

**U.S. DEPARTMENT OF ENERGY
OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT**

**PRESENTATION TO
THE NUCLEAR WASTE TECHNICAL REVIEW BOARD**

**SUBJECT: GEOCHEMICAL AND ISOTOPE
METHODS FOR DETERMINING
FLOWPATHS AND TRAVEL TIME
USING CARBON, OXYGEN, AND
TRITIUM DATA**

PRESENTER: DR. IN CHE YANG

**PRESENTER'S TITLE
AND ORGANIZATION: PROJECT CHIEF OF UNSATURATED-ZONE
HYDROCHEMISTRY PROGRAM, YUCCA MOUNTAIN PROJECT
U.S. GEOLOGICAL SURVEY
DENVER, COLORADO**

**PRESENTER'S
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**HYDROLOGIC AND TRANSPORT
PROPERTIES BY HYDROCHEMICAL
CHARACTERIZATION OF UZ-BOREHOLES
AND EXPLORATORY STUDIES**

HYDROCHEMICAL CHARACTERIZATION OF THE UNSATURATED ZONE (SCP SECTION 8.3.1.2.2.7)

OBJECTIVES:

- **TO UNDERSTAND THE GAS TRANSPORT MECHANISM, DIRECTION, FLUX AND TRAVEL TIME WITHIN THE UNSATURATED ZONE**
- **TO DESIGN AND IMPLEMENT METHODS FOR EXTRACTING PORE FLUIDS FROM THE TUFF**
- **TO PROVIDE INDEPENDENT EVIDENCE OF FLOW DIRECTION, FLUX, AND TRAVEL TIME OF WATER IN THE UNSATURATED ZONE**
- **TO DETERMINE THE EXTENT OF THE WATER-ROCK INTERACTION, AND TO MODEL GEOCHEMICAL EVOLUTION OF THE WATER IN THE UNSATURATED ZONE**

CONTENTS OF THE PRESENTATION

● GENERAL

PARAMETER CATEGORIES, CHEMICAL SPECIES TO BE MEASURED AND THEIR PURPOSES

● GAS-PHASE CHEMICAL INVESTIGATIONS

- GAS SAMPLING METHODS**
- DEGASSING AND ANALYSES**
- RESULTS**

● AQUEOUS-PHASE CHEMICAL INVESTIGATIONS

- PORE-WATER EXTRACTION METHODS**
- TRITIUM DATA**
- STABLE ISOTOPE DATA**

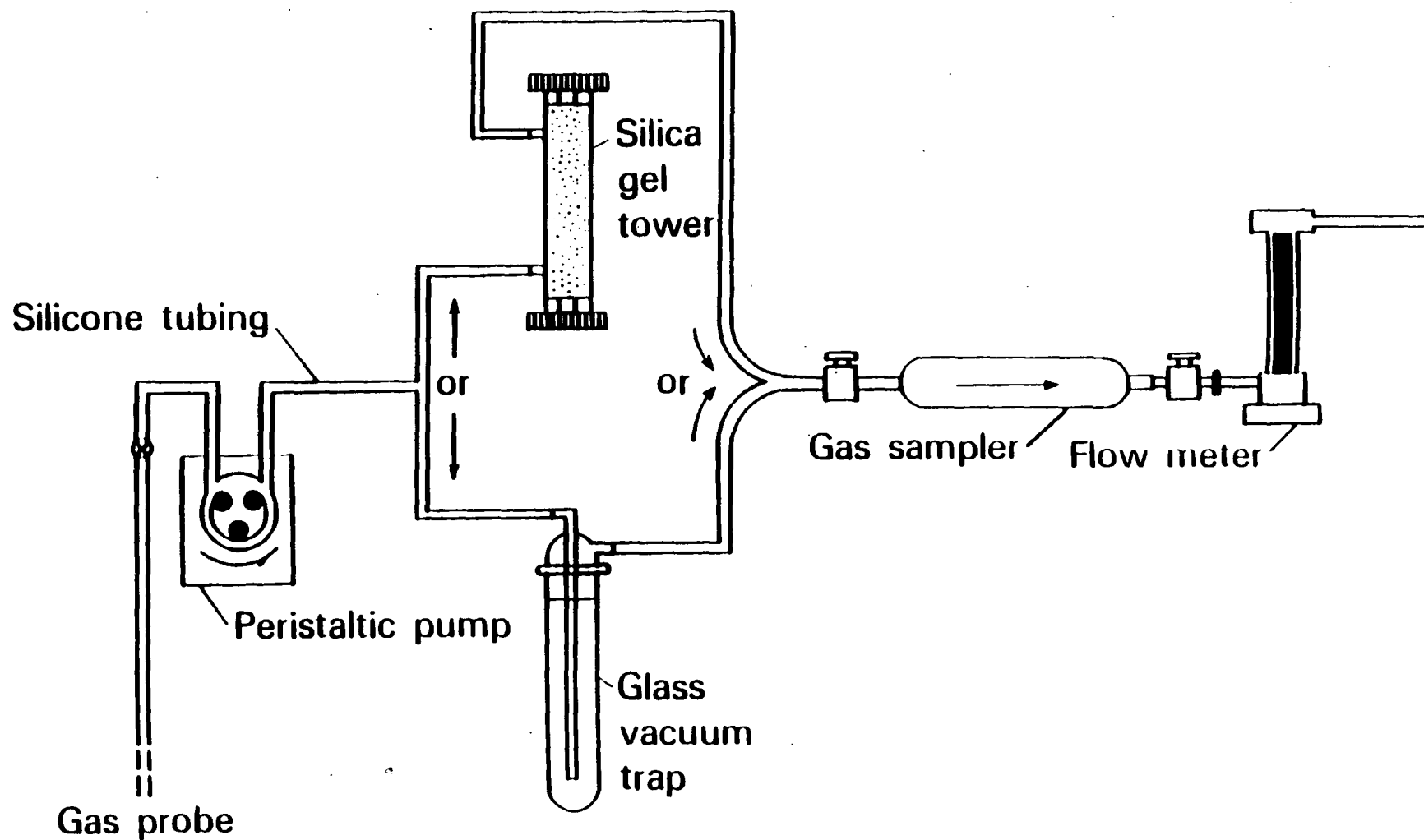
PARAMETER	CHEMICAL SPECIES	REMARKS
INORGANIC CATIONS AND ANIONS	Na, Ca, Mg, K, HCO ₃ , So ₄ , Cl, pH, SiO ₂ , Mn, Fe, Al	TYPES OF ONGOING CHEMICAL REACTIONS. RESIDENCE TIMES OF FRACTURE FLUIDS
	RARE-EARTH ELEMENTS AND OTHER TRACE ELEMENTS	FLUID INCLUSIONS IN SECONDARY MINERALS TO IDENTIFY THE SOURCE OF WATER
ORGANIC COMPOUNDS	ORGANIC COMPOUNDS (TRACE AMOUNTS)	FORMING OF ORGANOMETALLIC COMPLEXES THAT CHANGE
STABLE ISOTOPES	¹⁸O/¹⁶O AND D/H RATIOS	TIMING OF MAJOR RECHARGE EVENTS. FLUID INCLUSION IN SECONDARY MINERALS TO IDENTIFY THE SOURCES OF WATER.
AGE DATING	¹⁴C, ³H, ¹³C/¹²C RATIOS, ³⁶Cl*	AGE AND TRAVEL TIME OF UNSATURATED-ZONE WATERS. STYLE AND PATTERN OF FLUID FLOW IN THE UNSATURATED ZONE.
GAS DIFFUSION	FREON-11, FREON-12, CO₂, H₂, SF₆, CH₄, Ar, O₂, N₂	DIFFUSION OF GASES (¹⁴C, ³H, AND ³⁹Ar) INTO THE UNSATURATED ZONE.
CONTAMINATION CHECK	Li, Br, I, NO₃, BO₃	WASHDOWN OF TRACERS.

* ³⁶Cl WORK TO BE PERFORMED BY LOS ALAMOS NATIONAL LABORATORY IN STUDY 8.3.1.2.2.2.1 (CHLORIDE AND CHLORINE-36 MEASUREMENT OF PERCOLATION AT YUCCA MOUNTAIN)

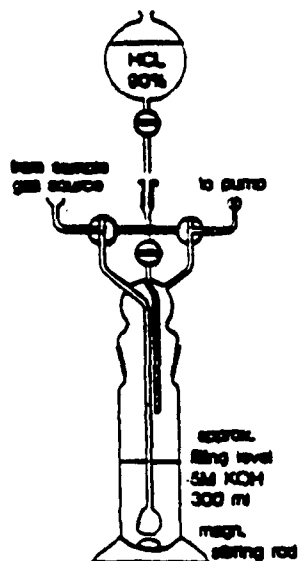
AVERAGE TERRESTRIAL ISOTOPIC ABUNDANCE

ELEMENT	ISOTOPES	AVERAGE TERRESTRIAL ABUNDANCE (%)	COMMENTS
HYDROGEN	¹ H	99.984	RADIOACTIVE † _{1/2} =12.35 yr
	² H	0.0148	
	³ H	10 ⁻¹⁴ TO ⁻¹⁶	
CARBON	¹² C	98.89	RADIOACTIVE † _{1/2} =5730 yr
	¹³ C	1.11	
	¹⁴ C	~10 ⁻¹⁰	
OXYGEN	¹⁶ O	99.76	
	¹⁷ O	0.037	
	¹⁸ O	0.203	

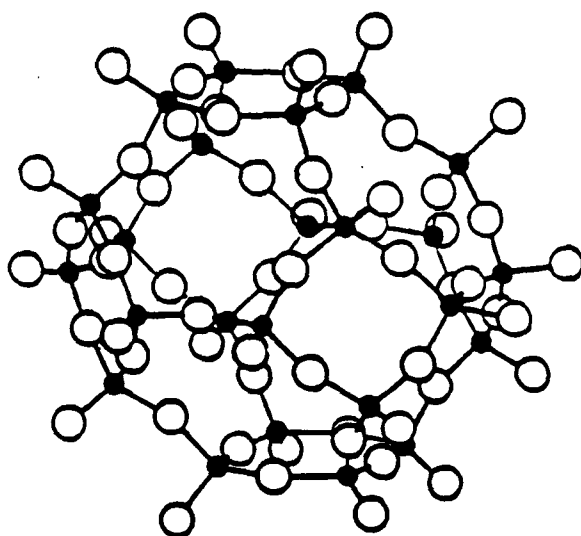
UZ-1 GAS SAMPLING SYSTEM



METHODS OF CO₂ GAS COLLECTION



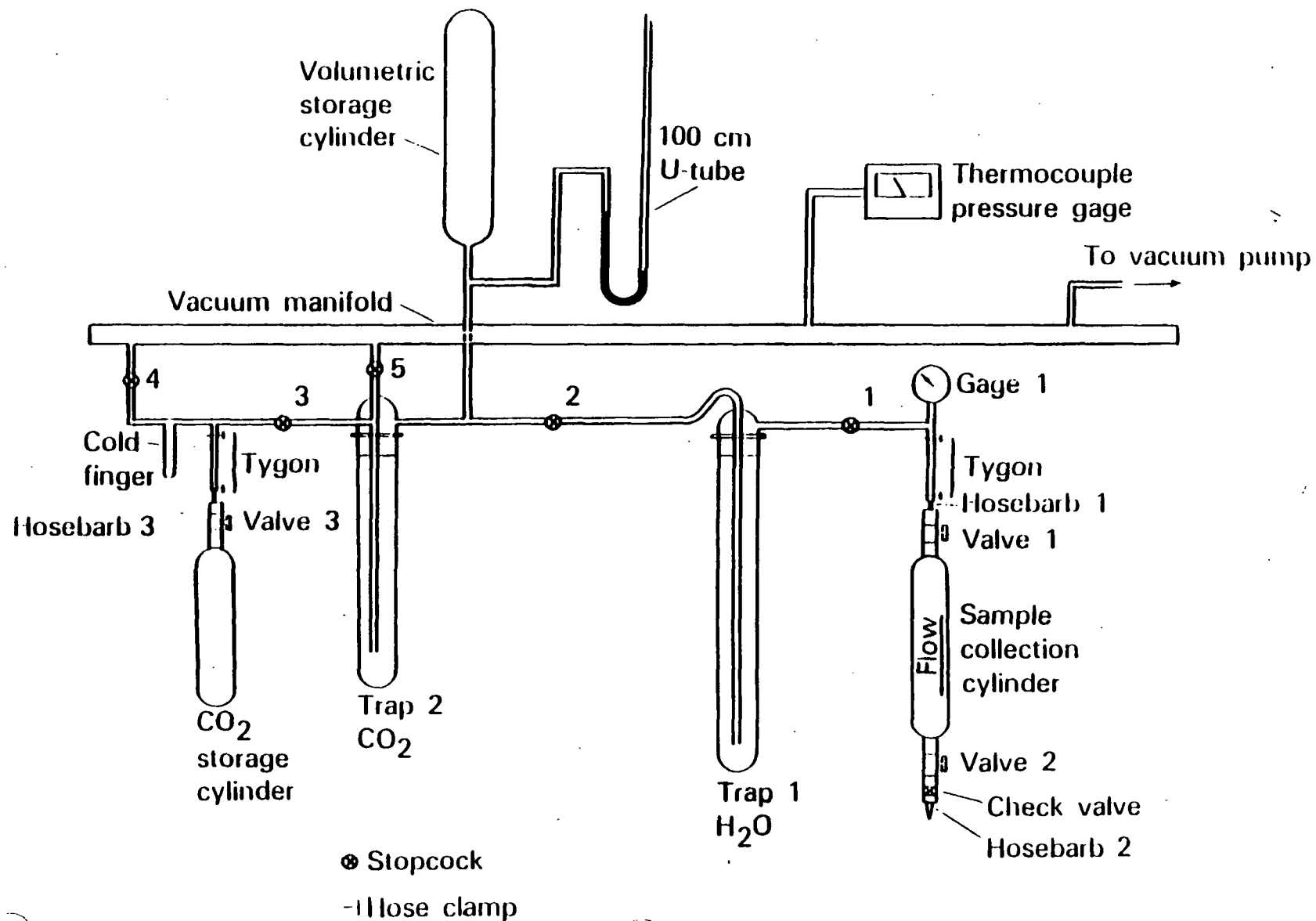
KOH METHOD



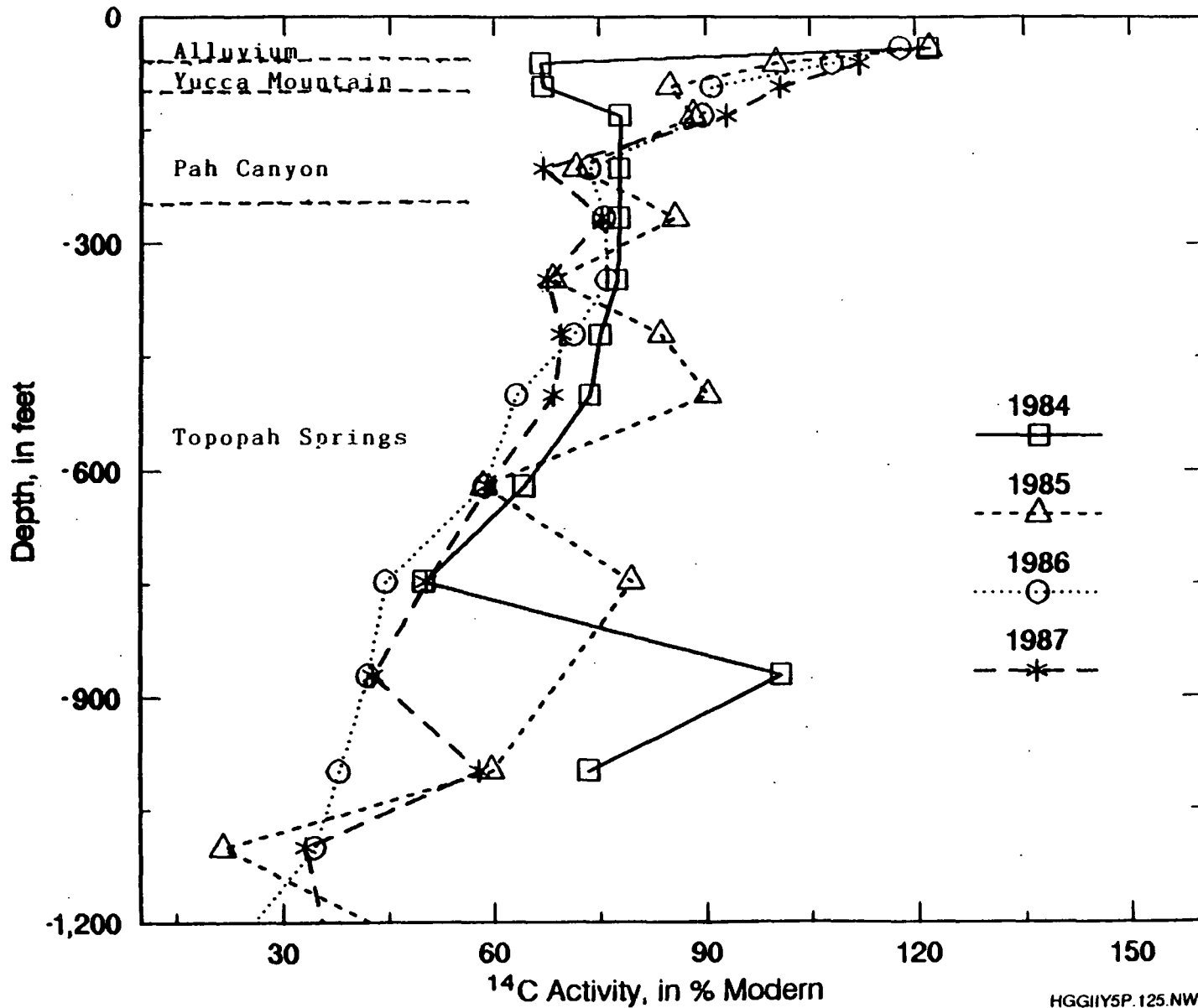
Physical absorption

MOLECULAR-SIEVE METHOD

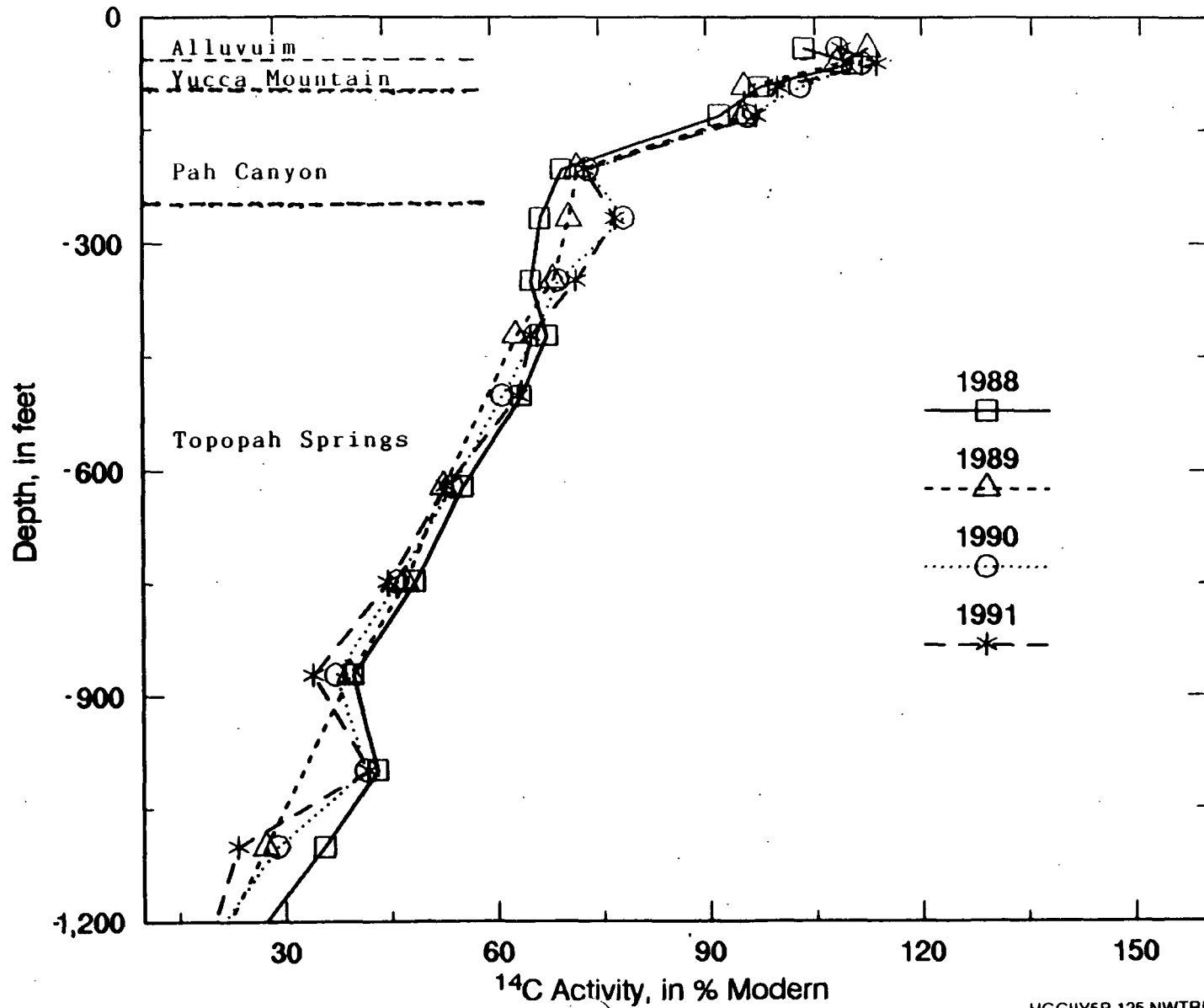
DEGASSING APPARATUS



UZ-1 ^{14}C ACTIVITY OF CO_2 GAS VERSUS DEPTH

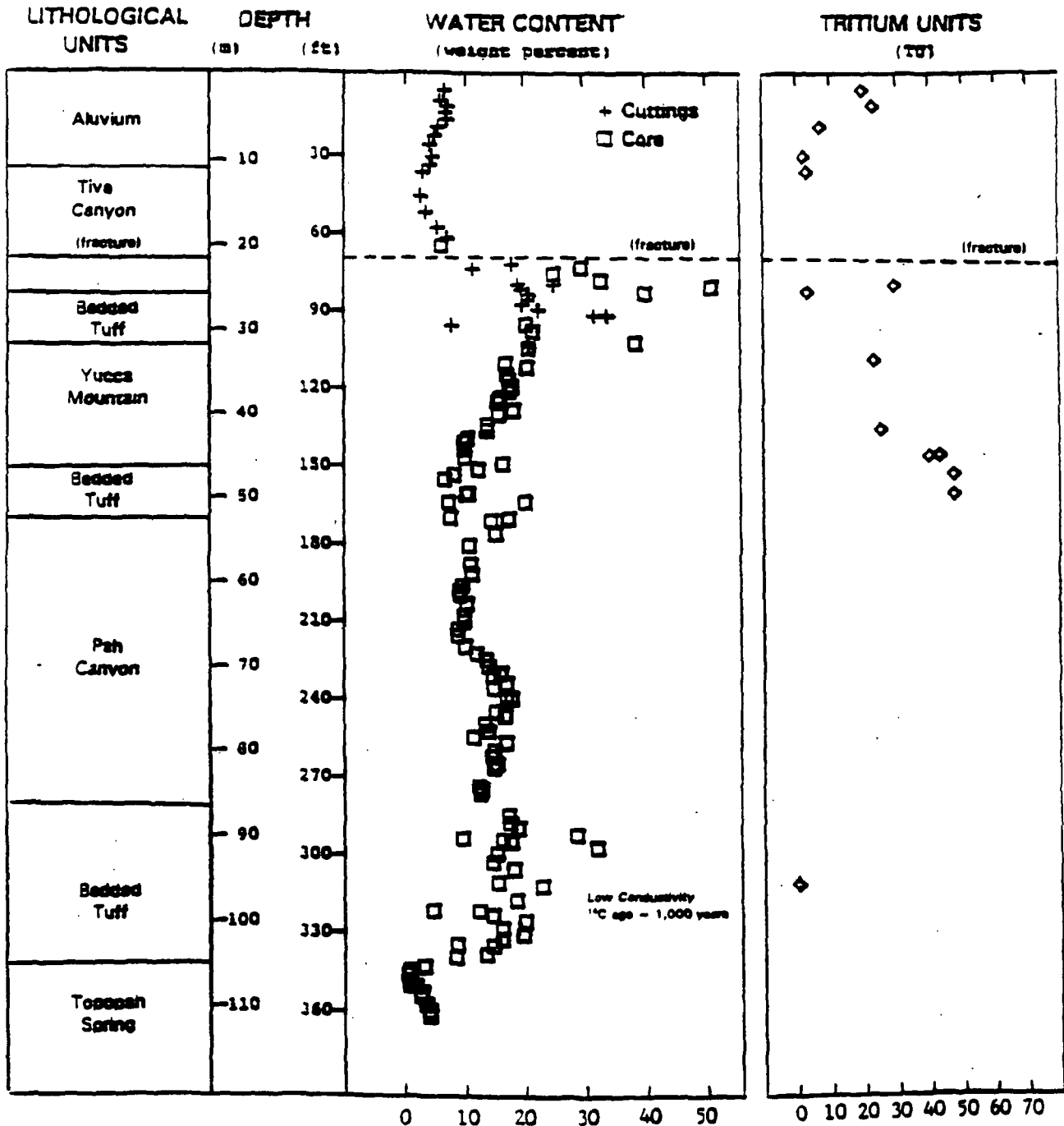


UZ-1 ^{14}C ACTIVITY OF CO_2 GAS VERSUS DEPTH

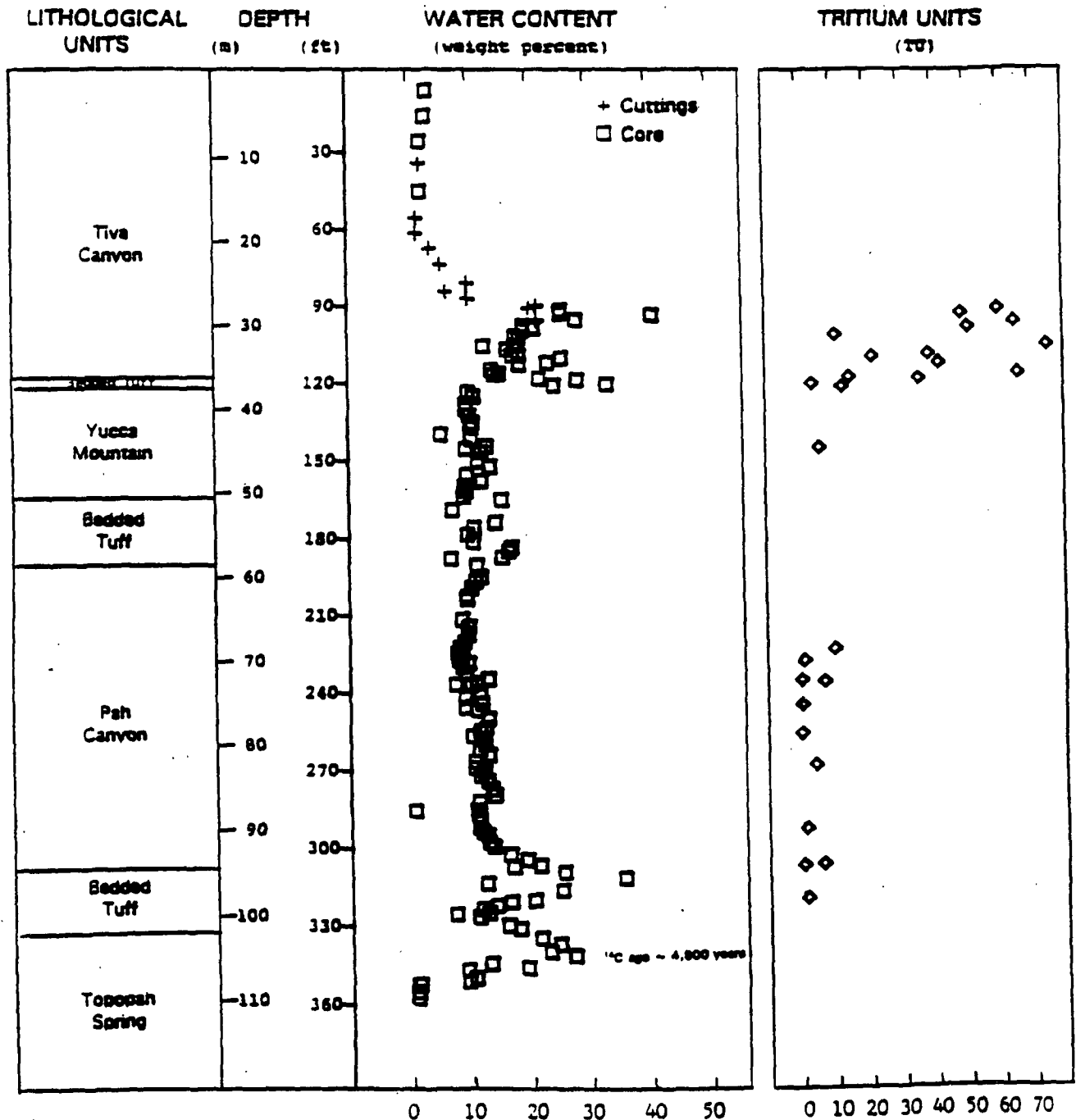


**PRESENTATION OF 16 SLIDES FOR
PORE-WATER EXTRACTION
(SQUEEZING AND CENTRIFUGING)
AND RESULTS**

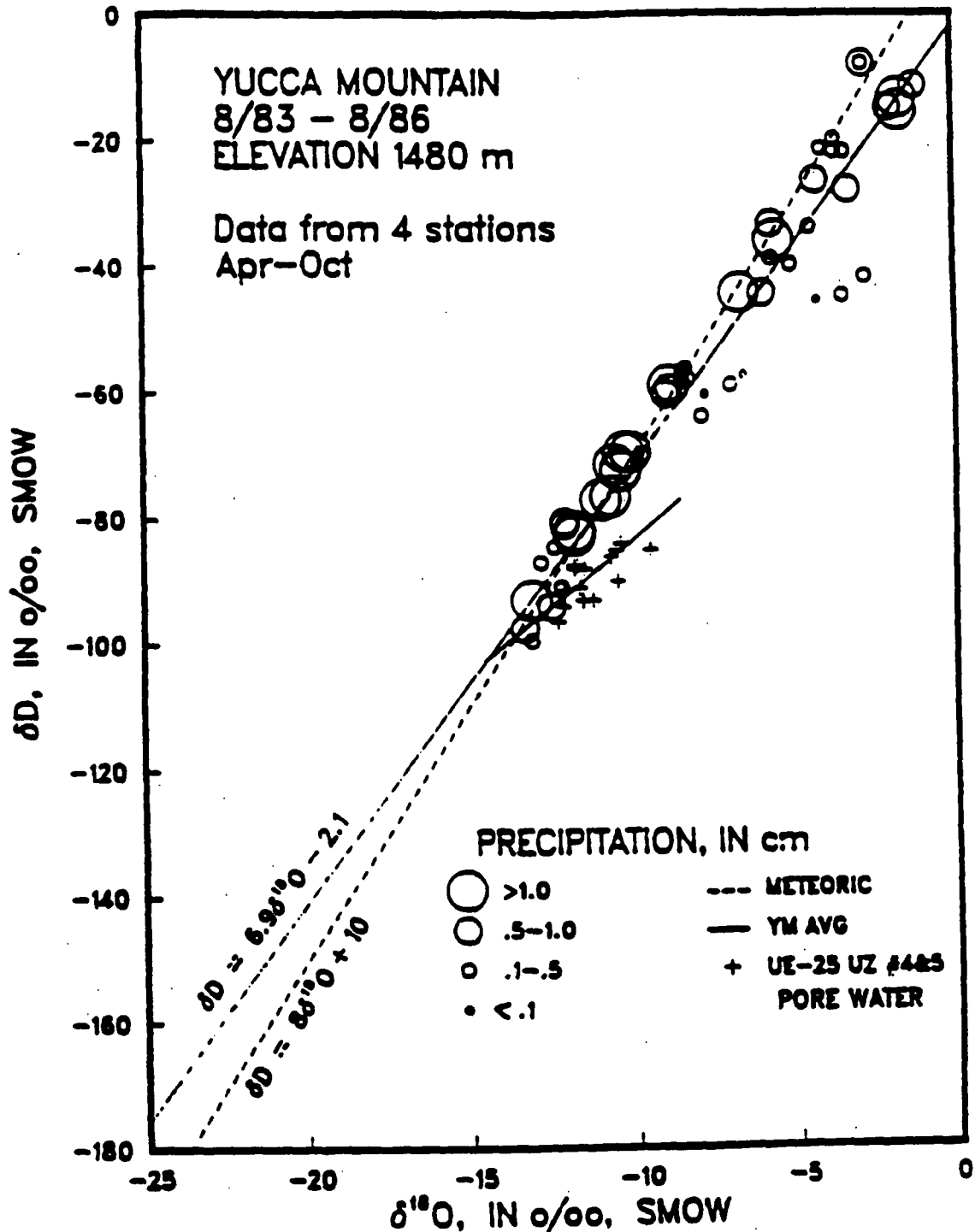
LITHOLOGICAL UNITS, WATER CONTENT, AND TRITIUM CONCENTRATIONS OF DRILL HOLE UE-25 UZ #4



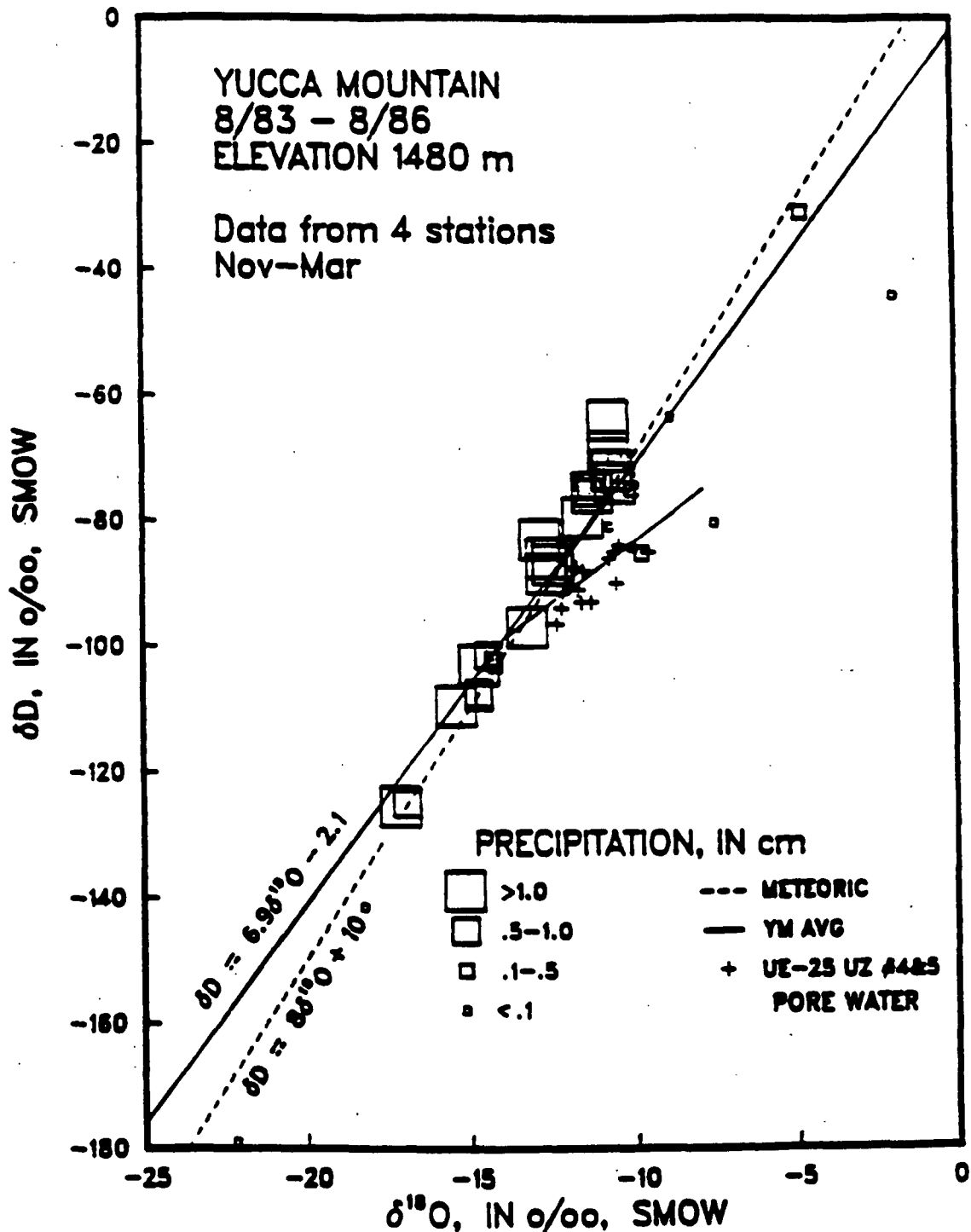
LITHOLOGICAL UNITS, WATER CONTENT, AND TRITIUM CONCENTRATIONS OF DRILL HOLE UE-25 UZ #5



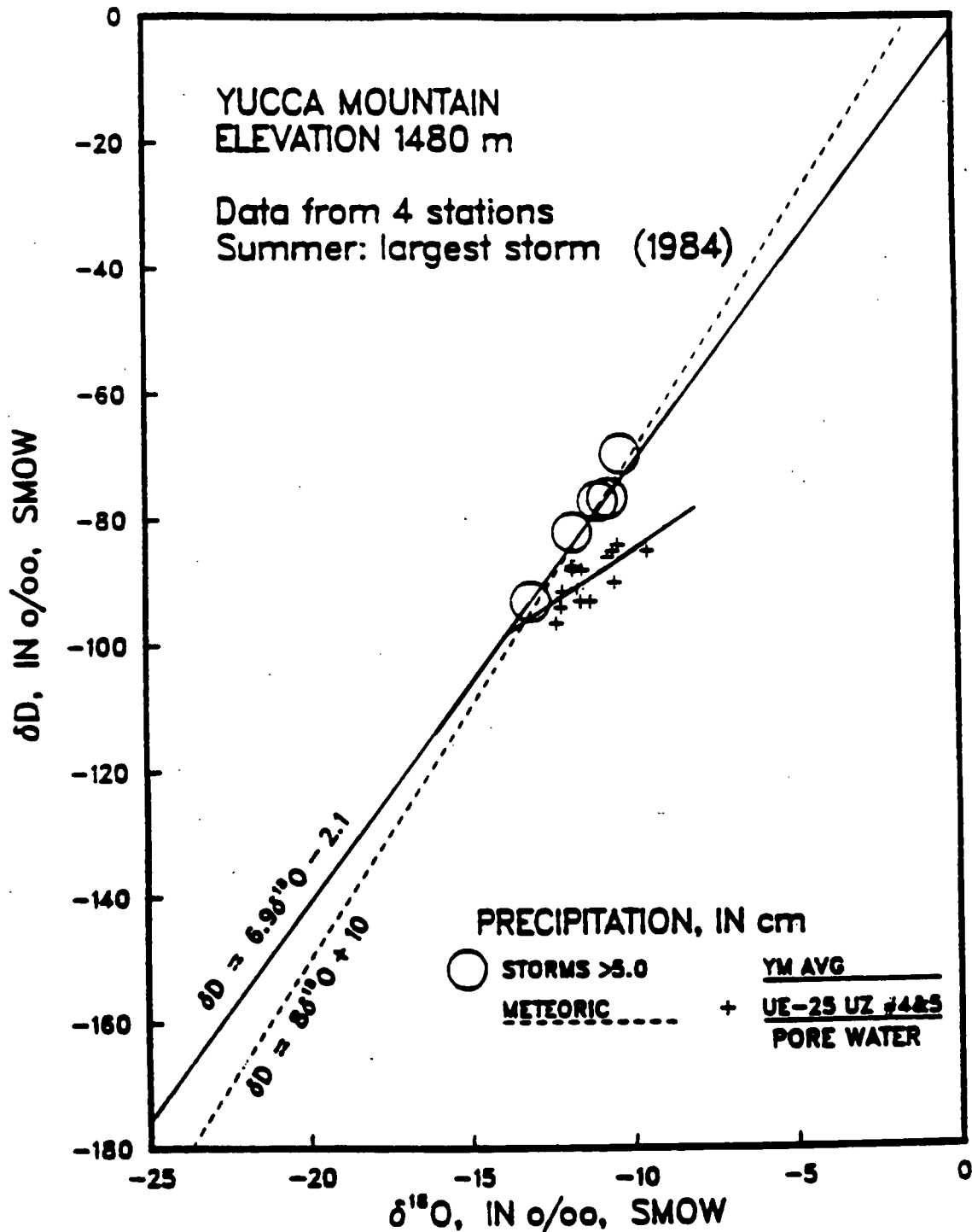
STABLE ISOTOPE RATIOS ($\delta^{18}\text{O}$ & δD) OF PRECIPITATION COLLECTED AT YUCCA MOUNTAIN FROM SUMMER 1983 TO 1986 AND UZ-4 & 5 PORE-WATER VALUES



STABLE ISOTOPE RATIOS ($\delta^{18}\text{O}$ & δD) OF PRECIPITATION COLLECTED AT YUCCA MOUNTAIN FROM WINTER 1983 TO 1986 AND UZ-4 & 5 PORE-WATER VALUES



STABLE ISOTOPE RATIOS ($\delta^{18}\text{O}$ & δD) OF PRECIPITATION COLLECTED AT YUCCA MOUNTAIN FROM WINTER 1983 TO 1986 AND UZ-4 & 5 PORE-WATER VALUES



FUTURE WORK

- **PORE-WATER EXTRACTION FROM WELDED TUFF OF LOW MOISTURE CONTENT**
- **OBTAIN CORES FROM REPOSITORY HORIZON AND CALICO HILLS FOR CHEMICAL AND ISOTOPIC ANALYSES**
- **ANALYSES OF PORE WATER FROM MATRIX AND FRACTURE WATER FOR THEIR AGES. THIS INFORMATION WILL BE USED TO DETERMINE THE DOMINANT FLOW IN MATRIX OR FRACTURES. SAMPLES WILL BE COLLECTED FROM NORTH AND SOUTH RAMPS, AND EXPLORATORY STUDY FACILITIES**
- **HYDROCHEMICAL CHARACTERIZATION OF CORES FROM UZ-BOREHOLES THROUGHOUT YUCCA MOUNTAIN, INCLUDING THOSE FROM FORTY MILE WASH**