Field Relationships and Isotopic Analysis of Stable Carbon and Oxygen Isotopes Within Calcium Carbonate Veins And How They Change As We Move Laterally Along Stratigraphic Horizons To Represent Ancient Fluid Travel Away From Fault Damage Zones to Better Understand Subsurface Fluid Reservoirs

Elizabeth Horne
Utah State University

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Elizabeth Horne
Department of Geology

Introduction:
Humans have been producing CO₂, a greenhouse gas since the Industrial Revolution. Over the decades, these CO₂ emissions have continued to increase and accumulate in the atmosphere due to consumption of fossil fuels in order to produce electricity and for transportation (Dockrill 2005). This accumulation of CO₂ is thought to be a key driver in global warming. There are a several methods proposed to mitigate this crisis of polluting our earth, amongst these methods is carbon capture and storage, also known as carbon capture and sequestration (CCS). This method captures CO₂ from large point source emitters, such as a coal-fired power plants and then injects the CO₂ into porous, permeable subsurface reservoirs, which are capped by low porosity and permeability shale’s. Carbon capture and storage might be capable of preventing as much as 90% of the fossil carbon from reaching the atmosphere and over the next 50 years, as much as 1 GtC/year of CO₂ can be stored in geologic reservoirs (Pacala and Socolow, 2004).

The focus of my proposed undergraduate research project is to understand the fluid flow history in the subsurface in a natural analog for CO₂ sequestration. I will examine the chemistry of deposits created by the flow of CO₂-charged fluids, and examine how the fluids evolved as they travel away from their source. I will examine the laterally continuous mineralized veins and altered zones along stratigraphic horizons that appear to represent ancient fluid travel away from the Salt Wash fault and fracture zones, in SE Utah. These alteration horizons and veins are associated with the modern and ancient natural CO₂ leaks in the form of geysers and springs. Preliminary field work associated with my College of Science Minigrant: Field Relationships and Isotopic Analysis of Stable Carbon and Oxygen Isotopes and How They Relate to Natural CO₂ Analogues to Better Understand Subsurface Fluid Reservoirs show different crystal habits within horizontal veins and zones of alteration in the host rock. If funded my URCO grant will continue the research started by the minigrant and allow me to perform whole-rock chemical analyses and stable isotope analyses, which may determine if there were different episodes of carbonate mineralization along these horizons and what possible mechanisms caused these different chemistries in the outcrop.

Geologic setting – the analog laboratory
The area of interest for this study is the Salt Wash Graben, 15 km from the town of Green River in southeastern Utah (Figure 1) This site has been the focus of several studies to understand subsurface fluid reservoirs and how fault zones affect them.
• Dockrill- factors causing leakage and determine the rates and consequences of carbon
dioxide leakage on the surrounding environment.

• Burnside- U-Th Dating Of Travertine's On The Colorado Plateau: Implications For The
Leakage Of Geologically Stored CO₂
  o These leaks have been active for hundreds of thousands of years and continue
    precipitating calcium carbonate (Burnside, 2010).

**Hypothesis:**
There will be a change in geochemistry of these travertine deposits between the two types of veins
(tan box veins and large white veins) and their geochemical signatures will change as we move away
from their proposed source, which is similar in chemical compositions of calcite veins located
adjacent to leaks (Shipton 2004).

**Research Objectives:**
• Better understand timing and fluid flow of laterally continuous mineralized calcium
  carbonate veins and altered host rocks along stratigraphic horizons that appear to represent
  paleo fluid flow away from the fault and fracture zones in Salt Wash graben.
• Understand any changes in CO₂ fluid composition or source based on changes in the isotopic
  composition of calcite veins and altered host rock, traveling along stratigraphic horizons.

**Methods:**
Field observations at the North Salt Wash Fault.
• By studying outcrops associated with North Salt Wash fault, I will:
  o Identify alteration horizons and veins that appear to be associated with the modern and
    ancient natural CO₂ leaks
  o Describe change in crystal structure of calcium carbonate veins and how they change as
    we move north of the associated fault zone.
  o Map cross-cutting relationships of calcium carbonate deposits associated with the Salt
    Wash Fault zone to understand timing of mineralization.
• Map crosscutting relationships in outcrop to understand timing of mineralization
• Optical microscopy- petrographic analysis of host rock and vein mineralization (thin section
  analysis) of calcite veins to understand relationships between host rock and calcium carbonate
  mineralization
• Stable carbon and oxygen isotope analysis to understand changes in the fluid reservoir
  composition. Variation may indicate change of source of fluids and/or depth of mineralization.
  Analyzing stable carbon isotope ratios is important because they serve as geochemical markers
  related to source fluids.
• Understand how the chemistry of these fluids evolved as the fluids travel away from their source
waters. Previous research has shown that the CO$_2$ charged springs and geysers are slightly acidic and the saline waters are supersaturated with respect to carbonates such as aragonite, calcite, and dolomite with stable carbon 13 values of total dissolved carbon that range from 0.0 to 1.2%. All of the waters contain high levels of bicarbonate, which indicate high CO$_2$ content (Shipton 2004).

- **Work Plan**

  - I will examine the laterally continuous mineralized veins and altered zones along stratigraphic horizons that appear to represent ancient fluid travel away from the fault and fracture zones (Figure 2). These alteration horizons and veins are associated with the modern and ancient natural CO$_2$ leaks in the form of geysers and springs. This work will focus on understanding the fluid flow history in the subsurface, and to understand how the chemistry of these fluids evolved as the fluids travel away from their source. Preliminary fieldwork associated with my College of Science Minigrant show different crystal habits within horizontal veins, zones of alteration in the host rock. I will determine places to sample and perform whole-rock chemical analyses and stable isotope analyses, which may determine if there were different episodes of carbonate mineralization along these horizons and what possible mechanisms caused these different chemistries in the outcrop.

Through the Supervision of Dr. James P. Evans, I will conduct this research

**Faculty Advisor:** James P. Evans, Structural Geologist  
Dennis Newell Geochemist with experience with carbon sequestration and stable isotope geochemistry  
Elizabeth Petrie, PhD candidate

**Outcomes:**

- Understanding relative timing of fluid flow and mineralization associated with fault movement and fault damage zone.
- Change in stable isotope signature to understand conditions at which mineralization's occurred depth of fluid flow
- Tie into previous research with motion of the fault (Dockrill, 2005)

**Timeline**

<table>
<thead>
<tr>
<th>Month</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>October</td>
<td>U.R.C.O. Grant proposal submission</td>
</tr>
<tr>
<td>December</td>
<td>Travel to my field area, Salt Wash Graben in Southeastern Utah and take detailed field descriptions of the outcrop, and collect samples for thin-section and isotope analysis. Detailed field descriptions of the outcrop (orientation, vein thickness measurements, crystal habit changes away from fault).</td>
</tr>
<tr>
<td>January</td>
<td>Prepare samples obtained from the outcrop for isotope analysis and send 5 samples out for thin section analysis.</td>
</tr>
</tbody>
</table>
February: Conduct stable carbon isotope analysis using Picarro CRDS, and send samples out for stable oxygen isotope analysis.

March: Analyze data received from carbon and oxygen isotope analysis.

April: Describe textures of minerals displayed in thin section to understand fluid properties.

May: Write final report and submit to Provost's Office and Vice President for Research Office.

Figures Referenced:

Figure 1 (Shipton, 2004) Geographic setting of field area.

![Map of geographic setting of field area](image1)

Figure 1: Regional geologic setting of the study area (after Nuccio and Condon, 1996; and Cappa and Rice, 1995). Dotted line marks the extent of the Paradox Basin. LGW = Little Grand Wash fault, SWG = Salt Wash Graben.

Figure 2: Outcrop photo displaying large horizontally continuous calcite vein within altered host rock.

![Outcrop photo](image2)
References Cited:


S. Pacala, R. Socolow., 2004, Stabilization Wedges: Solving the Climate Problem for the Next 50 Years with Current Technologies. Science Vol. 305 no. 5686

Budget

Total Budget Requested: $1000.00

Amount Requested from URCO: $500.00

Matching Funds from Department of Geology: $500.00

Breakdown of total budget requested:

Expenses
I will use the cavity ring down spectrometer to obtain stable carbon isotope data; this data will be run in the USU Geology department. I will look at thin sections for detail petrographic analysis, using microscopy equipment housed in the Geology department.

Field work:
- Gas: 100 dollars
- Camping: free
Food for 4 days of field work $150

Stable Isotope Analysis:
In total, I analyze stable carbon isotopes from fifty samples
Stable Isotope Analysis (50@$10ea.)........................ $500.00

Thin-Section Preparation:
In total, I will cut a total of 10 thin sections for optical, petrographic analysis of veins and travertine.
- Thin-Section Preparation (10 @$25ea.).................$250.00

TOTAL EXPENSES: $1000.00