

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

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

**SUBJECT: ISOTOPIC CONSTRAINTS ON  
TRANSPORT MODELS BASED  
ON <sup>36</sup>Cl ANALYSES**

**PRESENTER: DR. JUNE FABRYKA - MARTIN**

**PRESENTER'S TITLE  
AND ORGANIZATION: HYDROLOGIST  
LOS ALAMOS NATIONAL LABORATORY  
LOS ALAMOS, NEW MEXICO**

**PRESENTER'S  
TELEPHONE NUMBER: (505) 665-2300**

**REGISTRY HOTEL, DENVER, COLORADO  
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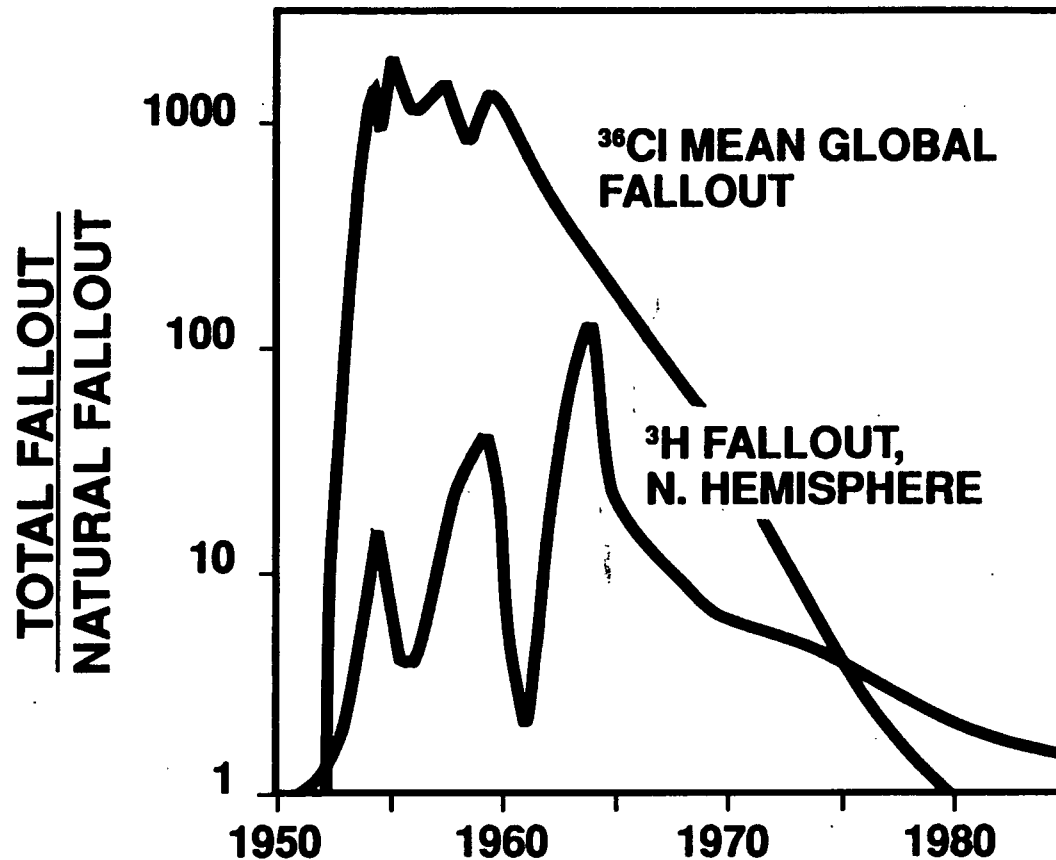
# PRESENTATION OUTLINE

- **$^{36}\text{Cl}$  IN THE HYDROLOGIC CYCLE**
- **APPLICATION OF  $^{36}\text{Cl}$  AT YUCCA MOUNTAIN**
- **INTERPRETATION OF  $^{36}\text{Cl}$  RESULTS FROM UZ-1**
  - OCCURRENCE OF FRACTURE FLOW
  - LOWER LIMIT ON WATER VELOCITY
- **MIXING MODEL TO OBTAIN BEST ESTIMATE OF VELOCITY**
- **ERROR ANALYSIS FOR GUIDING FUTURE WORK**
- **CURRENT SCOPE OF WORK**

# **$^{36}\text{Cl}$ CHARACTERISTICS USEFUL FOR TRACING WATER MOVEMENTS**

- **GEOCHEMICAL AND ISOTOPIC CHARACTERISTICS**
  - PRESENT AS CHLORIDE ANION
  - HIGHLY SOLUBLE, NONSORBING, NONVOLATILE
  - HALF-LIFE IS 301,000 YEARS
- **QUANTITATIVE ASSAY BY ACCELERATOR MASS SPECTROMETRY**
- **SOURCES OF  $^{36}\text{Cl}$  IN HYDROLOGIC CYCLE**
  - GLOBAL FALLOUT OF COSMOGENIC  $^{36}\text{Cl}$
  - GLOBAL FALLOUT OF BOMB-PULSE  $^{36}\text{Cl}$
  - IN SITU PRODUCTION IN ROCKS

# COMPARISON OF GLOBAL FALLOUT OF $^{36}\text{Cl}$ AND $^3\text{H}$



$^{36}\text{Cl}$  FALLOUT, BENTLEY et al., 1983, NATURE 300:737.

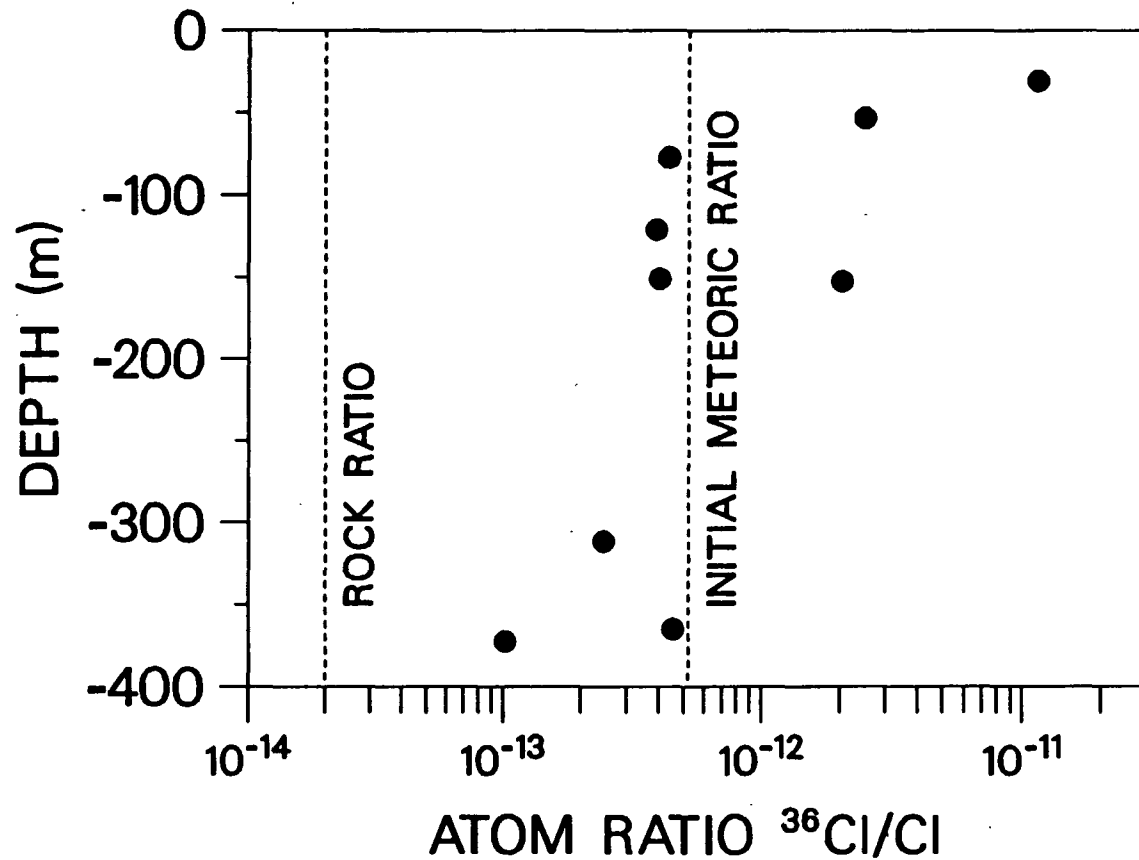
$^3\text{H}$  FALLOUT, IAEA, 1983, TECH. REP. SERIES NO. 228.

# **APPLICATIONS OF $^{36}\text{Cl}$ FOR CHARACTERIZING WATER MOVEMENT AT YUCCA MOUNTAIN**

- **DEEP PERCOLATION RATES IN MATRIX AT ESF LEVEL**
- **TEST HYPOTHESES IN CONCEPTUAL FLOW MODEL**
  - **OCCURRENCE OF FRACTURE FLOW**
  - **FLOW ALONG FAULTS**
  - **PERCHED-WATER STABILITY**
  - **MATRIX/FRACTURE INTERACTION**
- **EXPAND DATA BASE FOR SHALLOW INFILTRATION RATES**
- **ANALOGUE FOR  $^{99}\text{Tc}$  MIGRATION**
- **TEST HYPOTHESES IN REGIONAL GROUND-WATER FLOW MODEL**



# $^{36}\text{Cl}/\text{Cl}$ MEASUREMENTS IN CUTTINGS FROM USW UZ-1, YUCCA MOUNTAIN



DATA FROM NORRIS ET AL. (1990)

# LOWER LIMIT FOR AVERAGE WATER VELOCITY FOR DEEP PERCOLATION AT UZ-1

**BASED ON LOWEST MEASURED  $^{36}\text{Cl}/\text{Cl}$  VALUE,  $103 \times 10^{-15}$  AT 372 m DEPTH, THE ESTIMATED NET DOWNWARD VELOCITY IS**

$$V \geq (372 \text{ m} / 779 \text{ ka}) = 0.5 \text{ mm/yr}$$

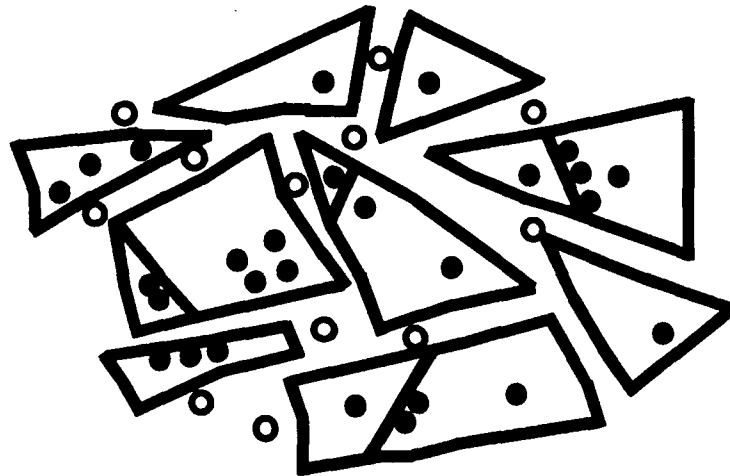
## **ASSUMING**

- **VERTICAL MOVEMENT THROUGH MATRIX**
- **INITIAL RECHARGE RATIO IS  $519 \times 10^{-15}$**
- **EQUILIBRIUM RATIO IS  $20 \times 10^{-15}$**
- **NEGLIGIBLE INFLUENCE OF J-13 WATER USED IN G-1 DRILLING ( $531 \times 10^{-15}$ )**

**NOTE: CORRECTION FOR PROBABLE DILUTION WITH ROCK Cl ( $20 \times 10^{-15}$ ) WOULD INCREASE ESTIMATED VELOCITY**



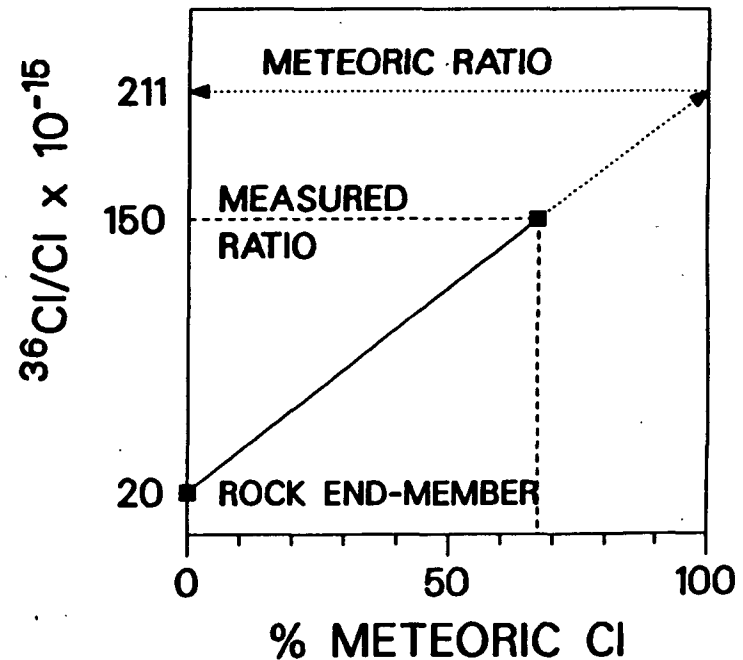
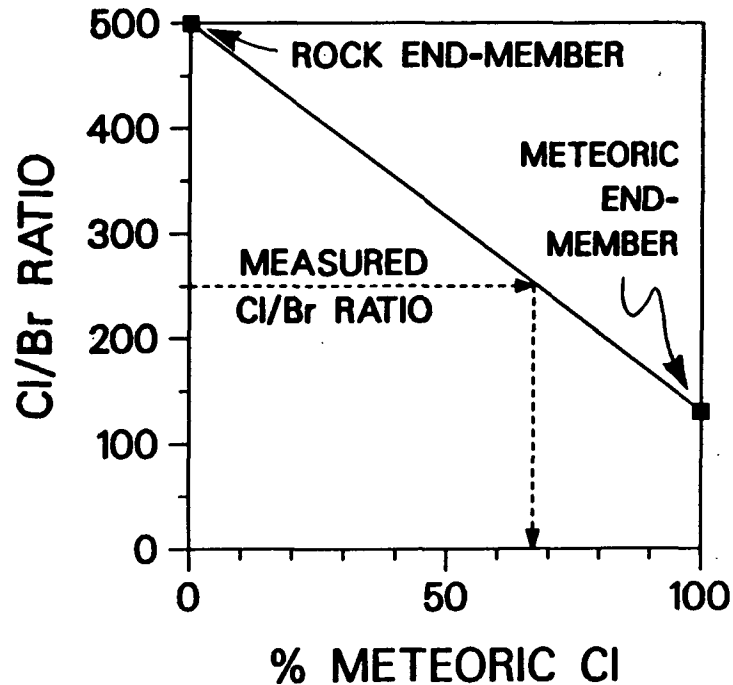
**PROBLEM:**  
**<sup>36</sup>Cl/Cl RATIOS ARE NOT REPRODUCIBLE DUE  
TO VARIABLE DILUTION BY ROCK CHLORIDE**



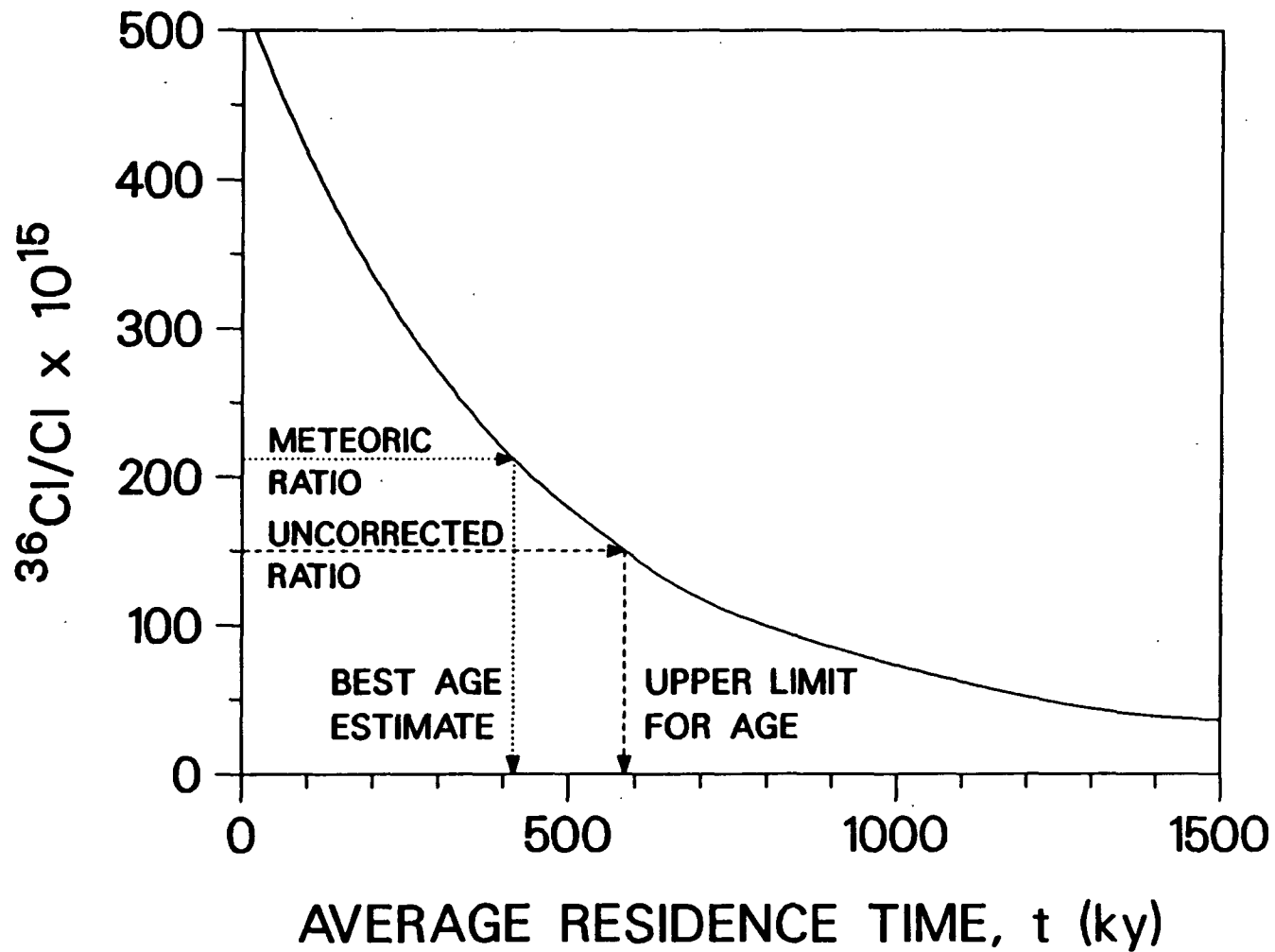
- **METEORIC Cl IN PORES**
- **ROCK Cl IN FLUID INCLUSIONS, GRAIN BOUNDARIES;**  
**<sup>36</sup>Cl/Cl = 2 x 10<sup>-14</sup>**

# SOLUTION: THE MIXING MODEL

**HYPOTHESIS: Cl/Br AND/OR  $^{37}\text{Cl}/^{35}\text{Cl}$  RATIOS CAN BE USED TO ESTIMATE THE PROPORTION OF METEORIC Cl IN THE LEACHATE, ALLOWING ONE TO EXTRAPOLATE THE MEASURED  $^{36}\text{Cl}/\text{Cl}$  RATIO TO THE RATIO OF THE METEORIC COMPONENT WHICH IS USED FOR AGE DATING**



# $^{36}\text{Cl}$ AGE-DATING MODELS



# **AVERAGE WATER VELOCITY FOR DEEP PERCOLATION AT UZ-1, BASED ON MIXING MODEL**

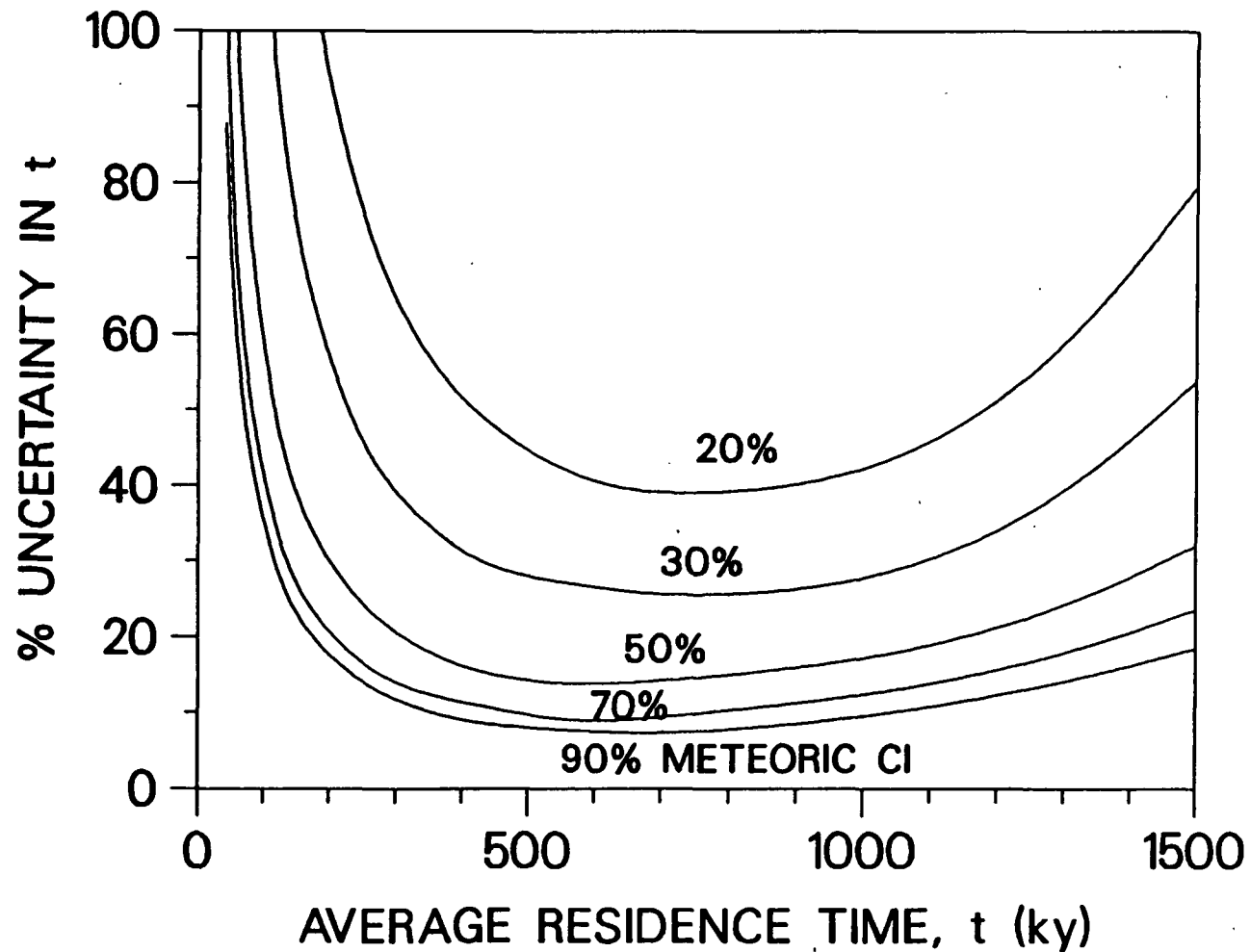
- **FOR SAMPLE FROM 372 m, THE MEASURED Cl/Br RATIO FOR LEACHED HALIDES INDICATES DILUTION WITH 52% ROCK Cl.**
- **THE MEASURED  $^{36}\text{Cl}/\text{Cl}$  VALUE,  $103 \times 10^{-15}$  IS CORRECTED TO A METEORIC  $^{36}\text{Cl}/\text{Cl}$  RATIO OF  $193 \times 10^{-15}$**
- **THIS RATIO CORRESPONDS TO A NET VELOCITY OF**

$$V = (372 \text{ m} / 460 \text{ ka}) = 0.8 \text{ mm/yr}$$

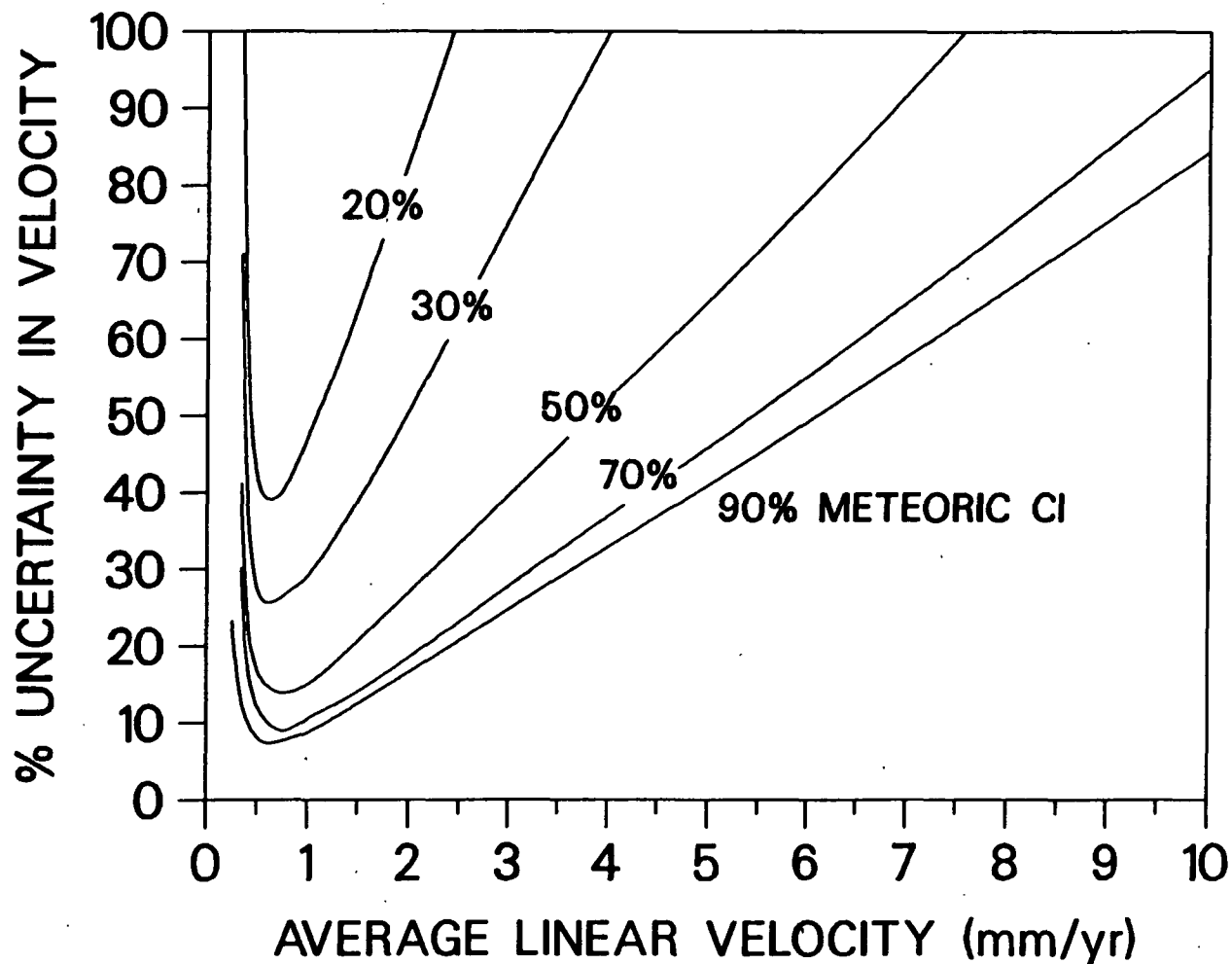
**COMPARE TO LOWER LIMIT ESTABLISHED BY UNCORRECTED  $^{36}\text{Cl}/\text{Cl}$  RATIO**

$$V \geq 0.5 \text{ mm/yr}$$

# UNCERTAINTY IN WATER AGE ESTIMATES AS A FUNCTION OF THE PROPORTION OF METEORIC CHLORIDE IN A SINGLE SAMPLE



# UNCERTAINTY IN WATER VELOCITY ESTIMATES FOR A SINGLE ESF SAMPLE FROM CALICO HILLS UNIT (425 m) AS A FUNCTION OF THE PROPORTION OF METEORIC CI



# SCOPE OF WORK IN REVISED STUDY PLAN

- **SURFACE SOIL SAMPLES TO DETERMINE METEORIC Cl/Br**
  
- **SOIL PROFILES TO DETERMINE:**
  - METEORIC Cl/Br
  - METEORIC  $^{36}\text{Cl}/\text{Cl}$
  - METEORIC  $^{37}\text{Cl}/^{35}\text{Cl}$
  - SHALLOW INFILTRATION RATES
  
- **STEP-LEACHING TUFFS TO DETERMINE:**
  - ROCK Cl/Br
  - ROCK  $^{36}\text{Cl}/\text{Cl}$
  - ROCK  $^{37}\text{Cl}/^{35}\text{Cl}$
  
- **MORE BOREHOLE PROFILES**
  
- **ESF SAMPLES**