Research Performance Progress Report

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Fossil Energy
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Methods to Enhance Wellbore Cement Integrity with Microbially-Induced Calcite Precipitation (MICP)

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Reporting Period End Date: December 31, 2014
Report Term/Frequency: Quarterly

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Date: 2015.01.09 09:04:34 -07'00'

ACCOMPLISHMENTS

Goal

The goal of this project is to develop improved methods for sealing compromised wellbore cement in leaking gas wells, thereby reducing the risk of unwanted upward gas migration. To achieve this goal an integrated workplan of laboratory testing, simulation modeling and field testing is underway. Laboratory testing and simulation modeling are being conducted at the Center for Biofilm Engineering at Montana State University and field testing will take place at the 1498 m (4915') deep Alabama Power Company well located at the Gorgas Power plant in Walker County, Alabama (Gorgas #1 well). This project will develop technologies for sealing compromised wellbore cement using the process known as Microbially Induced Calcite Precipitation (MICP). The project has two main objectives:

Objective 1: Prepare for and conduct an initial MICP field test aimed at sealing a poor well cement bond in the Gorgas well approximately located 820 feet (249 meters) below ground surface (bgs).

Objective 2: After thorough analysis of the results from the first field test, conduct a second MICP test using improved MICP injection methods. The second field test will target compromised wellbore cement located approximately 960 feet (293 meters) bgs at Gorgas.

Note. *The exact elevations of the planned field tests at Gorgas well (i.e. 820 and 960 feet bgs) are currently under review. The final elevations may be altered depending on results from the side wall coring test currently scheduled for early February 2015, as discussed below.*

After each test at Gorgas the following methods will be employed to assess effectiveness of the MICP seal: Pressure falloff testing, sustained natural gas flow rate testing at the well head, USIT (ultrasonic imaging tool) logging to assess the cement bond log, and side wall coring. Successful demonstration of improving wellbore integrity and sealing gas leaks from poor cement bond regions will result in a reduction in the pressure falloff, reduction in the sustained gas flow rate at the well head, noticeable differences in the USIT data in the targeted biomineralization regions, and demonstration of MICP byproducts ($CaCO_3$) in the treated regions on side wall cores.

The Project Milestones are shown Below in Table 1.

Table 1. Project Milestones

Related Task	Milestone Number	Milestone Title	Planned Completion Date	Actual Completion Date	Verification Method
1.0	1	Update Management Plan	11/30/2014	PMP was approved 12/01/2014	Project Management Plan

1.0	2	Kickoff Meeting	11/06/2014	Kickoff Meeting was Held 11/06/2014	Presentation
2.1	3	Complete construction and testing of wellbore-cement analog testing system. Expected result is a system which facilitates biomineralization sealing in annular spaces representative of field conditions.	3/31/2015		Quarterly Report
3.2	4	Complete first wellbore cement remediation field test. Expected results include obtaining side wall cores and pressure testing to evaluate the extent of biomineralization sealing.	9/30/2015		Quarterly Report
4.1	5	Complete analysis of field data from first field test. Expected result is a data set which will enhance the design of the second field test.	3/31/2016		Quarterly Report
4.1	6	Complete design of injection protocol for second field test.	9/30/2016		Quarterly Report
5.2	7	Complete second field test. Expected results include obtaining side wall cores and pressure testing to evaluate the extent of biomineralization sealing.	3/31/2017		Quarterly Report

6.0	8	Complete analysis of laboratory, simulation modeling and field data. The expected result will be a comprehensive evaluation of MICP sealing technology for well cement repair.	9/30/2017		Quarterly Report

Accomplishments under the goals

Major activities this reporting period include:

(1) Successful completion of the Kickoff Meeting held by teleconference November 6, 2014 (Milestone 2 completed)
(2) Submission of Project Management Plan (PMP) which was approved December 1, 2014 (Milestone 1 completed)
(3) Completion of a Project Planning Meeting involving Montana State University (MSU), Schlumberger Carbon Services (SCS), Southern Company (SC), and University of Alabama at Birmingham (UAB), December 16-19 in Birmingham, Alabama
(4) Initiated development of wellbore cement analog testing system

Project Planning Meeting. A project planning meeting was held December 16-19, 2014 in Birmingham, Alabama. In attendance were Al Cunningham, Lee Spangler, and Adie Phillips (MSU), Jim Kirksey and Bob Butsch (SCS), Richard Esposito (SC), and Peter Walsh (UAB). Discussion topics included review of the cement bond logs for the Gorgas well and scheduling field work to obtain side wall cores from multiple elevations in the Gorgas well.

Review of cement bond log at Gorgas. Analysis of the Gorgas well cement bond logs revealed the presence of multiple locations where the cement layer outside the well casing appears to be compromised thereby creating voids in the cement which can be occupied by either brine (formation water) or gas (methane). As the result of discussions, the project team identified at least four and possibly five potential locations where cement debonding is significant enough to conduct sealing repair using MICP technology. This discussion will continue by way of a teleconference call scheduled for January 14, 2015. During this call, the list of possible target sites for MICP field testing will be finalized.

Obtaining sidewall cores from Gorgas well. The next step will be to go to the Gorgas well site (likely in early February 2015) and extract side wall cores from each potential location of interest. These cores will be drilled through the well casing to extract a one inch diameter plug of well cement along with a few inches of outside formation material. After examining these side wall cores, the project team will have a much better idea of

the exact geometry of fractures and void space within the wellbore cement at each location. From this information the first MICP field test location will be chosen.

Development of wellbore cement analog testing system. The preliminary design process for the laboratory wellbore cement analog system has been initiated. We have begun construction of multiple 1 inch (2.54 cm) core plugs which will replicate various types of well cement debonding. Examples of these cores are shown in Figure 1 which shows cores with a designed annular space between well casing steel and cement and cement and formation sandstone. These annuli will be varied in size to represent fractures and debonding spacing of different aperture size.

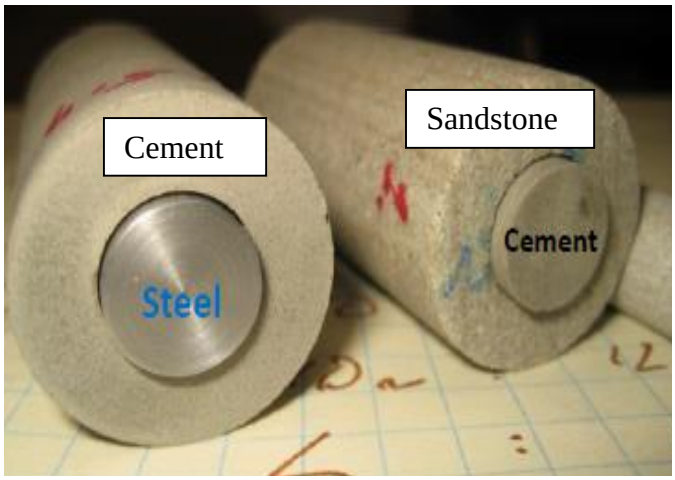

Figure 1. *Well casing/cement and cement/formation material analogs.*

These core plugs will be tested by injecting biomineralization fluids into the annuli using the test system shown in Figure 2. This system will allow for rapid screening of various microbially induced calcite precipitation (MICP) injection protocols. Effectiveness of MICP seals will be evaluated by measuring the change in permeability through the annuli before and after biomineralization.

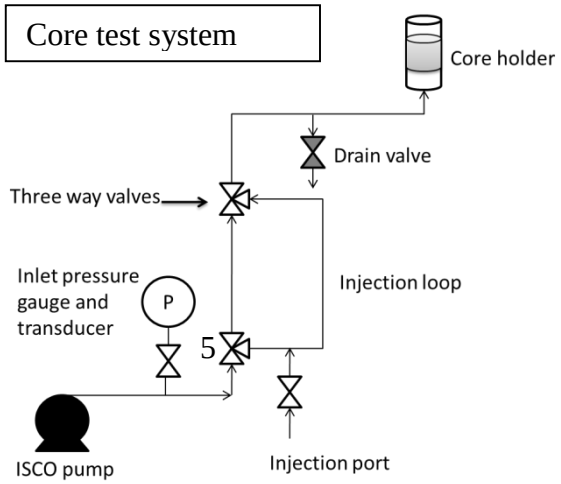

***Figure 2**. Test system for developing MICP seal in 1 inch (2.54 cm) diameter cores.*

This system will likely be redesigned after reviewing the results from side wall core testing from the Gorgas well.

Opportunities for training and professional development

Dr. Adrienne (Adie) Phillips was a Ph.D. student in Environmental Engineering when this proposal was written in June 2014. Adie was subsequently hired as an Assistant Professor in Environmental Engineering at Montana State University. This project is affording Adie the opportunity for professional development by serving as a co-principal investigator and taking responsibility for overseeing the laboratory testing and field demonstration activities.

Disseminating results to communities of interest.
Project results will be disseminated in a timely fashion through publications, conference participation etc.; however, during this reporting period there are no results to report.

Planed activities during the next reporting period.
During the next reporting period our project team will continue MICP seal testing one the 1-inch (2.54 cm) core analogs described above. This testing will facilitate development of MICP injection protocol suitable for developing MICP sealing in de-bonded well cement. We will continue the project planning process by way of teleconferences with SCS, SC, UAB, and Stuttgart collaborators. We also plan to conduct side wall coring at the Gorgas well in February. Analysis of side wall cores will provide the basis for guiding future laboratory analog testing and help determine the exact location in the Gorgas well for the first field test currently scheduled for October 2015.

PRODUCTS

There are no products to report this quarter.

PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS

Individuals who worked on the project
The work done on this project during this reporting period was performed almost entirely by the Project PI (Al Cunningham), Co-PI's Dr. Adie Phillips and Robin Gerlach and MSU Energy Research Institute Director Lee Spangler. The breakdown for time and effort for each is shown below:

Name:	**Al Cunningham**
Project Role:	Principal Investigator (PI), responsible for all technical, administrative and programmatic management issues.
Nearest person month worked:	1
Contribution to Project:	Dr. Cunningham was responsible for organization of the November Project Kickoff Meeting, preparation and submission of the PMP, and organization of the December Project Planning Meeting in Birmingham, Alabama.
Funding Support:	Not applicable
Collaborated with individual in foreign country:	Yes
Country(ies) of foreign collaborator:	Germany
Travelled to foreign country:	No
If traveled to foreign country(ies), duration of stay:	0

Name:	**Adie Phillips**
Project Role:	As Co-PI Dr. Phillips has a major role in this project. She is responsible for overseeing laboratory testing, field testing, and publication preparation.
Nearest person month worked:	1
Contribution to Project:	Dr. Phillips participated in the November Kickoff meeting and helped write the PMP prior to submission. She attended the December Project planning meeting in Birmingham, Alabama and has begun designing the MICP laboratory analog test system described above.
Funding Support:	Not applicable
Collaborated with individual in foreign country:	Yes
Country(ies) of foreign collaborator:	Germany
Travelled to foreign country:	No
If traveled to foreign country(ies), duration of stay:	0

Name:	**Robin Gerlach**
Project Role:	As a Co-Principal Investigator. Dr. Gerlach will participate in laboratory MICP testing and planning for field test activities.
Nearest person month worked:	1
Contribution to Project:	Dr. Gerlach is currently on sabbatical leave in Germany. He participated by providing slides used

	in the kickoff meeting and helped review the PMP prior to submission.
project. Funding Support:	Not applicable
Collaborated with individual in foreign country:	Yes
Country(ies) of foreign collaborator:	Germany
Travelled to foreign country:	Yes
If traveled to foreign country(ies), duration of stay:	Currently on sabbatical leave in Germany
Name:	**Lee Spangler**
Project Role:	Energy Research Institute Director. Director Spangler will provide the direction for the collaborations with cost-share partners and serve as the primary point of contact for MSU business and legal matters. All internal programmatic questions will be brought to the attention of the Director before presenting questions or concerns to DOE/NETL. The Director will have open-line communications with the DOE/NETL Project Manager.
Nearest person month worked:	1
Contribution to Project:	Dr. Spangler participated in the Project kickoff meeting, the development of the Project Management Plan (PMP), and the Project planning meeting held in Birmingham, Alabama December 16-19, 2014. His contribution to the interpretation of Gorgas wellbore cement bond logs was very valuable to the planning effort.
Funding Support:	Not applicable
Collaborated with individual in foreign country:	No
Country(ies) of foreign collaborator:	None
Travelled to foreign country:	No
If traveled to foreign country(ies), duration of stay:	0

Other organizations involved as partners

Schlumberger Carbon Services (SCS). SCS is providing matching support for this project. SCS field workers, let by Jim Kirksey, will help identify and characterize the test locations in the Gorgas well, perform the packer initialization, well perforation, injection of biomineralization fluids, pre- and post-experiment pressure tests and well logging and coring. During this reporting period Jim Kirksey and others from SCS participated in the Project Planning Meeting held in Birmingham, Alabama. SCS will conduct the side wall coring at Gorgas during February 2015.

Southern Company (SC). SC is providing matching support for this project. Dr. Richard Esposito of SC, together with SCS, has identified and secured the 1493 m (4915 foot) deep well (Gorgas #1 well, Walker County, Alabama) to be used for our MICP field tests. During this reporting period Dr. Esposito attended the Project Planning Meeting in Birmingham, Alabama.

University of Alabama at Birmingham (UAB). Dr. Peter Walsh is in charge of the UAB Core Testing Laboratory. He will be conducting core testing activities throughout the duration of this project. Dr. Walsh also attended the December Project Planning Meeting in Birmingham, Alabama.

University of Stuttgart. Dr. Rainer Helmig, Director of the Institute for Modelling Hydraulic and Environmental Systems (IWS), and Johannes Hommel, Ph.D. Student, are project collaborators at the University of Stuttgart. They along with other colleagues have developed a reactive transport simulation model, referred to herein as the Stuttgart MICP model, that has been integrated with previous laboratory and field research. This model was successfully used to help design the Gorgas field test in April 2014, and will be used again for the design of both laboratory field tests for the current project. During this reporting period Drs. Cunningham, Phillips and Gerlach have had several conversations with Johannes Hommel regarding progress in model development.

IMPACT

It is too soon to evaluate the impacts of this project. Impact will be addressed in future reports as appropriate.

Dollar amount of award budget spent in foreign country(ies)

No project funds were spent in foreign countries this reporting period.

CHANGES/PROBLEMS

As of this reporting period there are no changes or anticipated problem to report.

SPECIAL REPORTING REQUIREMENTS

At this time there are no special reporting requirements.

BUDGETARY INFORMATION

Below is the cost status report.

Table 1. *Cost Plan Status Report*

Baseline Reporting Quarter	YEAR 1 Start:	10/1/2014	End:	9/30/2015
	Q1	Q2	Q3	Q4
Baseline Cost Plan (from SF424A)				
Federal Share	163,575	163,575	163,575	163,575
Non-Federal Share	31,739	31,739	31,739	31,739
Total Planned Shares	195,314	195,314	195,314	195,314
Cumulative Shares	195,314	390,628	585,942	781,256
Actual Incurred Costs				
Federal Share	6,268			
Non-Federal Share				
Total Incurred Costs	6,268	-	-	-
Cumulative Incurred Costs	6,268	6,268	6,268	6,268
Variance				
Federal Share	157,307	163,575	163,575	163,575
Non-Federal Share	31,739	31,739	31,739	31,739
Total Variance	189,046	195,314	195,314	195,314
Cumulative Variance	189,046	384,360	579,674	774,988
	12/31/2014	3/31/2015	6/30/2015	9/30/2015