# FACTSHEET FOR PARTNERSHIP FIELD VALIDATION TEST

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| **Partnership Name** | Big Sky Regional Carbon Partnership | | |
| **Contacts:** | Name | Organization | E-Mail |
| DOE/NETL Project Mgr | David Lang | NETL | LANG@netl.doe.gov |
| Principal Investigator | Lee Spangler | | |
| **Field Test Information:** Field Test Name | Wyoming Phase II Saline Injection | | |
| Test Location | Riley Ridge Field, Moxa Arch, southwestern Wyoming | | |
| Amount and Source of $CO_2$ | 3000-5000 tons | | |
| Field Test Partners (Primary Sponsors) | University of Wyoming<br><br>Cimarex Energy, | | |
| | Schlumberger | | |
| | Columbia University | | |

**Summary of Field Test Site and Operations:**

This project will perform a field validation test to characterize the Triassic Nugget Sandstone Formation on the Moxa Arch, and assess the viability and capacity of the Nugget as a deep saline formation for a large-scale geologic sequestration test. The validation test will involve injecting super critical carbon dioxide ($CO_2$) into the target formation to provide the fundamental information for sequestration in this large-scale structure.
The Moxa Arch is a structural feature that forms a north-south trending anticline approximately 40 x 90 miles in extent. Within this large structure, an area of 21x 65 miles of Paleozoic rocks about 6000 feet thick is currently saturated with approximately 162 TCF of gas. The majority of this gas (65-95%) is carbon dioxide in a supercritical state with accompanying methane, hydrogen sulfide and helium.
Currently, Exxon-Mobil extracts the resource from the Madison Formation at 18,000 feet depth, primarily for helium and compresses a portion of the carbon dioxide for sale to enhanced oil recovery projects in Wyoming. Cimarex Energy has designed a new gas plant to be installed in 2008 at the Riley Ridge Field for extraction of helium and methane. This project will use existing and new Cimarex Energy wells to inject $CO_2$ into the Nugget sandstone at about 12,000 feet depth.

The planned injection site occurs west of LaBarge, Wyoming and is east of the thrust belt that creates the LaBarge Platform and Moxa Arch geological features. Land ownership is a mix of public and private lands with the largest proportion of lands under management of the United States Department of Interior's Bureau of Land Management (BLM). United States Forest Service Lands occur to the west and most riparian areas are privately owned or comprise a segment of the "checkerboard" lands that are alternating private and public lands for 20 miles on each side of the Union Pacific Railroad Line that transects the state in a location roughly approximating US Highway 30. Figure 1 is a map of LaBarge, Wyoming.

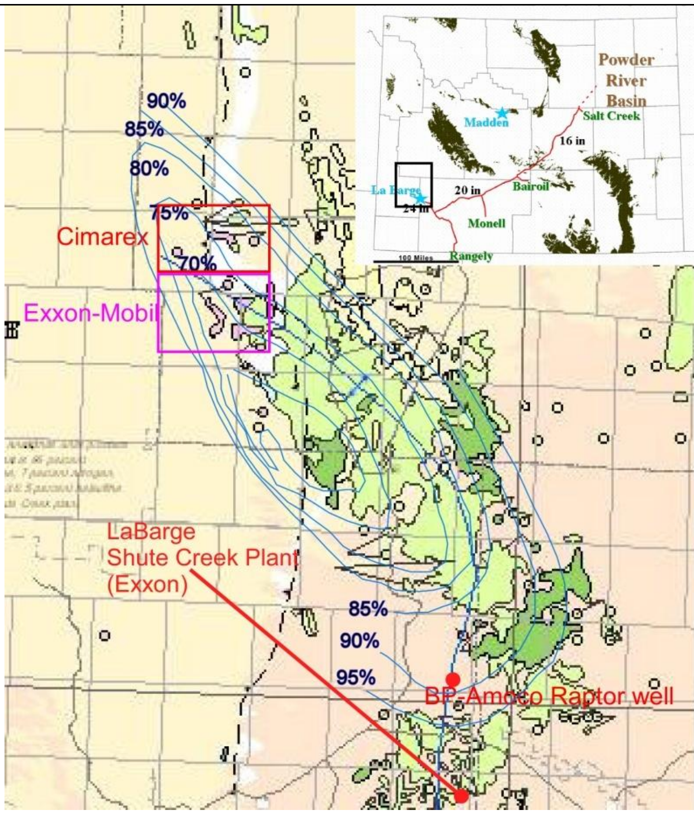



**Figure 1 Map showing LaBarge location**

The site has been subjected to significant oil and gas exploration and production beginning in the mid 1970's and continues to date. Oil, methane gas, helium and $CO_2$ are the principal products with a large $CO_2$ production facility supplying $CO_2$ to EOR operations in Colorado and Wyoming. This plant also has two acid gas disposal wells located at the facility and currently vents approximately 200 MMCF of $CO_2$ per day. Cimarex will be building a new gasification plant to strip methane, helium and a relatively pure stream of $CO_2$ (approximately 1.8 million tons/yr) from a $CO_2$ saturated Madison formation in the immediate vicinity. Cimarex intends to dispose of excess $CO_2$ back into the Madison formation or to provide the $CO_2$ to oil and gas operations pursuing EOR opportunities.

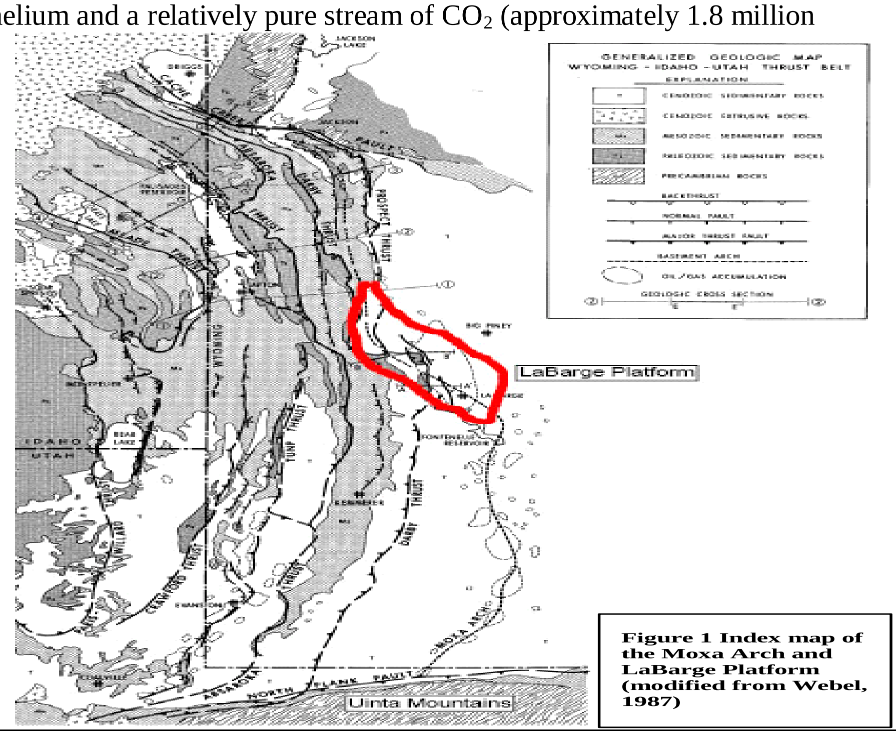


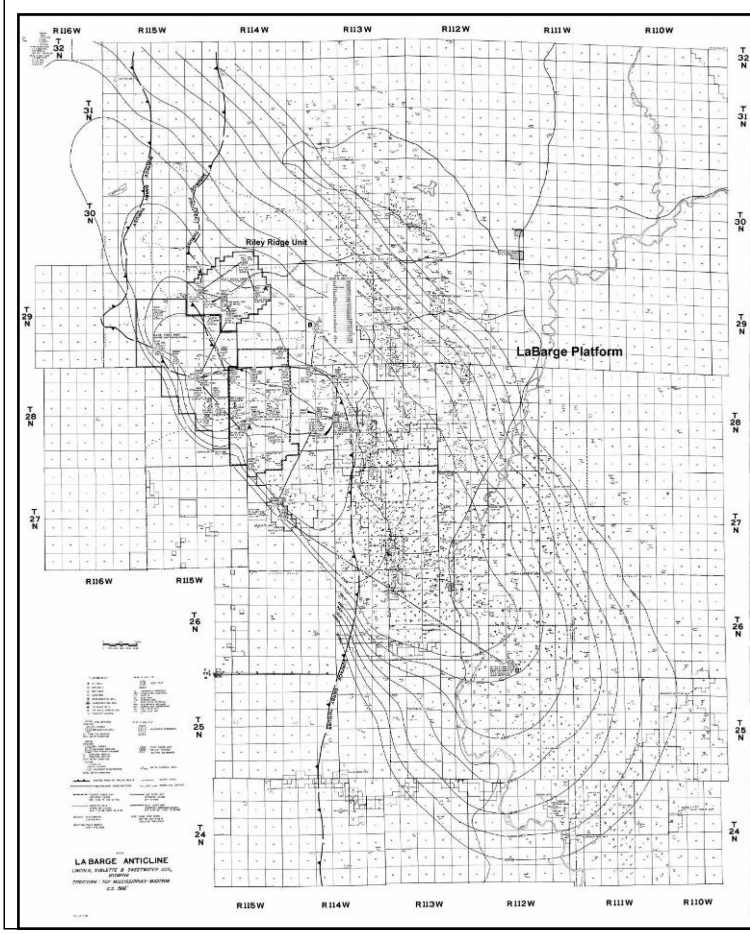

**Figure 1 Index map of the Moxa Arch and LaBarge Platform (modified from Webel, 1987)**

**Description of Target Formation**

The small volume injection will be located at the Riley Ridge Unit on the LaBarge Platform, southwest Wyoming. The LaBarge Platform encompasses a large structural closure at the northern limit of the Moxa Arch (Figure 2). The Moxa Arch is a large north-south trending anticline bound on the south by the Uinta Mountains and trending north for 120 miles before plunging beneath the leading edge thrust of the Wyoming Thrust Belt. The west flank of the anticline dips below the Wyoming Thrust Belt and the east flank is the western margin of the Green River Basin. The closure of the LaBarge Platform encompasses approximately 800 square miles on the northern region of the Moxa Arch (Figure 2; WGA, 1992). Three small, mature Nugget oil fields are present on the LaBarge Platform and produce from smaller anticlines superposed on the much larger structural feature. The Nugget Sandstone is a very extensive brine aquifer located on the LaBarge Platform and extending across the remainder of the Moxa Arch and into the Green River Basin as well. This saline aquifer of the Nugget Sandstone within the closure of the LaBarge Platform is the target of this Phase III project. The LaBarge Platform has the potential to store large volumes of $CO_2$ in the Nugget Formation and takes on even greater long-term significance, as the Nugget Formation on the remainder of the Moxa Arch and within the Green River Basin, is also a potential sequestration target of even greater volumetric significance. This Phase II activity, however, will focus on the static trap of the structurally closed LaBarge Platform.

The Phase II sequestration target formation is the Nugget Sandstone (Figure 3). The Nugget Sandstone is a Jurassic aged regional sheet sandstone that covers the entire southwestern area of the state of Wyoming. Total thickness of the Nugget Sandstone in the area of LaBarge is approximately 700 feet. It is equivalent to the Navajo Sandstone (Utah) and has similar properties to the Tensleep (Montana and Wyoming), Weber Sandstone (Wyoming, Colorado, and Utah, Quadrant Sandstone (Montana) and the Sundance Sandstone (Wyoming) and thus has important regional significance. The Nugget Sandstone was deposited as a series of sand dunes and interdunal deposits in an eolian depositional environment. The porous sandstones that are the injection target have an average thickness of greater than 200 feet, an average porosity of greater than 15 percent, and are highly permeable (Webel, 1977).

**Figure 2 Structure contour map of the top Madison Formation (modified from WGA, 1992)**



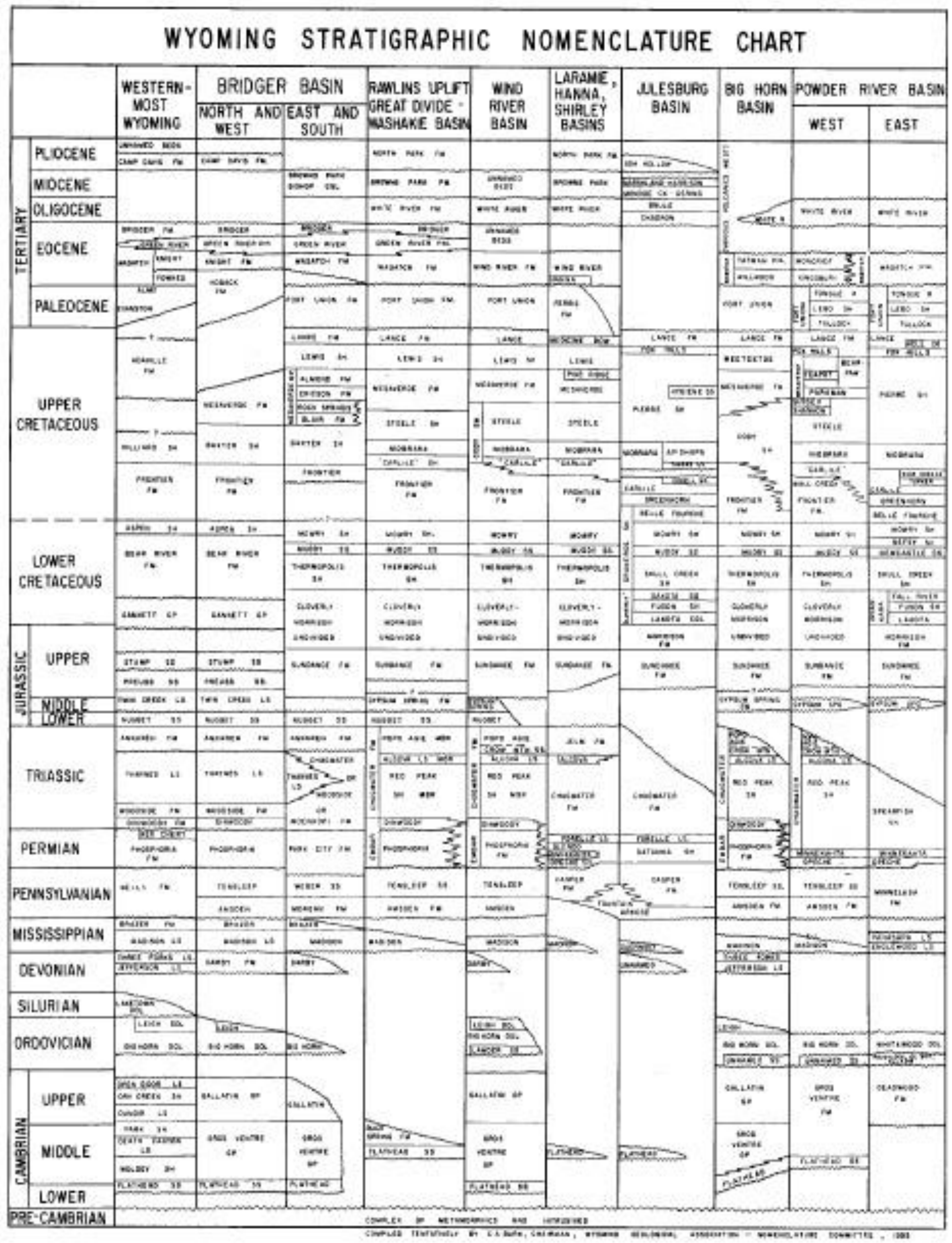



**Figure 3 Wyoming Stratigraphy**

The specific descriptions of the target formation characteristics are below:

- <u>Current Data:</u> Extensive well logs, cores, and seismic data exists both in the public and private domain. The Partnership is in negotiations for key private domain data.
- <u>Depth, Temperature, and Pressure:</u> 11,000 ft depth with 3850 psi pressure and 209$^{o}$F temperature (reservoir conditions; Carlson, 1979; Golden, 1979; Webel, 1979)
- <u>Orientation:</u> The LaBarge Platform is a structurally closed static trap.
- <u>TDS Data / Fluid Chemistry:</u> Chemical analyses of the Nugget Formation are available from the USGS oil field waters database. A search of the database found a total of 32 samples taken from the nearby Birch Creek, Hogsback, Tip Top and Big Piney oil fields over depths between 9432 and 11,033 feet. The total dissolved solids ranged from 72,033 to 108,740mg/L. The brine is composed primarily of NaCl with minor amounts of Ca, Mg and $SO_4$.

- Chemistry of Formation Water: Chemical analyses of the Nugget Formation are available from the USGS oil field waters database. A search of the database found a total of 32 samples taken from the nearby Birch Creek, Hogsback, Tip Top and Big Piney oil fields over depths between 9432 and 11,033 feet. The total dissolved solids ranged from 72,033 to 108,740mg/L. The brine is composed primarily of Na-Cl with minor amounts of Ca, Mg and $SO_4$.

**Research Objectives:**

1) Evaluate the local scale reservoir and adjacent formation responses to injection of supercritical $CO_2$ using a small volume (3000-5000 ton) injection test.
2) Track the post-injection migration and containment of the $CO_2$ in the Nugget Sandstone Formation to compare with pre-injection reservoir modeling predictions and serve as a basis to refine the initial multiphase flow reactive-transport modeling.
3) Characterize the large-scale potential of this saline aquifer using the static geological model coupled to multiphase flow reactive-transport to model injection of supercritical $CO_2$ into the Nugget Sandstone Formation on the Moxa Arch for commercial sequestration.

**Summary of Modeling and MMV Efforts:**

Planned MMV components include:

- Vertical seismic profiling - Given the depth and small volume of the injection, surface-based geophysical monitoring of the $CO_2$ will not be a part of the Phase II MMV plan. However, downhole vertical seismic profiles will be collected pre- and post-injection to evaluate the post-injection distribution of the plume in the subsurface and to accurately tie the local stratigraphy to seismic reflections such that existing 2-d seismic data and planned 3-d seismic data to be collected during Phase III can be more accurately interpreted.
- Micro-seismic techniques - micro-seismic techniques will be employed to monitor micro-fracturing associated with plume movement and expansion.
- Microgravity - Gravity measurements are sensitive to changes in formation density and can be used to monitor the injected $CO_2$ in these locations. The small density contrast of supercritical $CO_2$ coupled with the reservoir depths of the Nugget sandstone at the well site will require the gravity change due to $CO_2$ injection be measured using post-injection borehole gravimeters. This will allow easy and rapid detection of gravity changes associated with $CO_2$ injections as well as a robust way to calculate in situ $CO_2$ mass, particularly in conjunction with gamma-gamma density, resistivity, and fracturing imaging from conventional well logs and laterally mapped flow geometry from seismic. Combined analysis of the cross-well seismic and borehole gravity surveys will enable the 3D geometry of the injected $CO_2$ plume to be tracked and estimation of its in-situ mass and saturation.
- Well sampling – water samples/produced fluids will be collected from both the injection and monitoring wells and analyzed for tracers and for geochemical indicators of the presence of $CO_2$
- Soil gas surveys – Pre- and post injection soil gas surveys will be conducted to establish the $CO_2$ soil gas flux background and determine if any leakage from the injected gas occurs. The samples will be taken over a sampling grid that includes the plume location and a buffer zone around the well site.
- Tracers - The tracers administered during injection will be monitored during the post-injection phase via samples collected from the monitoring well. Tracers will be designed to: (1) interact with the $CO_2$, water and mineral pha the reservoir, (2) limit the problem of interference from naturally occurring $CO_2$ background concentrations, and provide a statistically sound monitoring and characterization method by using multiple tracers. Currently, the lea chemical tracer candidates are $SF_6$, $CH_3F$, and $CH_2F_2$, although others will be considered. Push-pull pre-injectio tracer tests will be performed using both the chemical tracers and additional conservative tracers (such as bromide PFBA, tritium) to better quantify the basic hydrologic properties such as porosity, hydraulic conductivity and disp near the injection well. The Partnership may temporarily suspend injection to allow pump back sampling to colle

breakthrough curves (BTCs) of the different injected tracer pulses. The succession of BTCs for each tracer durin phase, when analyzed together and in comparison with the pre-injection BTCs, will reveal information about the and transport of injected $CO_2$ as a function of time as well as changes in the reservoir matrix properties.

**Accomplishments to Date:**
**This project is awaiting approval as part of the Partnership's Continuation Application.**

**Summarize Target Sink Storage Opportunities and Benefits to the Region:**

This project will serve as a precursor to the large volume test in the Nugget on the Cimarex Energy site. This area is the endpoint for a State-wide $CO_2$ pipeline infrastructure and the Nugget Sandstone on the Moxa Arch is projected to be able to store in excess of 10GT, which is about 100 years of current Wyoming carbon dioxide emissions from power plants. The nearby Rock Springs uplift is estimated to have a storage capacity of 26GT that will supplement the Moxa storage. On a regional scale, the Nugget is equivalent to other major eolian saline aquifers being considered as sequestration targets including the Tensleep, Weber, and Navajo formations.

**Cost:**

**Total Field Project Cost: $7,973,762**

**DOE Share: $2,976,806 37%**

**Non-Doe Share: $4,996,956 63%**

**Field Project Key Dates:**

**Baseline Completed:**

**Drilling Operations Begin: 4/1/08**

**Injection Operations Begin: 9/1/08**

**MMV Events: 6/1/08**

**Field Test Schedule and Milestones (Gantt Chart):**

| Task 14.0 - Wyoming Field Validation Test | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | FY06 | | | | FY07 | | | | FY08 | | | | FY09 | | | |
| **Task 14.1 Site Characterization** | | | | | | | | | | | | | | | | |
| Develop Static Geologic Model | | | | | | | | | | Gm20 | | | | | | |
| **Analyze Cores** | | | | | | | | | | | Gm21 | | | | | |
| Develop Multi-Phase Flow Model | | | | | | | | | | | Gm22 | | | | | |
| Submit Detailed Design Package | | | | | | | | | | Gm23 | | | | | | |
| **Task 14.2 Planning and Permitting** | | | | | | | | | | | | | | | | |
| Obtain Class II or Class V Well Permit | | | | | | | | | | Gm24 | | | | | | |
| **Task 14.3 Site Preparation** | | | | | | | | | | | | | | | | |
| Install Temporary Pipeline | | | | | | | | | | | Gm25 | | | | | |
| **Task 14.4 Injection** | | | | | | | | | | | | | | | | |
| Initiate Injection | | | | | | | | | | | | Gm26 | | | | |
| **Task 14.5 Site Monitoring and Verification** | | | | | | | | | | | | | | | | |
| Submit Detailed MMV Plan | | | | | | | | | | | | Gm27 | | | | |