Business Case for CCUS – Business Models

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CCUS Deployment Training

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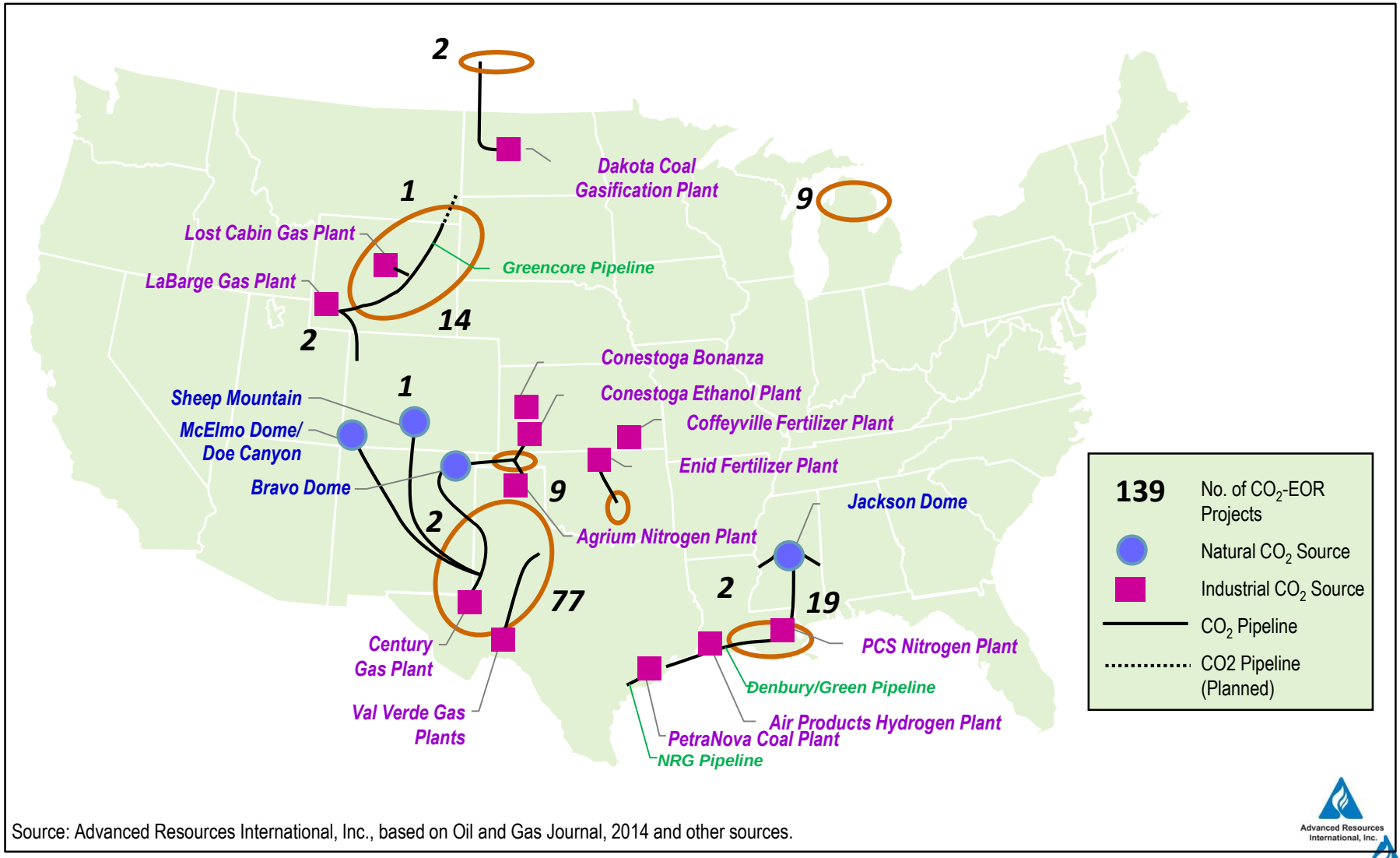
Overview of CO_2-EOR in N. America



Source: Advanced Resources International, Inc., based on Oil and Gas Journal, 2014 and other sources.

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Historical Business Models

- Natural sources. The earliest projects leveraged their proximity to large, natural sources of CO_2.
- Industrial capture. Commoditization of products at industrialized centers have recognized the value of CO_2.
- Government subsidized. Government subsidized in order to achieve commercial viability.
- Infrastructure development. Field operators link to major pipeline sources of CO_2.

New business models are likely to evolve as 45Q incentives spur new deployment.

CO_2 Supply from Natural Sources

- The large natural sources effective in providing high-volume, low cost CO_2.
- Because of the volcanic nature of these deposits, most pipelines are “downhill,” resulting in additional cost savings.
- Today, more than 75% of the CO_2 in the U.S. comes from natural sources.

Courtesy: Melzer Consulting

CO_2 from Industrial Capture

- Processes to produce natural gas, hydrogen, ammonia, and fertilizer have generated relatively pure sources of CO_2.
- Because of its purity, this CO_2 is able to compete with the pricing for natural sources.
- In the case of gas processing, this have been very significant for EOR.

Courtesy: Melzer Consulting

Government Subsidized CO_2 Supply

- To encourage first-of-a-kind applications, the US government has subsidized pilot and large-scale initiatives.
  - A syn-gas plant that generates, among other saleable products, significant volumes of CO_2 for the Weyburn and Midale EOR projects.
  - A capture facility at NRG's Parrish Power Plant that generates 4,300 tpd of CO_2 for West Ranch oil field.
- These are relatively unique first applications that required timely government aid.

Courtesy: Melzer Consulting

Boundary Dam and Alberta Carbon Trunk Line

Since 2014, SaskPower's Boundary Dam Power Station has captured and sold to the EOR industry 2 million metric tons of CO_2.

Source: SaskPower, 2018

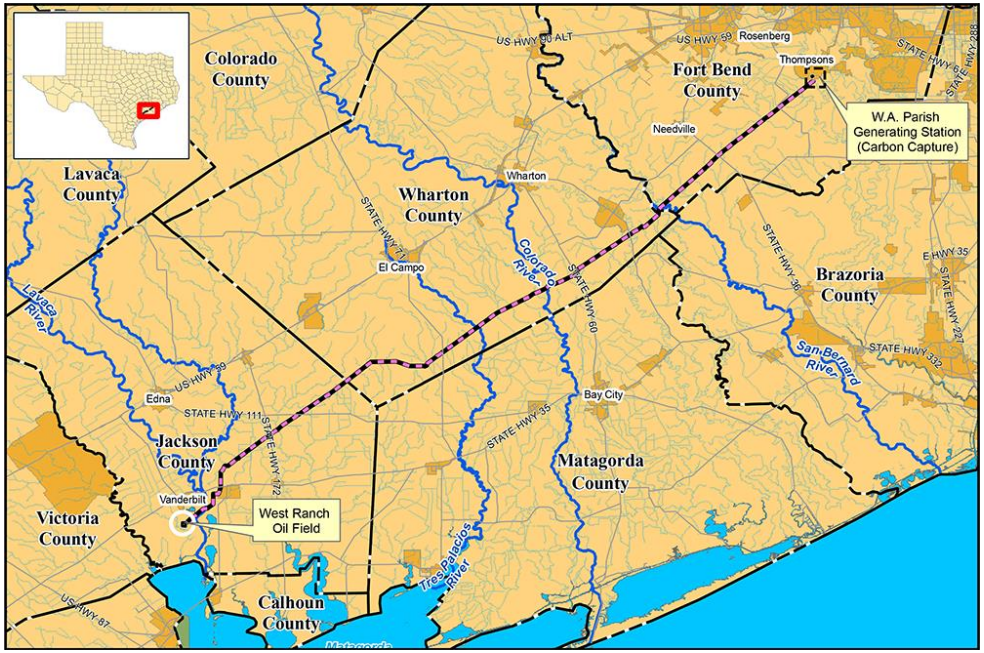
By end of 2019, the 240 km Alberta Carbon Trunk Line (ACTL) will transport 1.5 million mt of CO_2 per year captured from the Redwater Fertilizer plant and NW Redwater's Sturgeon Refinery for use and storage with EOR.

At full capacity, the ACTL will provide access to reservoirs capable of storing 14.6 million metric tons per year.

PetraNova: "Poster Child" of Carbon Utilization

PetraNova has installed post combustion CO_2 capture on a 240 MW coal-fired unit at the WA Parish power plant near Houston, Texas.

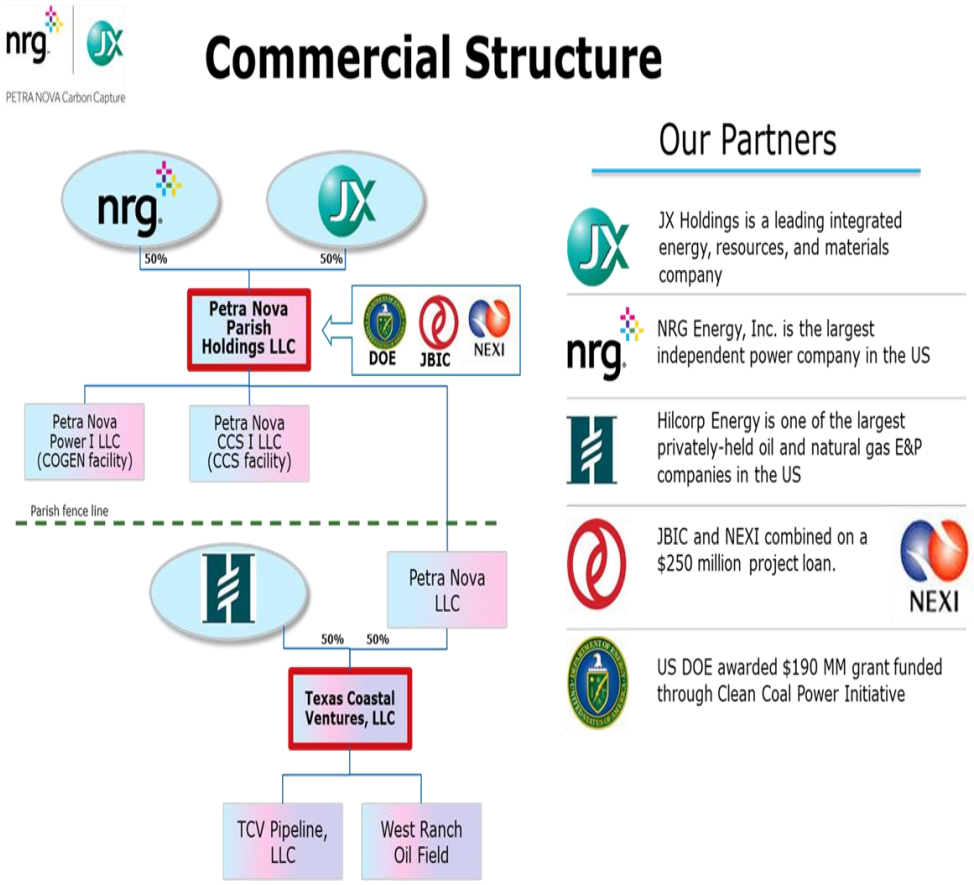
The 80 MMcfd of captured CO_2 is transported and used for EOR at Hilcorp's West Ranch oil field with an oil production goal of 15,000 B/D.



Source: NRG, 2017

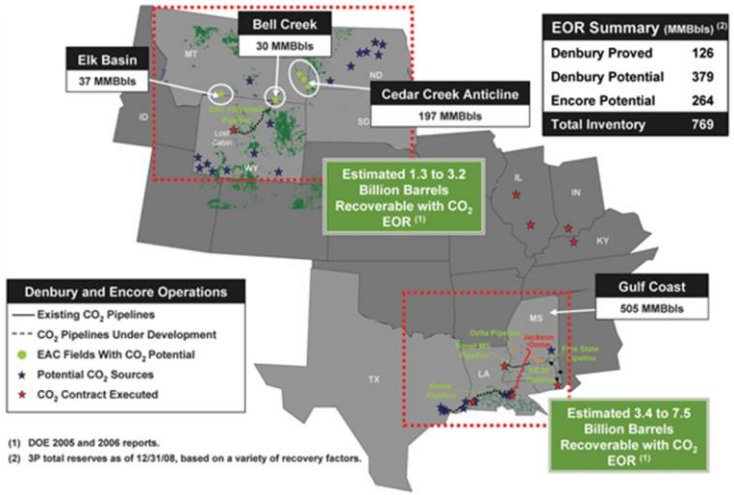
Petra Nova Carbon Capture Project: a Closer Look

- $1 billion project 50-50 JV between NRG Energy's Carbon 360 unit and JX Nippon Oil & Gas Exploration.
- Financing Petra Nova required creative combination of partners.
  - US DOE awarded a $167 million grant as part of a competitive solicitation under the DOE's Clean Coal Power Initiative.
  - NRG decided to build/own the CO_2 delivery pipeline and take a 50% equity stake in the West Ranch oil field.
  - JX Nippon eventually matched NRG's $300 million equity stake.
  - $250 million in loans from Japanese banks.



Building off Existing Pipeline Infrastructure

- In each of the previous business models, low-cost CO_2 was the driver to develop the oil field cluster.
- An oil field and CO_2 pipeline operator has developed an additional 320 mile pipeline in the Gulf Coast to link their low-cost natural source of CO_2 to a new cluster of oil fields.
- At a cost of US$660 million, this pipeline crosses a multitude of CO_2 sources across the chemical corridor of the Gulf Coast, US.

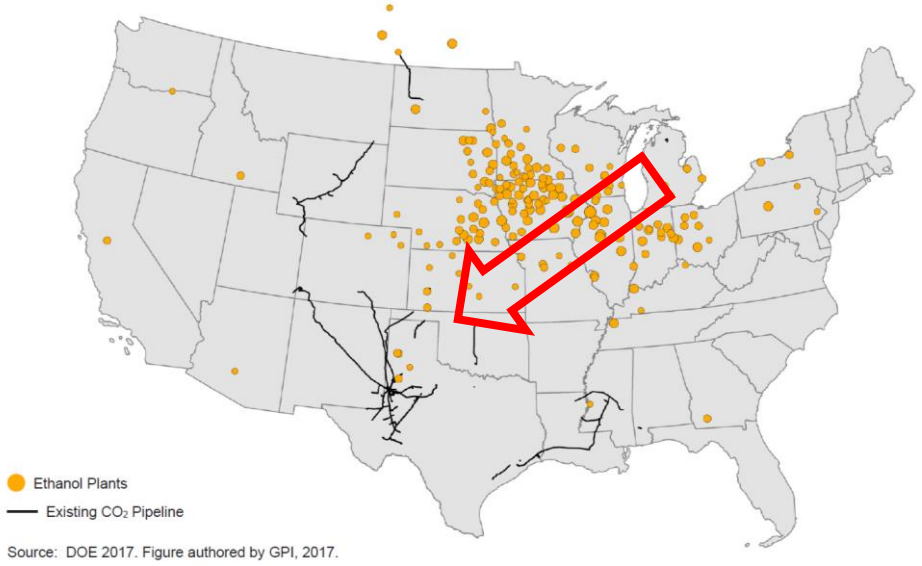


Courtesy: Melzer Consulting

Aggregating Capture from High Purity, Low Volume Sources

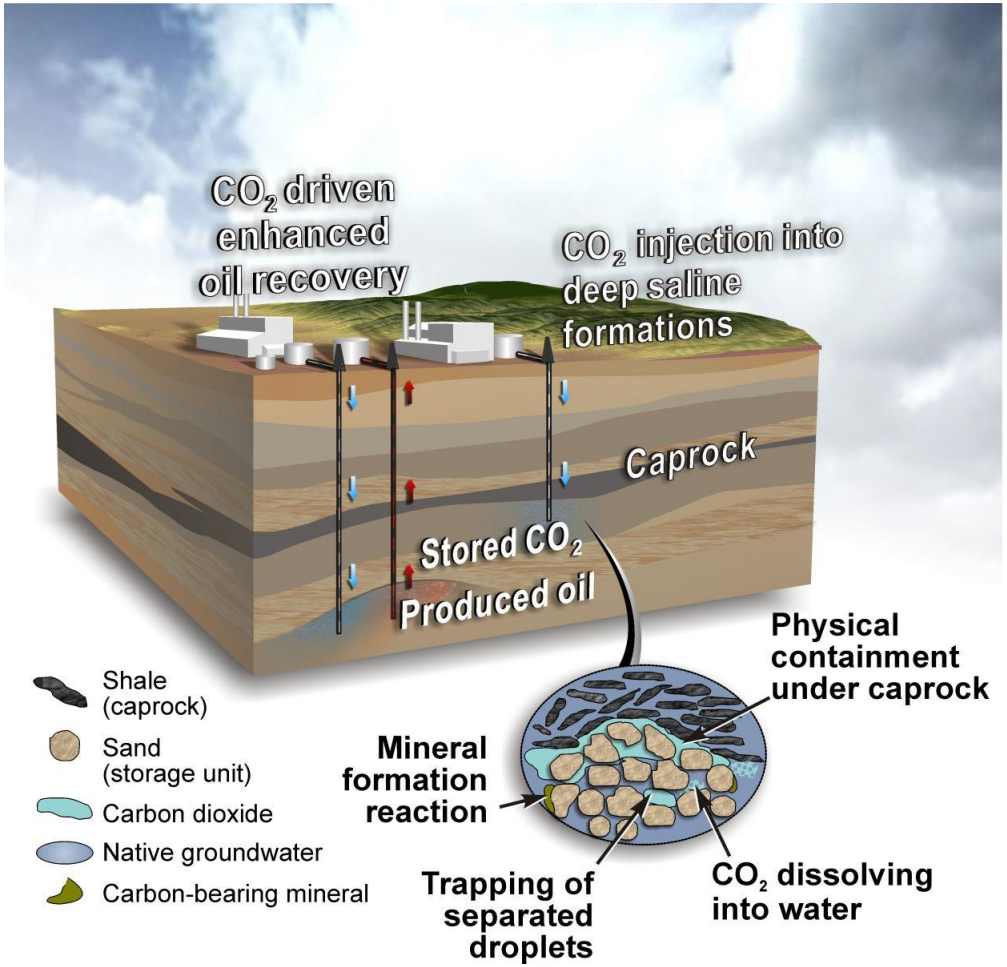
Each of these high purity sources emits CO_2 at near atmospheric pressure, requiring significant compression to reach pipeline pressure. Further, these sources, such as ethanol plants, require pipeline infrastructure to get the CO_2 to market. However, these sources are located in places (generally) without existing infrastructure.

It would not take much to develop CO_2 delivery lines across the U.S. plains in order to tie into existing pipelines and oil fields.



Source: DOE 2017. Figure authored by GPI, 2017.

"Stacked" Storage/Combined CO_2-EOR plus Storage

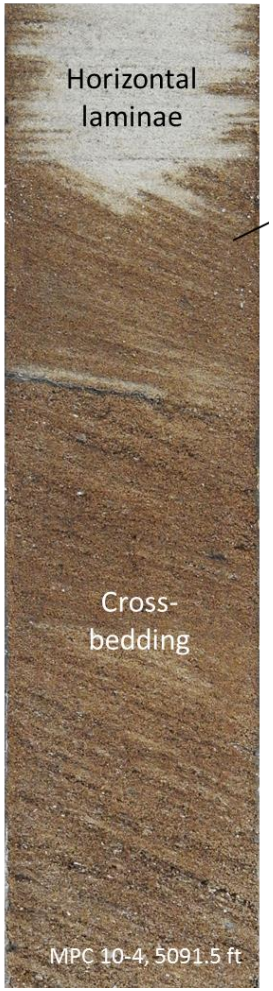


https://www.arb.ca.gov/cc/sequestration/seq.htm

- Associated storage with CO_2-EOR may not achieve emissions reduction targets.
- In association with the EOR project, "pure" storage may be conducted in a high permeability saline formation above or below the oil reservoir.
- This could require regulatory mandates or incentives to push forward.

Saline Storage Hubs -- Project ECO$_2$S

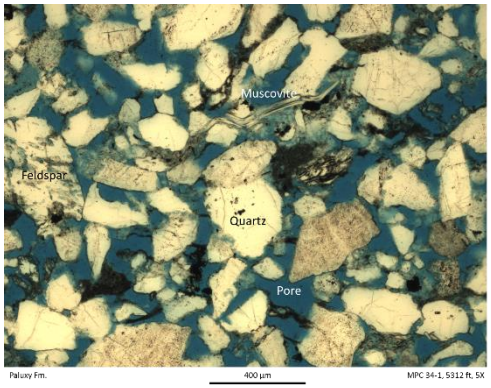
Paluxy sandstone

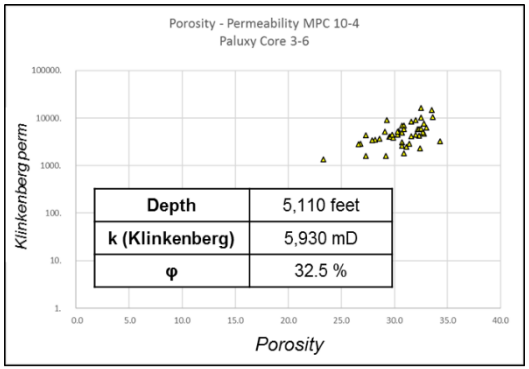


Interpretation: sandy braided stream deposit

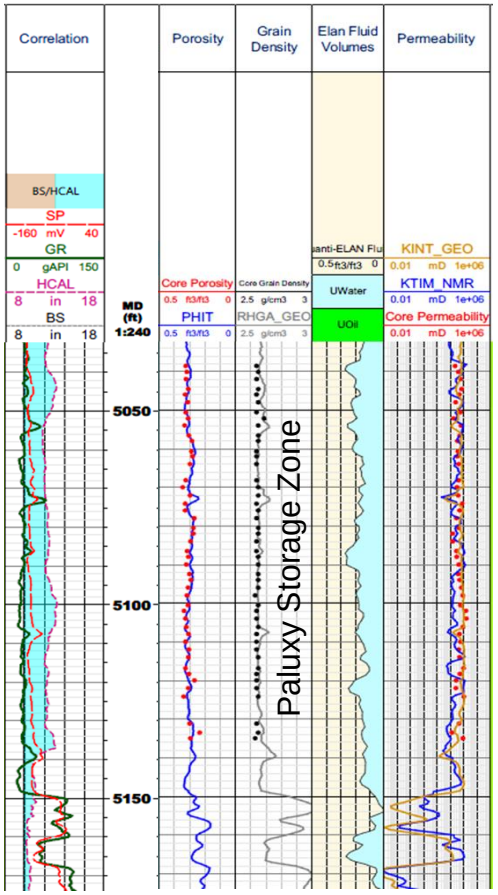
- **Goal: Demonstrate the subsurface at Kemper can safely/permanently store commercial volumes of CO_2**
- Abundant stacked saline sandstone bodies in Paluxy, Wash-Fred, and lower Tuscaloosa.
- 350 meters of net sand. Logs and core show sandstone average porosity of 30%(!!)
- Core analysis indicates all sandstones water-saturated
- Darcy-class permeability common (up to 16 Darcies)

High-porosity sandstone in Paluxy Formation





Elemental Log Analysis (ELAN*) interpretation



**ELAN is a mark of Schlumberger*

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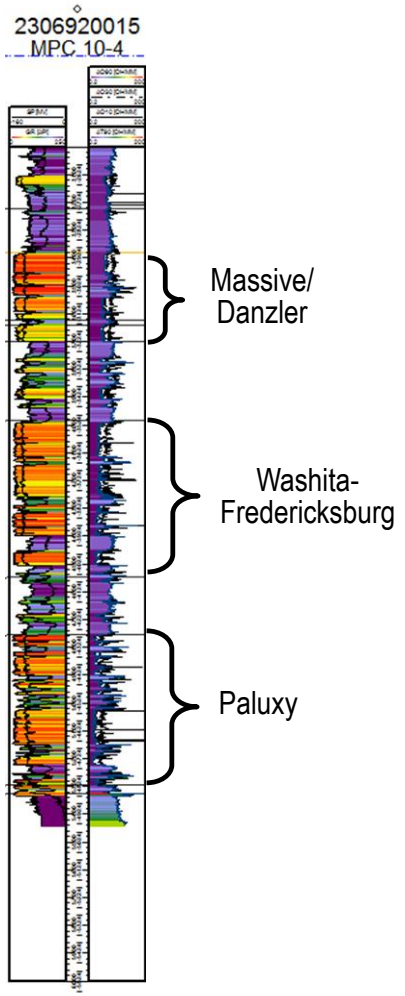
Storage Complex Capacity

- Each of the three potential storage zones have commercial capacity
- Together the three storage zones result in a gigatonne capacity storage complex that has the potential to act as a regional hub

CO_2 Storage Reservoir	P_{10} Capacity (MMmt)	P_{50} Capacity (MMmt)	P_{90} Capacity (MMmt)
Massive/Dantzler	60	120	200
Wash.-Fred.	280	540	920
Paluxy	160	310	530

DOE methodology for site-specific saline storage efficiency calculation based on fluid displacement factors for clastic reservoirs where net pay, net thickness and net porosity are known of 7.4% (P_{10}), 14% (P_{50}) and 24% (P_{90}) (Goodman et al., 2011)



- Low-cost storage options occur beneath the energy facility -- $2.00 - $4.00 USD per metric ton depending on volume of CO_2 captured (*after DOE investment*)
- Drives the value proposition where existing infrastructure could be utilized for CO_2 capture, compression, transportation and storage

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