# Carbon Capture, Utilization and Storage (CCUS) in Redtail Area, Weld County, Colorado

Chris Beliveau

CBeliveau@mymail.mines.edu

M.S. Geology Candidate

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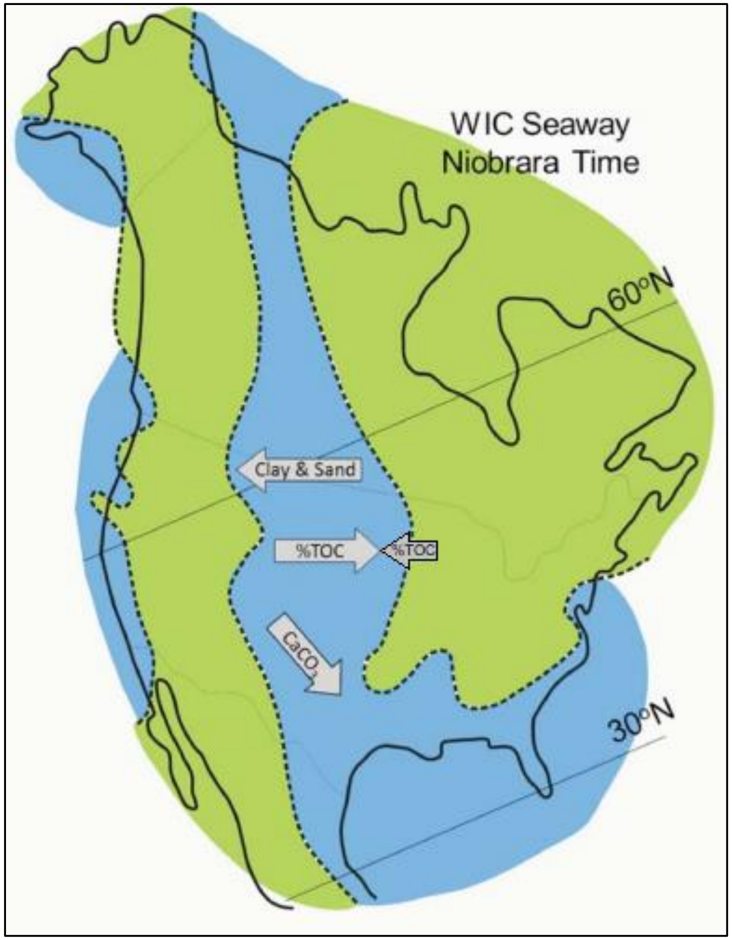
# Outline

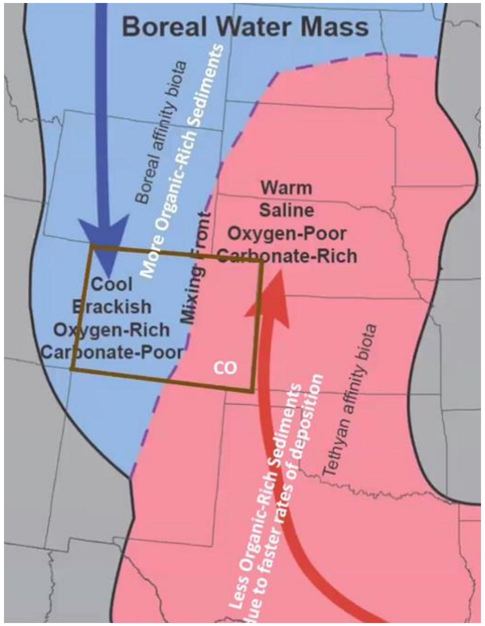
- Brief geologic history of the Niobrara
- Overview of CCUS; where the technology stands today
- Data collection & plan going forward
- Different lab techniques to look at the feasibility of CCUS

# Brief Niobrara Background



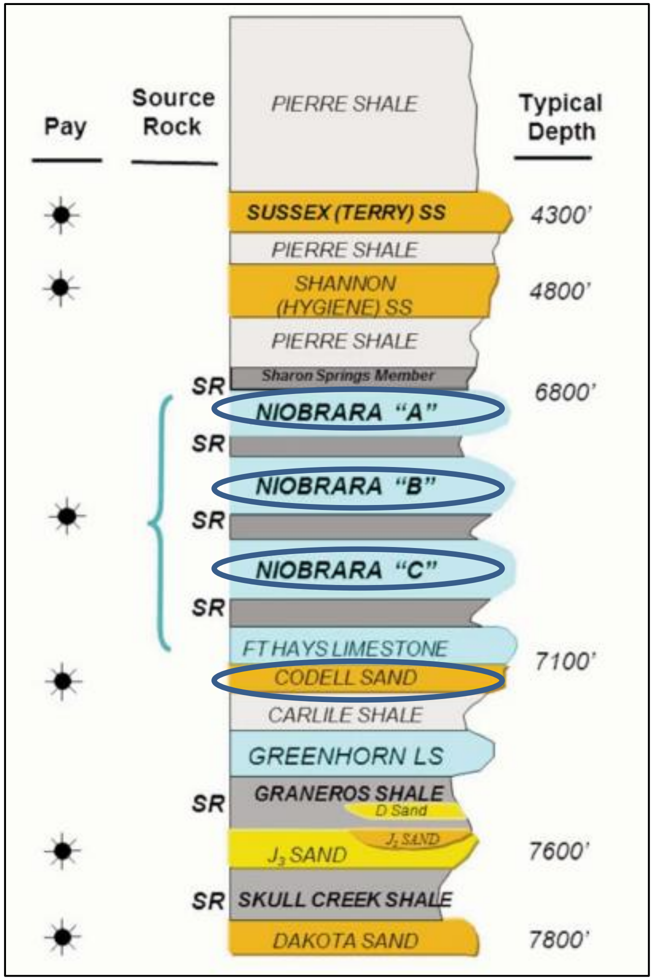

*Schematic of the Western Interior Cretaceous Basin during the Niobrara time modified from* (Longman, Luneau, & Landon, 1998)

- Increasing TOC% to the east to a certain extent though we now know TOC% extending into Kansas and Nebraska is not as high as once thought
- Deepest part of WIC along the Western Margin
- Cooler, nutrient rich, carbonate poor arctic water from the north mixed with warmer, oxygen poor, carbonate rich chalk-rich water from the Gulf of Mexico

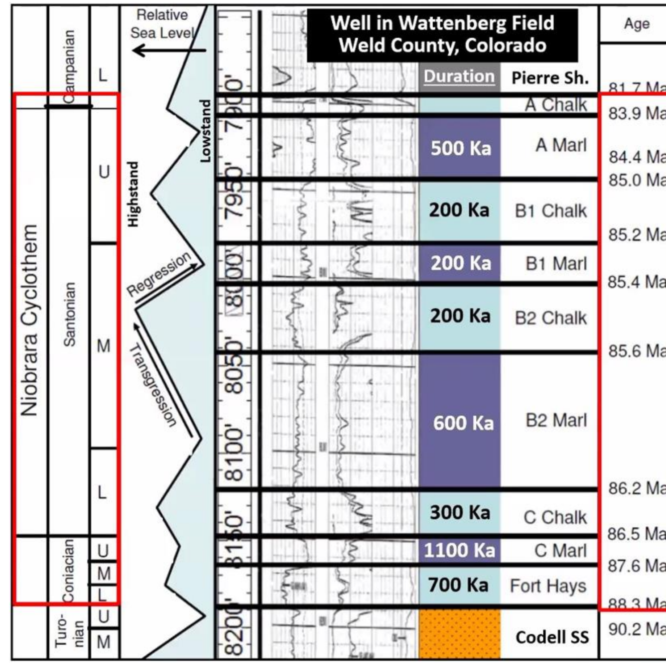



*Schematic of the Western Interior Cretaceous Basin water mixture during the Niobrara time* (Lowery, et al. 2017)

# Brief Niobrara Background



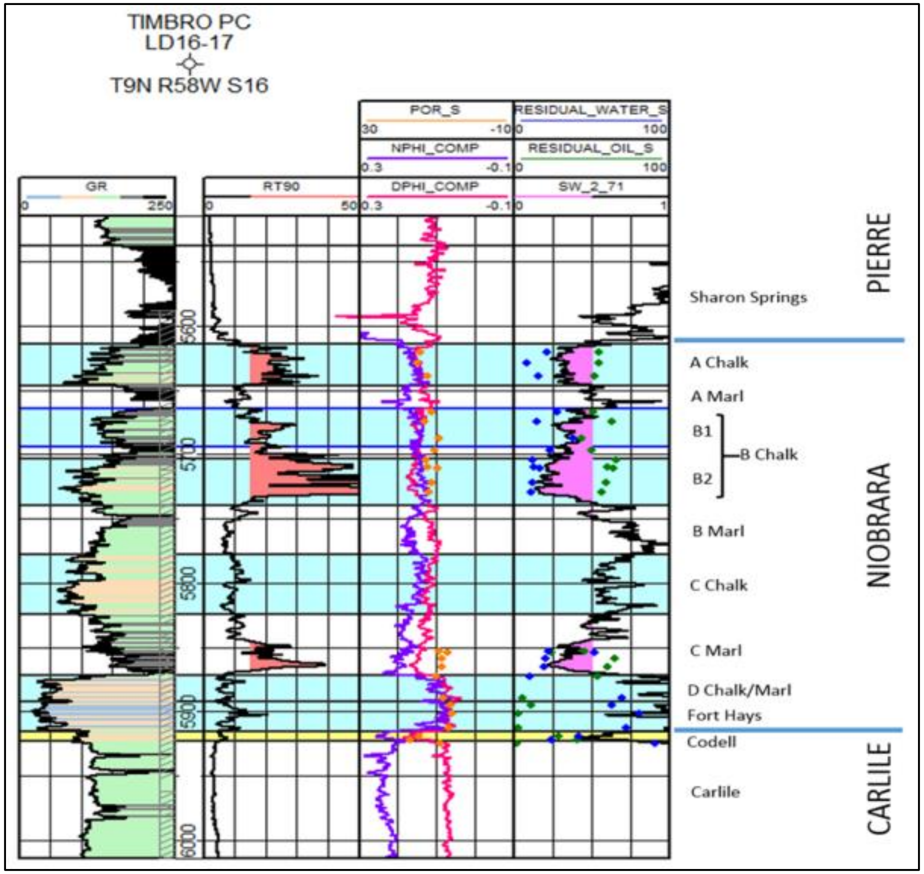

*Stratigraphic column for the Niobrara specifically for the Wattenberg Area* (Sonnenberg, 2011)




*Stratigraphic column for the Niobrara showing relative sea level, duration of deposit, and age of deposit.* (Longman & Luneau, 2020)

- Warmer Gulfian currents dominated the B Chalk through a strong transgression as shown
- In the B2 Marl, we see a large amount of deposition in a relatively short period of time

# Petrophysical Properties Overview




*Type log from East Pony/Redtail field area* (Sonnenberg, Keys to Niobrara and Codell Production, East Pony/Redtail Area, Denver Basin, Colorado, 2017)

- Most favorable petrophysical properties are over the Niobrara A and B with increased resistivity and porosity

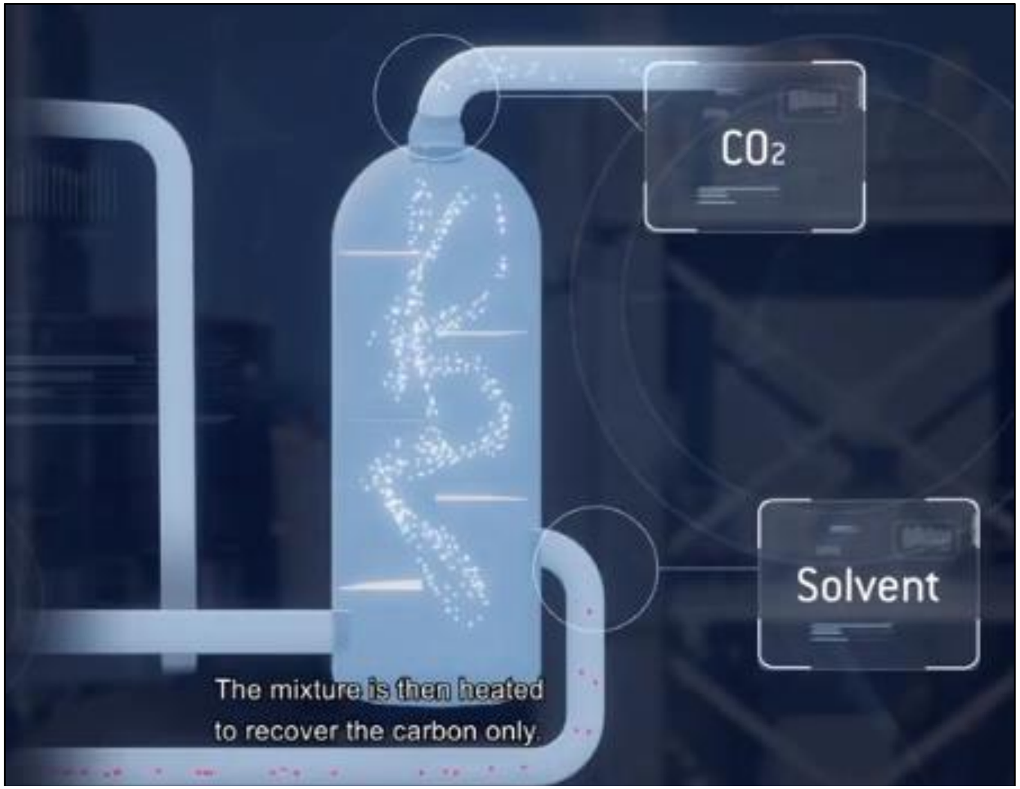
# CCUS Overview

- CCUS is the is the process to capture $CO_2$ from gas, utilize that carbon in some way, and find a safe, permanent storage option
- $CO_2$ can and has been used successfully by the oil and gas industry for enhanced recovery techniques, most notably, Enhanced Oil Recovery (EOR)
  - Up to 80% of oil can be left in place after primary and secondary recovery methods
- Four major types of enhanced recovery are:
  - **Enhanced Oil Recovery (EOR)**
  - Enhanced Coalbed Methane Recovery (ECBM)
  - Enhanced Gas Recovery (EGR)
  - Enhanced Shale Gas Recovery (ESGR)

# CCUS Process

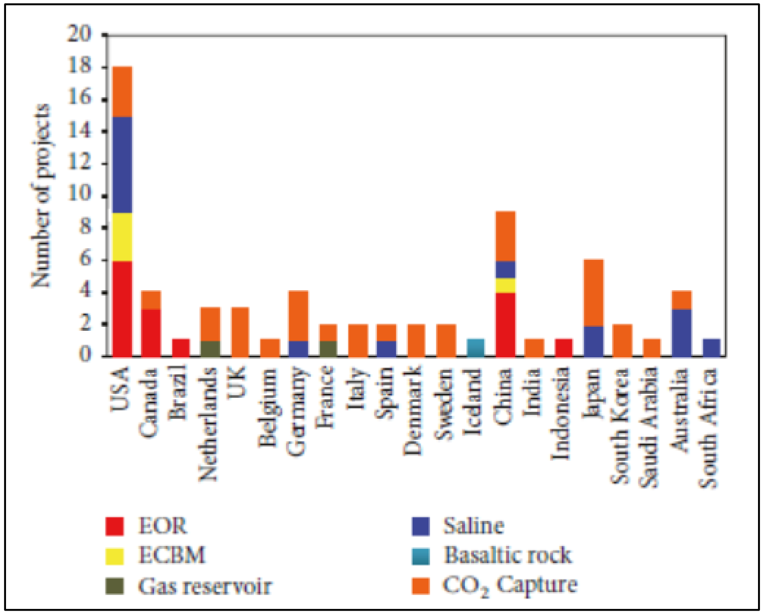
*Images from a Video Explaining Part of the CCUS Process* (Total, 2018)

| | |
|---|---|
| $CO_2$ | ○ |
| Flue Gas | (blue) |
| Solvent | (red) |

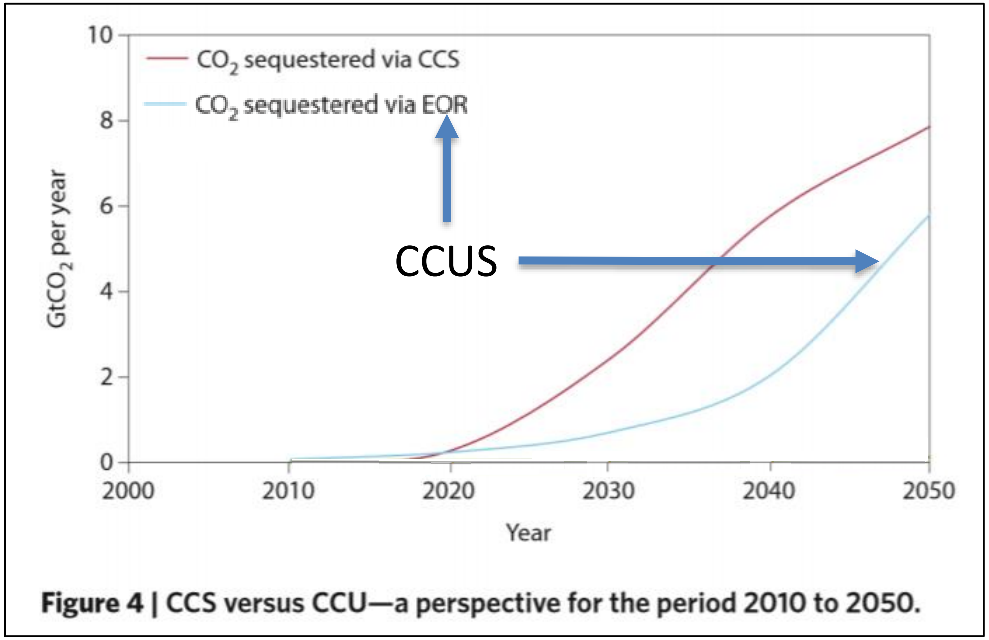



Finally, the mixture is heated to recover just the carbon where it is cooled and used for various purposes including to produce more hydrocarbons

# CCUS- Where Are We Today?




*Graph from* (Liu, et al., 2017) *Showing CC(U)S Projects by Country*




*Projections of* $CO_2$ *Sequestration by Method Modified Amended from* (Serdoner, 2019)

- Most of the CCUS projects are in the United States and most of those are EOR
- To put the graph on the right in perspective, the world released ~33 gigatons of $CO_2$ in 2019

# CCUS Geologic Parameters

| Number of projects | Lithology | Porosity (percent) | Perm. (md) | Depth (feet) | Gravity (°API) | Viscosity (cp) | Temp. (°F) |
|---|---|---|---|---|---|---|---|
| Miscible | | | | | | | |
| 42 | ss. | 7–26 | 16–280 | 1,600–11,950 | 30–45 | 0.6–3.0 | 82–257 |
| 2 | ss./ls.-dol. | 10 | 4–5 | 5,400–6,400 | 35 | 1 | 170–181 |
| 41 | dol. | 7–5 | 2–28 | 4,000–11,100 | 28–42 | 0.6–6.0 | 86–232 |
| 12 | dol./ls. | 3–12 | 2–5 | 4,900–6,700 | 31–44 | 0.4–1.8 | 100–139 |
| 6 | ls. | 4–20 | 5–70 | 5,600–6,800 | 39–43 | 0.4–1.5 | 125–135 |
| 1 | dol./trip. chert | 13.5 | 9 | 8,000 | 40 | NA | 122 |
| 7 | tripolite | 18–24 | 2–5 | 5,200–7,500 | 40–44 | 0.4–1.0 | 101–123 |
| 1 | | | | inadequate data | | | |
| Immiscible | | | | | | | |
| 8 | ss. | 17–30 | 30–1,000 | 1,500–8,500 | 11–35 | 0.6–45 | 99–198 |
| 1 | dol. | 17 | 175 | 1,400 | 30 | 6 | 82 |

*Table Showing EOR Projects Broken into Lithology, Porosity, Permeability, etc.* (Koottungal, 2012)

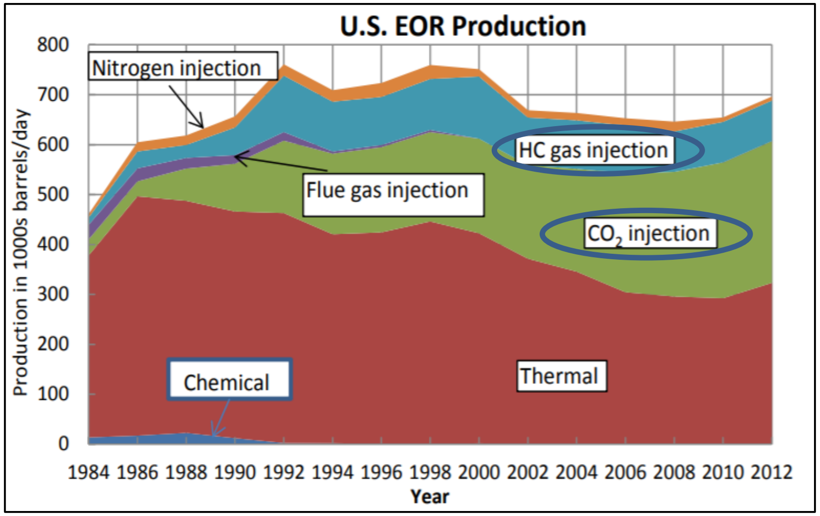
Optimum reservoir parameters and weighting factors for ranking oil reservoirs suitable for $CO_2$ EOR

| Reservoir parameters | Optimum values | Parametric weight |
|---|---|---|
| API Gravity (°API) | 37 | 0.24 |
| Remaining oil saturation | 60% | 0.20 |
| Pressure over MMP (MPa) | 1.4 | 0.19 |
| Temperature (°C) | 71 | 0.14 |
| Net oil thickness (m) | 15 | 0.11 |
| Permeability (mD) | 300 | 0.07 |
| Reservoir dip | 20 | 0.03 |
| Porosity | 20% | 0.02 |

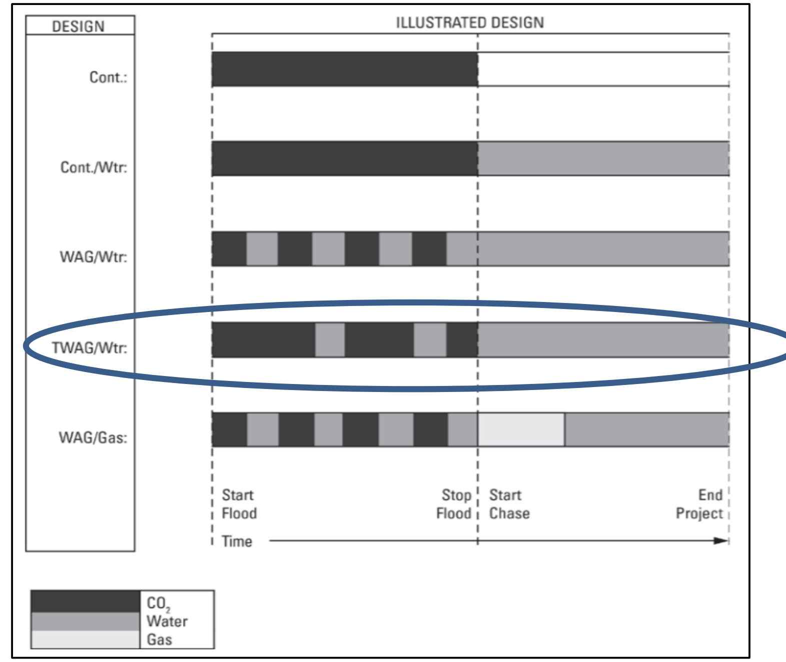
*Chart Weighing the Various Parameters for EOR* (Gozalpour, Ren, & Tohidi, 2005)

- All types of reservoirs (siliciclastic, carbonate, etc.) are suitable for EOR
- Most of the applications of EOR have been with medium to light gravity oils
- As shown, the API of oil, OIP, pressure and temperature matter more than other geologic parameters though permeability is important and imperative
- Miscible (where $CO_2$ mixes with oil) is preferred as that better facilitates production

# CCUS Practicality and Design




*U.S. EOR Production by year Showing an Increase in* $CO_2$ *Injection* (Koottungal, 2012)




$CO_2$ *Flood and Injection Designs Schematic (Jarrell et al., 2002)*

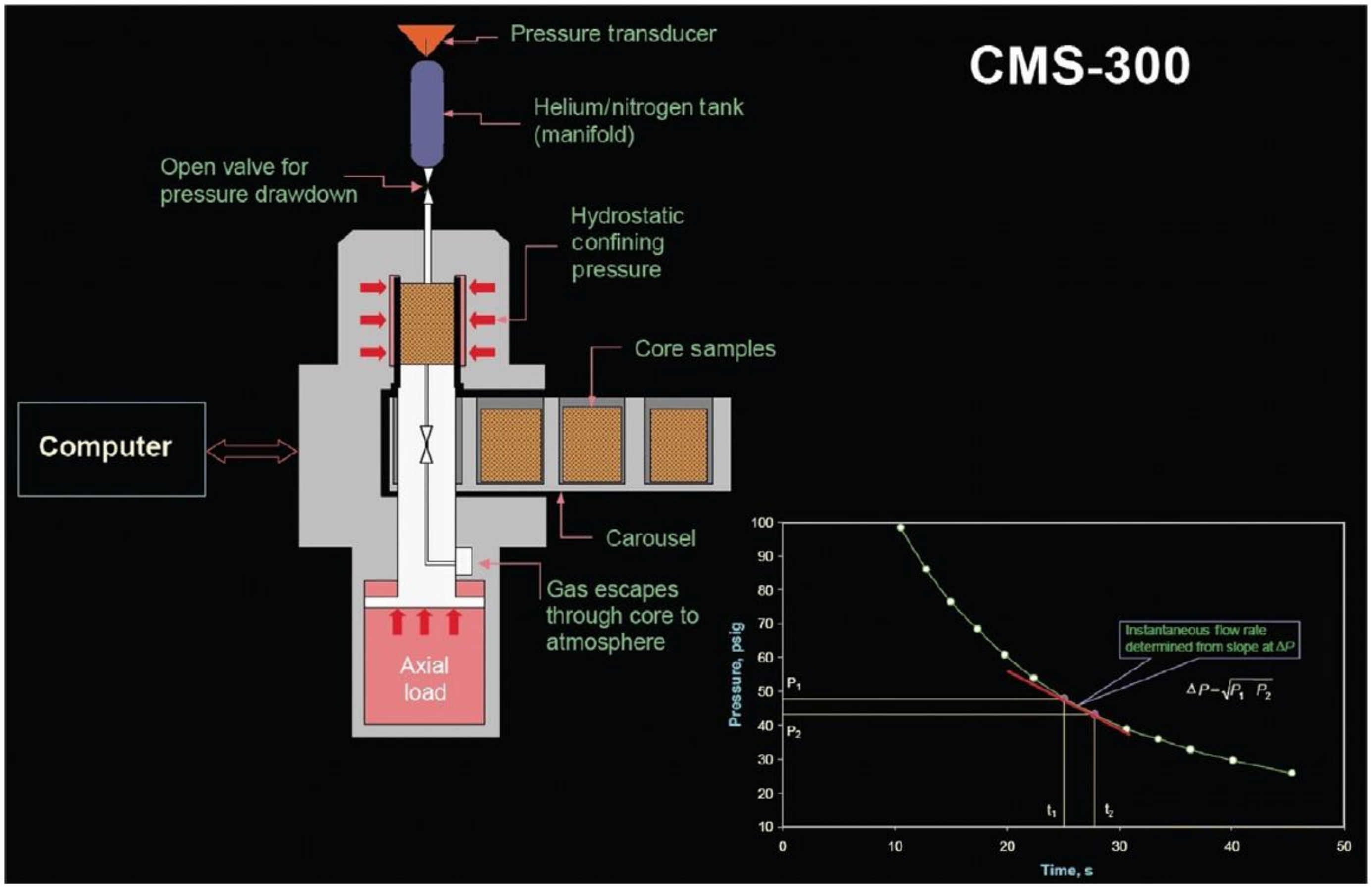
- Both hydrocarbon gas injection and $CO_2$ injection have increased in recent years for EOR
- The viscosity of oil in EOR projects ranged from .4 to 6 cp where $CO_2$ has a viscosity of .05 to .08 cp
- Tapered Water Alternating Gas or TWAG is the most common technique where the water acts as a “slug” pushing the hydrocarbons through the reservoir to production
- $CO_2$ has ~60% success factor in remaining stored

# Data Collection & Analysis

- Pick a well that has sufficient core data over the Niobrara A, B, C, and the Codell (at a minimum)
- Use reservoir properties (including permeability, porosity, thickness, produced fluids, and lithology) to observe changes in $CO_2$ or Methane injection
- Obtain well production and flow-back data
- Look at PVT analysis
- Work with petrophysical data (including NMR logs) to correlate log properties to favorable CCUS environments with the idea to make this work scalable and an analog for other basins
- Look at around a 1 township area to start around the well of choice with sufficient core data

# Methodology of Lab Work

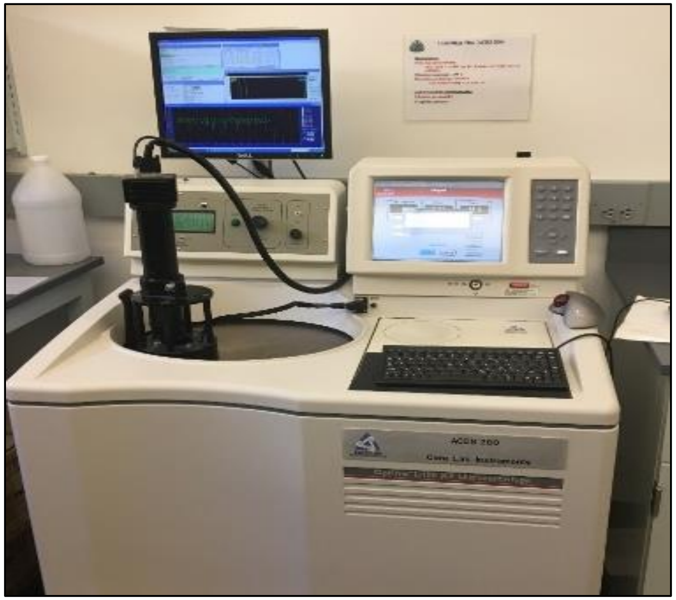
- Obtain 1.5” core plugs and use Core Measurement System (CMS 300) to measure porosity, permeability, and pore volume at different confining stresses



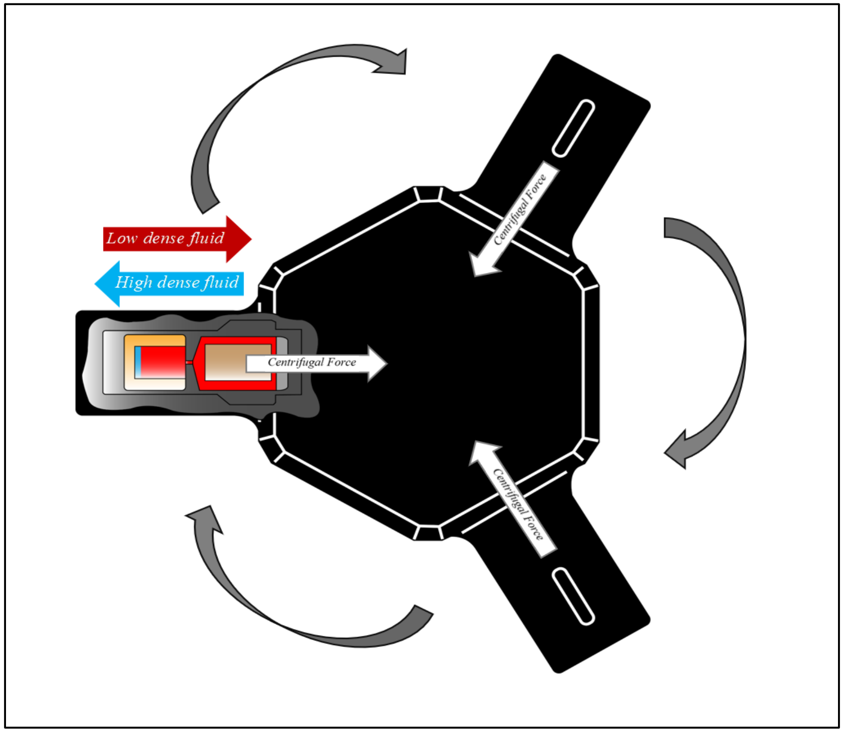

*Core Laboratories CMS-300 unsteady-state permeameter/porosimeter*
*(McPhee et al. 2015)*

# Methodology of Lab Work

- Use the Beckman ultra-fast centrifuge (ACES-200) to surround and oil saturated core plug with another type of fluid (such as $CO_2$ or methane) to displace the fluid inside the core observing changes quantitatively and qualitatively
- A high resolution camera and captures the fluid interaction and data is collected looking at changes in oil saturation (good proxy for miscibility)



*Core Laboratories ACES-200 ultra-high-speed centrifuge (Uzun 2018)*




*Schematic of Centrifuge (Uzun 2018)*

# Methodology of Lab Work

- Chandler's Formation Response Tester (FRT) Model 6100 allows $CO_2$ to be flowed across the core to observe permeability changes
  - Can look at both potential production flow or injection treatments of various fluids including carbon dioxide, methane, or hydrocarbons


*Chandler's FRT Model 6100 (Chandler Engineering, 2020)*

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