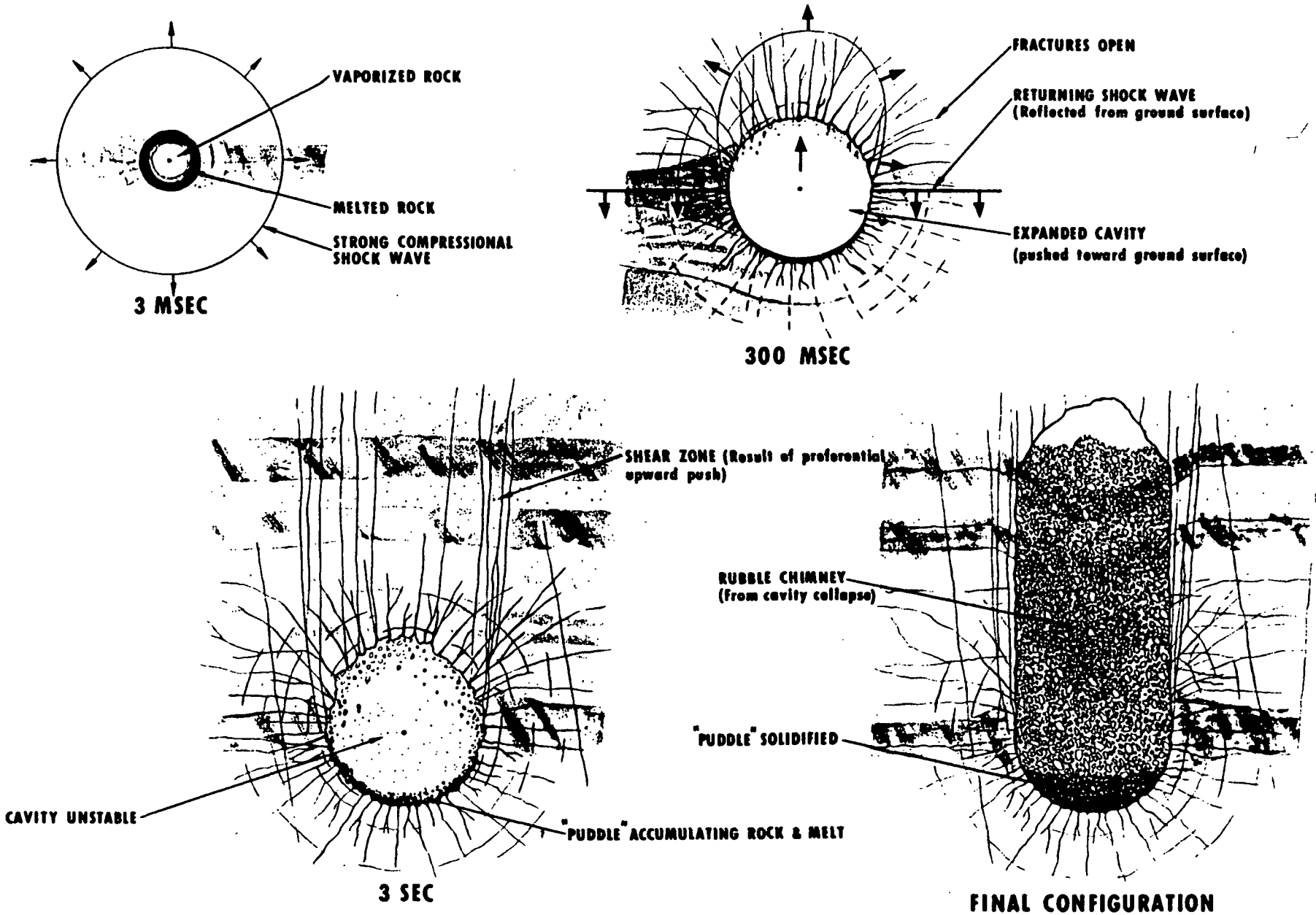
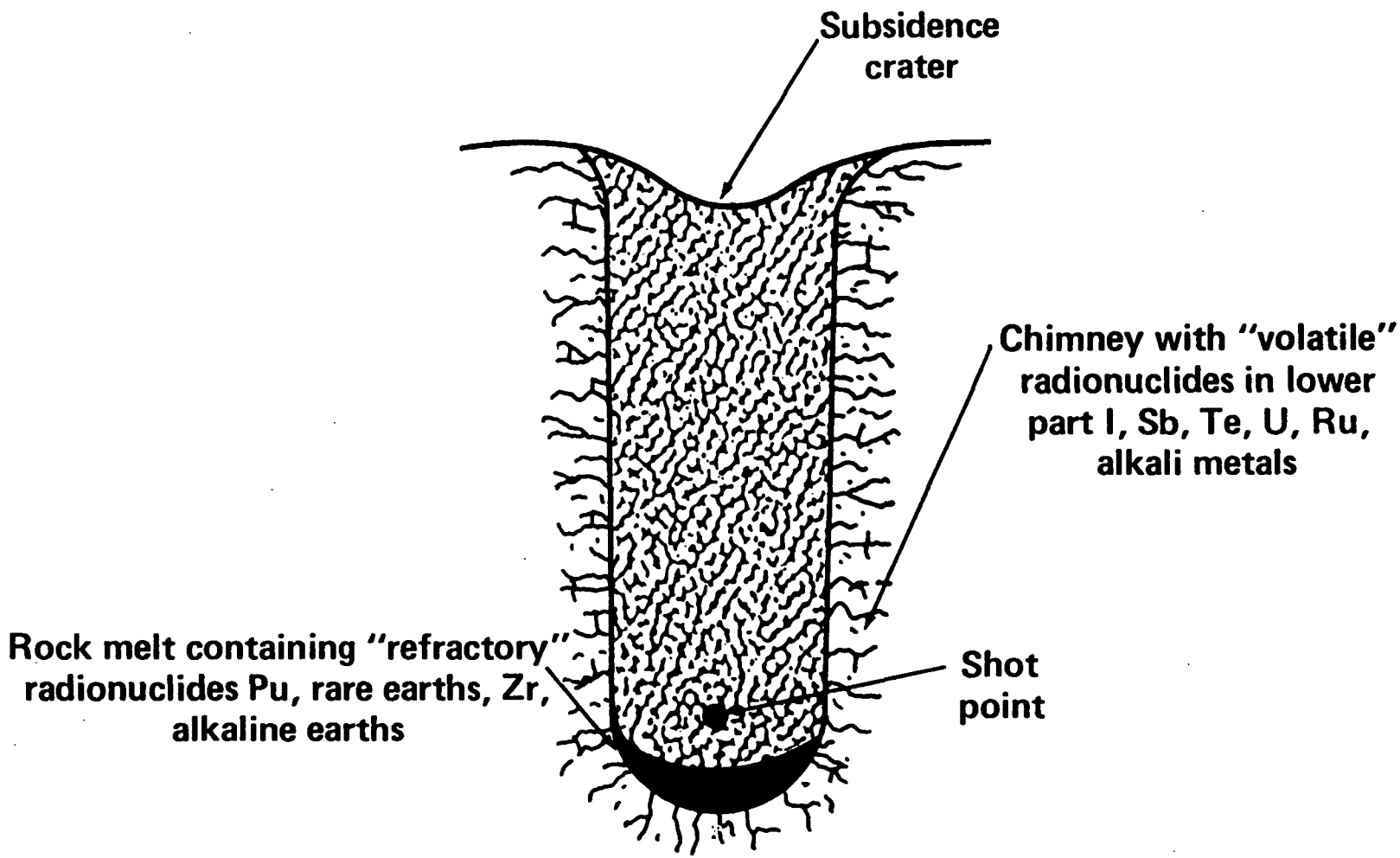
CAVITY-CHIMNEY FORMATION HISTORY



RADIONUCLIDES ARE FRACTIONATED WITHIN THE CAVITY-CHIMNEY SYSTEM BY THEIR VOLATILITY



THE DEEP WATER TABLE AT YUCCA FLAT MAKES DATA TAKING DIFFICULT

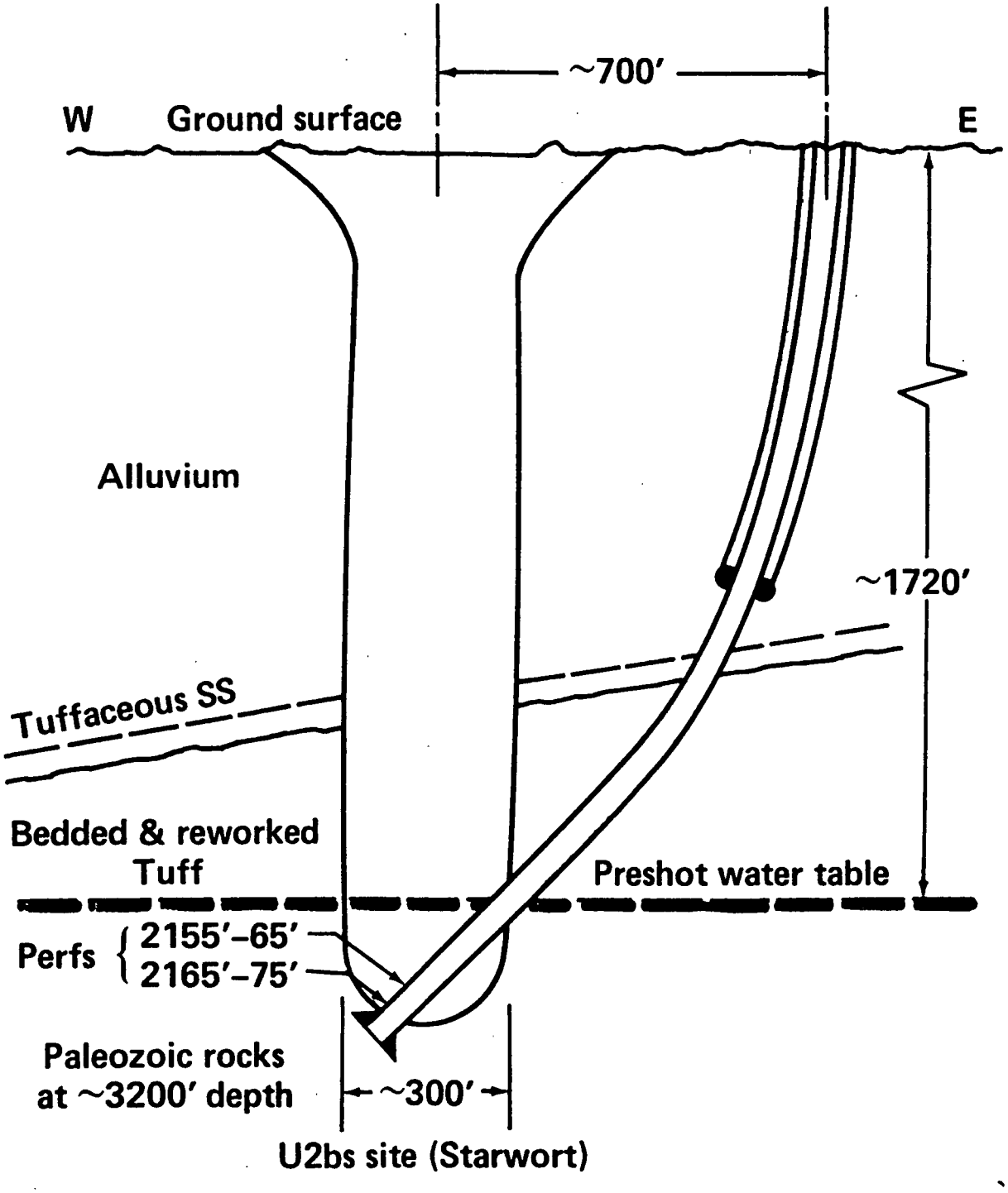


Photo of Rainier cavity boundary

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Comparison of properties of vitrified high-level reactor waste and melt glass from nuclear explosions

	Reactor	NTS tests
Glass	Borosilicate	Fused siliceous rock
Density (GM/cm^3)	3.0 - 3.6	1.0 - 2.3
SiO_2	27 - 52%	~ 70%
Porosity	< 1%	up to 50%
Container	Double steel wall	None
Radionuclides		
Pu	130-325 PPM	2-40 PPM
^{235}U	120-300 PPM	0-40 PPM
F. P.	100,000-260,000 PPM	0.1* PPM
Devitrification	None Below 400-500°C	Partial recrystallization

* A high proportion of many fission products escape from melt.

Comparison of leach rate data

Glass	Element	Water	Rate (g/m^2-day)
NTS glass (1)	Na	J-13 ground water	1xE-02 to 1xE-04
DWPF glass (2)	Li	J-13 ground water	5xE-02 to 2xE-02
PNL 76-68 (3)	B	Bicarbonate	1xE-02 to 7xE-03

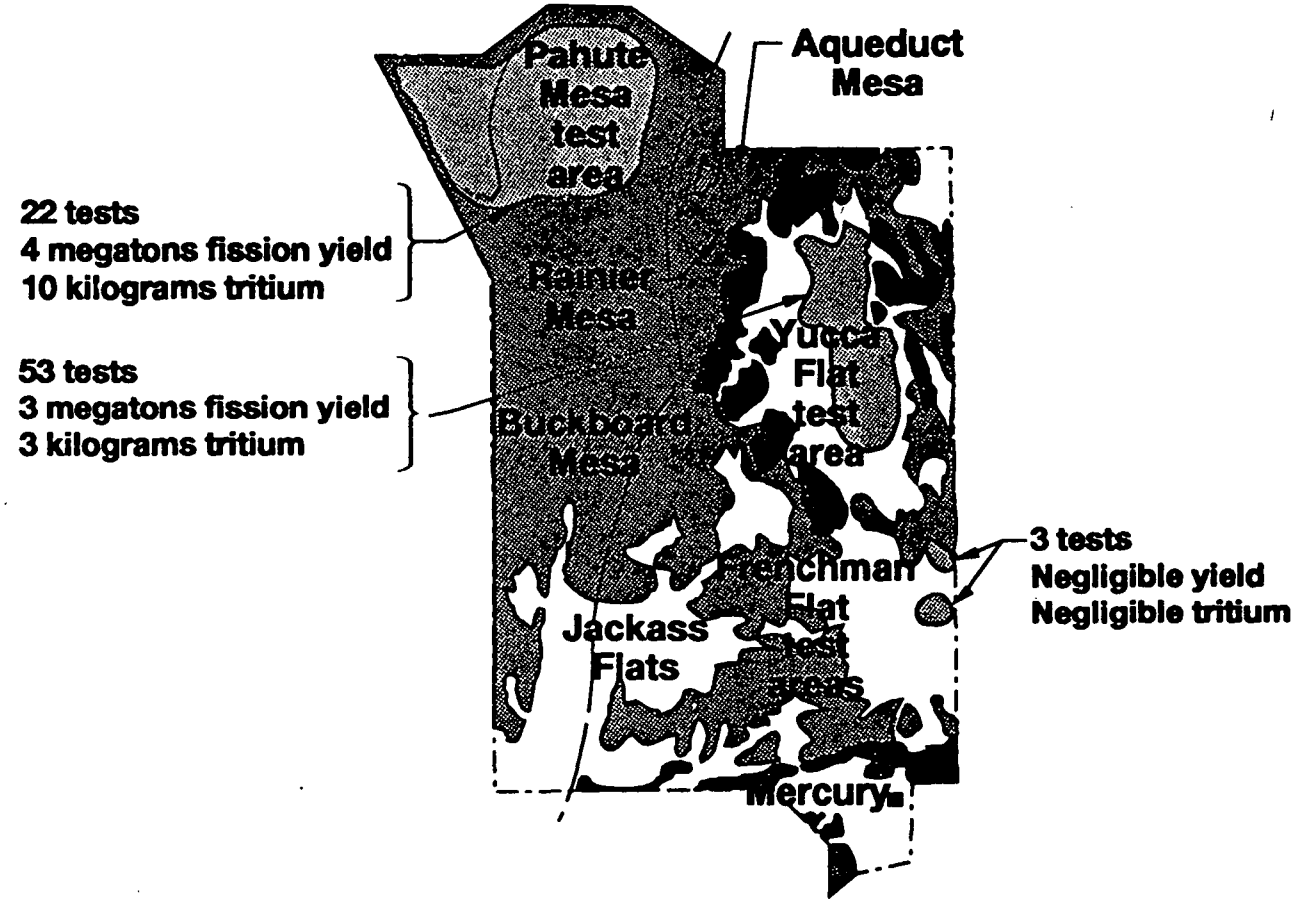
References:

(1) Failor, Coles, and Rego: LLNL Rept. UCID-19729 (1983)

(2) Bazan and Rego: LLNL Rept. UCRL-53606 (1985)

(3) Bazan, Rego, Failor, and Coles: LLNL Rept. UCID-19764 (1983)

Although more tests were at Yucca Flat, more radioactivity was deposited at Pahute Mesa



The three cavities or chimneys pumped have only a few radionuclides in the water above RCG

- Cambric - Frenchman Flat - tuffaceous alluvium at 970 feet depth
  - only tritium and Sr-90 above RCG

- Cheshire - Pahute Mesa - rhyolite at 3830 ft depth
  - only tritium and Kr-85 above RCG

- Bilby - Yucca Flat - tuff at 2000 feet depth
  - lost cavity access but retained chimney access
  - only tritium above RCG

- Starwort - Yucca Flat - tuff at 1780 feet depth
  - lost cavity access before refill

- Almendro - Pahute Mesa - tuff at 3500 feet depth
  - lost access

Cambric nuclear test data

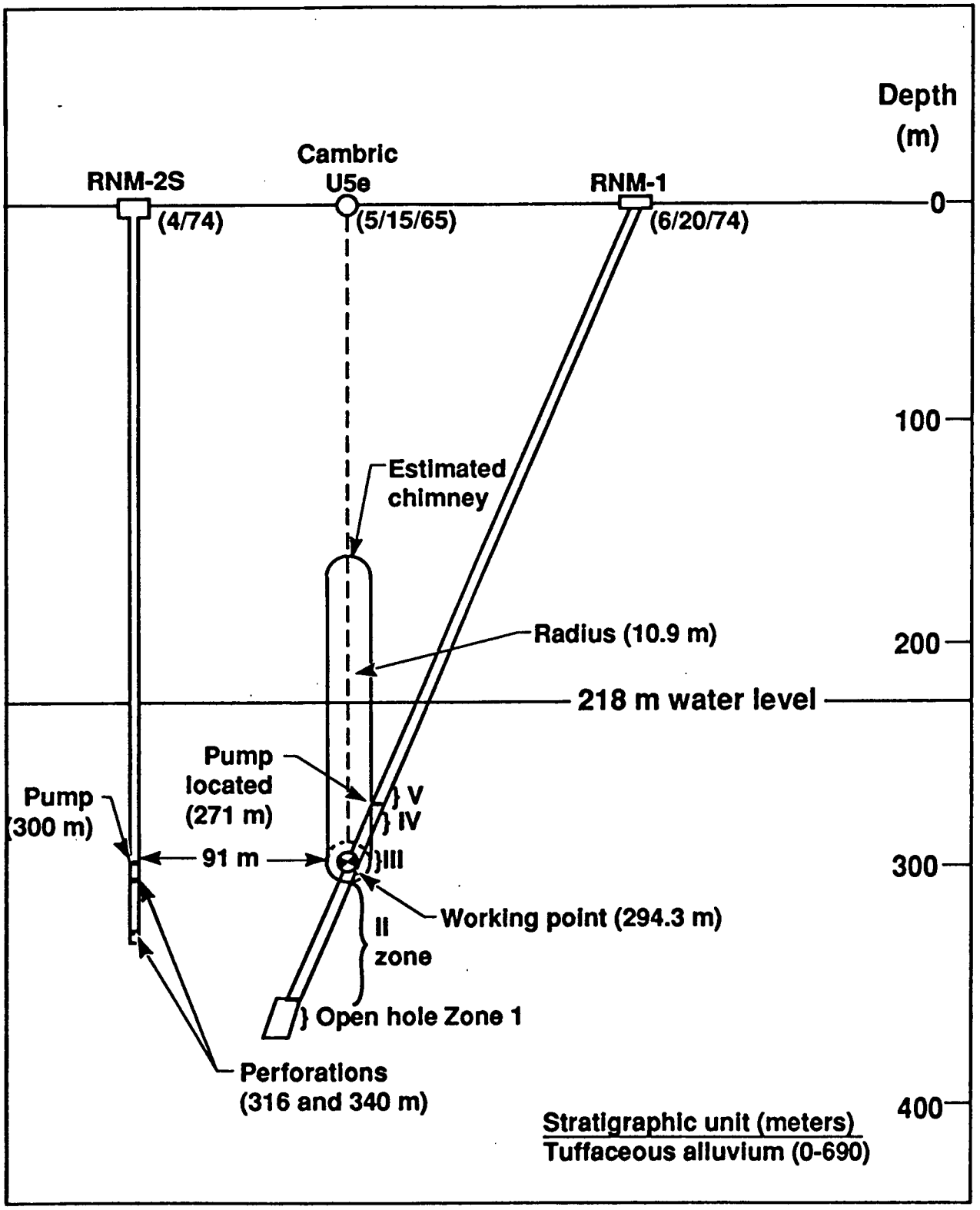
- Detonated in May 1965 at Nevada Test Site
- Yield: 0.75 kt high explosive equivalent
- 6 grams residual tritium
- Cavity water samples first taken in 1974

Objectives of Cambric experiment

- Cavity reentry
  - Measurement of radionuclide content of ground water in explosion zone
  - Estimate the partitioning of radionuclides between ground water and solid material
  - Provide source data for migration measurements

- Satellite well pumping
  - Provide field confirmation of retardation predictions
  - Monitor changes in cavity concentrations as water migrates to satellite well
  - Compare soluble radionuclides as tracers

Cambric site cross section



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ACTIVITY LEVELS IN WATER AT TIME OF SAMPLING

Zone	^{3}H (μ Ci/ml)	^{90}Sr (dpm/ml)	^{106}Ru (dpm/ml)
Adjacent to chimney (V)	0.028	0.2	n.d.
Chimney (IV)	0.084	5	n.d.
Upper cavity (III)	4	5	4
Lower cavity (II)	6	8	11
Below cavity (I)	BG	BG	BG
Drinking water concentration guide	0.003	0.67	22.2

BG – background level

ACTIVITY LEVELS IN WATER AT TIME OF SAMPLING

Zone	^{125}Sb	^{137}Cs (dpm/ml)	^{239}Pu
Adjacent to chimney (V)	n.d.	0.2	n.d.
Chimney (IV)	n.d.	0.8	n.d.
Upper cavity (III)	2	1.4	2.6×10^{-3}
Lower cavity (II)	5	1.6	2.9×10^{-3}
Below cavity (I)	BG	BG	BG
Drinking water concentration guide	222	44.4	11.1

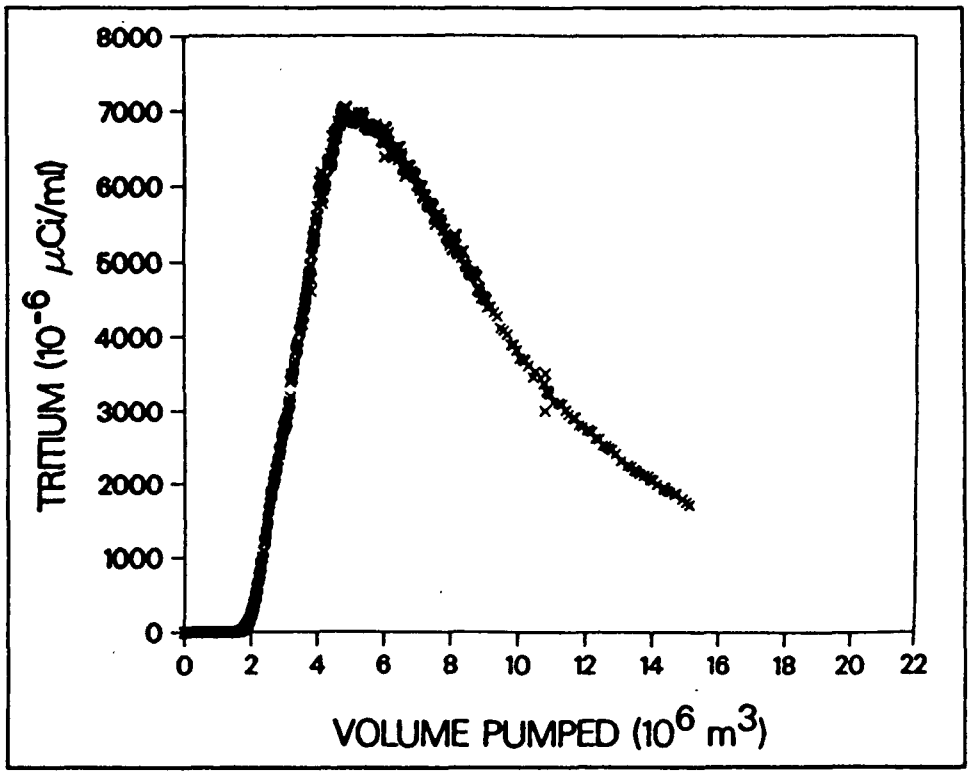
Cambric cavity studies summary

- Most activity still confined to region of explosion cavity at first reentry 10 years after test
- No activity above background found in water from 50 m below cavity
- Water from bottom of cavity contained H-3, Sr-90, Ru-106, Sb-125, Cs-137, and small amounts of Ce-144, Pm-147,and Pu-239
- Only H-3 and Sr-90 found in water at levels above the RCG for drinking water
- After 16 years of pumping at the satellite well, concentrations in the cavity have decreased to levels barely above detection limits.

Cambric satellite well

- 90 m from source
- Pumped nearly continuously from 1974 to 1991
- 4 billion gallons and 92% of H-3 source has been pumped

T concentration vs volume pumped for Cambric satellite well



Cambric satellite well results

- H-3, Cl-36, Kr-85, Ru-106, and I -129 have been observed. Only H-3 ever exceeded RCG for effluent water in an uncontrolled area

- Other fission products and actinides have been searched for but not observed.

- Migration of H-3 from the discharge ditch has been monitored to provide data on recharge and vadose-zone migration in the alluvial soil

Brief summary of other RNM results

- At Cheshire only H-3 and Kr-85 were above RCG for uncontrolled effluent water in "hottest" samples obtained

- Decay-corrected concentrations of H-3 Kr-85, Sr-90, Sb-125, and Cs-137 have decreased in Cheshire chimney and are present in observation hole 300 m away -- apparent natural migration

- Explicit search for Tc-99 detected it at Cambric, Cheshire, Bilby and Faultless, orders of magnitude below the RCG for drinking water

- Mn, Co, Ce, Cs, and Eu fission isotopes are associated with colloidal material at Cheshire

Relevance of RNM program to the potential repository site at Yucca Mountain

- The RNM program has focussed on sites below the water table whereas proposed repository is unsaturated

- Tests above the water table have been assumed to be isolated from aquifers where flow occurs
  - great depth to saturated zones
  - low rainfall at NTS
  - distribution of caliche, bomb-pulse tritium, and other evidence against vertical recharge

- Direct measurements below a cavity have not been made

- Opportunity exists to make measurements relevant to Yucca Mountain situation

Relevance of RNM program (cont'd)

- Nuclear explosion melt glass as a "waste form"
  - about same as borosilicate glass
  - not a good analog for spent reactor fuel

- Are the observed low levels of activity in ground water due to low radionuclide concentrations in melt glass ?
  - concentration of actinides in ground water appears to be solubility limited; concentration in glass may be irrelevant
  - many fission products deposited outside melt glass
  - low concentration of radionuclides in ground water may be due in part to sorption on rock

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