Applications of $^{14}$C Ground-water Dating in Hydrologic and Geochemical Studies of the Regional Aquifer, Pajarito Plateau, New Mexico

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Motivation of Study

Establish an understanding of the ground-water flow system at Los Alamos (water sources, ages and travel times, mixing relations, and flow paths) that is independent of numerical models.

This understanding can be used either to guide the development or evaluation of results of corresponding flow models.
Analytical Methods

- **Carbon-14**, accelerator mass spectrometry
- **Tritium**, helium ingrowth and electrolytic enrichment
- **Stable isotopes**, isotope ratio mass spectrometry
- **Anions**, ion chromatography
- **Metals**, inductively couple (argon) plasma-optical emission spectroscopy (ICP-OES) and inductively couple (argon) plasma-mass spectrometry (ICP-MS)
- **Total carbonate alkalinity**, titration
LANL Stratigraphy
Generalized Cross Section Showing Ground-water Type and Expected Trends in Ground-water Age for Conceptual Model of Ground-water Flow

Zone 1 – Perched in Mountain Block/Front (Modern and Mixed)

Zone 2 – Alluvial (Modern)

Zone 3 – Intermediate Beneath Plateau (Modern and Mixed)

Zone 4 – Regional (Submodern and Mixed)

West

East

Tuff
Basalts
Dacite
Sediments

Recharge Paths

Rio Grande

10x VE

1 cm = 1000 m
Sampling Stations for Radiocarbon Dating
Average Mixing Ratios for the Regional Aquifer Containing Chloride from Alluvial Ground Water, Pajarito Plateau, New Mexico
Unadjusted Radiocarbon Ages of DIC and Geology near the Regional Aquifer Water Table, Pajarito Plateau, New Mexico
Los Alamos Production Wells

Mix of regional ground water from west and east of Rio Grande???

These artesian wells are located west of the Rio Grande in lower Los Alamos Canyon.

Los Alamos Recharge Waters – Sierra de Los Valles Mean $\delta^{13}C$: $-13.7 \pm 1.7$ per mil, 17 Stations

碳-14（现代碳百分比）与$\delta^{13}C$，Pajarito高原及周边地区，新墨西哥州
Saturation Index Map for CaCO$_3$ (Calcite) for the Regional Aquifer
Carbon-14 (Percent Modern Carbon) Versus Chloride (mmol/L), Los Alamos, New Mexico

- **Regional - Contaminated**
- **Regional - Background**
- **Los Alamos Production Wells**

- **TW-1:** 164 pmC, 1.11 mmol/L
- **R-28:** 49 pmC, 0.81 mmol/L
- **LA-1B:** 0.9 pmC, 0.52 mmol/L (inactive)
- **LA-1** (inactive)
- **O-1** (inactive)
- **O-4** (active)

(NO₃, Cl, ³H, ClO₄, CrO₄)
Summary and Conclusions

- The regional aquifer consists of submodern (pre-1943) or mixed (pre- and post-1943) ages.

- Submodern-ground water is common in the regional aquifer. Average ages for the regional aquifer range from 570 to 13,005 years based on unadjusted $^{14}$C results.
Summary and Conclusions

• Variations in unadjusted $^{14}$C ages for the regional aquifer result from sources of recharge water, mixing of waters, and hydraulic properties of the aquifer material.

• Application of $^{14}$C ages with mobile chemicals such as chloride define preferred ground-water flow paths within the regional aquifer.

• The next step in this work will be to apply these unadjusted $^{14}$C ages as constraints to hydrologic flow and transport models and as input to geochemical models.
Supplemental Material
Average Ground-Water Flow Rates Near the Regional Water Table, Based on Unadjusted $^{14}$C Ages, Pajarito Plateau, New Mexico
Ranges of Apparent $^3\text{H}/^3\text{He}$ Ages in the Regional Aquifer
Bicarbonate (mmol/L) Versus $\delta^{13}$C (per mil), Los Alamos, New Mexico

- Regional - Contaminated
  (NO$_3^-$, Cl, $^3$H, ClO$_4^-$, CrO$_4^{2-}$)
- Regional - Background
- Los Alamos Production Wells

LA-1B (inactive)
Carbon-14 (Percent Modern Carbon) Versus Tritium (TU), Los Alamos, New Mexico

TRITIUM ACTIVITY (TU)

14C (pmC)

Regional - Contaminated
(NO₃, Cl, ³H, ClO₄, CrO₄)

Regional - Background

Los Alamos Production Wells

TW-1: 194 pmC, 113 TU
Tritium (TU) Versus Chloride (mmol/L), Los Alamos, New Mexico

Trinium (TU) Versus Chloride (mmol/L), Los Alamos, New Mexico

- **R-28**: 0.81 mmol/L, 53.4 TU
- **TW-1**: 1.11 mmol/L, 113 TU

**Legend**:
- **Regional - Contaminated**
  - NO$_3$, Cl, $^3$H, ClO$_4$, CrO$_4$
- **Regional - Background**
- **Los Alamos Production Wells**