Quarterly Research Performance Progress Report

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FOA Name	Field Evaluation of the Caney Shale as an Emerging Unconventional Play, Southern Oklahoma
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Prime Recipient Type	Not for profit organization
Project Title	Field Evaluation of the Caney Shale as an Emerging Unconventional Play, Southern Oklahoma
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Reporting Frequency	Quarterly
Signature of Principal Investigator:	 Mileva Radonjic

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1. INTRODUCTION

The Caney Shale is an emerging unconventional resource play in the southern mid-continent and is prospective in the Anadarko, Ardmore, and Arkoma basins. The Caney reservoir is about 60-300m thick, is rich in total organic carbon, contains a large oil resource platform, and has a strong natural gas drive; however, development has been hampered by high clay content and reactivity of the formation with water. The main objective of this four-year program is to address these issues by establishing a Caney Shale Field Laboratory in the Ardmore Basin of southern Oklahoma to (a) conduct a comprehensive field characterization (2) perform field experiments, and to validate cost-effective technologies that will lead to a comprehensive and efficient development strategy plan for the Caney Shale. The first step is development of an open, collaborative, and integrated program to comprehensively characterize the geophysical, geological, petrophysical, geochemical, and geomechanical properties of the Caney Shale and further perform a baseline analysis of well production potential and overall well economics. The second step is to improve our understanding of hydraulic fracture propagation, fracture and proppant embedment, and fluid-rock interaction through detailed core and geophysical well log analysis. The third step is validating the findings and recommendations from these analyses by drilling and stimulating a horizontal well. Based on the results of this research, a well development plan and best practices manual will be developed for the Caney Shale in southern Oklahoma, which will facilitate accelerated development of the play. To fulfill the goals discussed above, the project is divided into two phases. Phase I (24 months) focuses on field characterization, and Phase II (24 months) focuses on field testing and formulation of a field development strategy plan.

This quarterly progress report is intended to provide a summary of the work accomplished under this project during the first quarter of the first budget period (October 1st, 2019 - December 31st, 2019). Summarized herein is a description of the project accomplishments to date, which include evaluation of existing literature on Caney formation; preliminary characterization of existing Caney cores; identification of sites for Mississippian Caney Shale outcrop locations for field visits and sample collection; Continental Resources Inc., prepared for the drilling of the well that will drill and obtain cores from Caney formation, Tomaney 1-35-34-27XHW, in Section 35, T.2S., R.4W., Stephens County, OK.

Also summarized herein is the Oklahoma State University Contract Number: DE-FE0031776 project's milestone status, along with the budgetary information corresponding to this reposting period.

2. ACCOMPLISHMENTS

2.1. Project Goals

- The goal for the first quarter of this project was to appraise the existing scientific data on the Caney Shale, develop research methodology, acquire core and outcrop samples, decide on the personnel needed to conduct the research, hire graduate students and postdocs, and develop and submit the Project Management Plan and Data Management Plan.

- Drilling data was used to test existing models; the data was provided by CLR Inc. from some of the past drilling activities, and relevant to the targeted Caney shale formation.
- Conducted detailed literature review of clay fundamentals and procedures of coating geomaterial micromodels with relevant clays that would be required for micro/nano fluidics experiments.
- Test existing Caney core in order to establish the appropriate workflow model for clay dominating shale, and identify relevance of sample orientation, polishing fluids and other sample-preparation procedures. Determine the sample size that would provide desired resolution for CT scanning, and other rock-fluid characterization protocols.

2.2. Accomplishments

This first quarter was spent organizing, planning and preparing to accomplish the deliverables as proposed.

- ✓ Kick off Meeting was held on October 28, 2019
- ✓ The Project Management Plan (PMP) was submitted and approved November 27, 2019
- ✓ The Data Management Plan (DMP) was submitted and approved December 18, 2019
- ✓ Started activities on Tasks 2,4,5,6 and 8, as shown in Table 2**.**
- ✓ Additionally, we held monthly planning and progress meetings as shown in Table 1, as well as weekly email and telephone conversations between team members, vendors, and technical experts as needed.

Here are some of the highlights of the activities completed during first quarter:

- Literature review for the Caney Shale was completed. A list of known existing Caney interval cores was constructed and land ownership of outcrop sections determined.
- OGS team has identified key cores and outcrops that are available for study and have made field maps for the locations of these key Caney Shale outcrops. Oklahoma Geological Survey Team (OGS) selected key samples, made plugs from field cores and have started the organic petrography (work in progress). OGS also visited Caney Shale outcrops in the Arbuckle Mountains/Wilderness and the Phillips Creek areas as well and collected samples from these areas.
- OGS have established plans for visiting these outcrops in a timely manner for sampling and viewing and have acquired the necessary permission from the land owners. Additionally, field and core samples have been selected for thin section petrography, XRD analysis and EPMA characterization.
- A workflow for Caney Shale characterization was proposed based on workflows developed for low permeability carbonates of equivalent age in the STACK play of Oklahoma. Specific components include characteristics of facies, pore systems, and rock mechanical properties (including rebound hardness, RHN) and distribution of fractures. A workflow for Caney Shale characterization was proposed based on workflows developed for low permeability carbonates of equivalent age in the STACK play of Oklahoma. Specific components include characteristics of facies, pore systems, and rock mechanical properties (including rebound hardness, RHN) and distribution of fractures.
- A review of current standard mechanical properties testing practices (ex: ASTM D7012) has been supplemented with an initial literature review of geomechanical modeling of shale formations. At the time of this report, the models available in the initial literature

review are being analyzed and compared for application to the Caney shale play. These were scheduled for brief summarization and review during the second project meeting on December 11th. Finally, the equipment in the hydraulic fracturing lab is being prepared to receive and test the shale samples provided by team members in Oklahoma.

- Geochemistry and Microstructural Characterization of Rock-fluid system is another major task that will help optimize production by understanding impact of hydraulic fluids and proppants on the permeability and primary production rates. A detailed understanding of the following topics is being investigated: Clay structure, Swelling potential, Clay charge, Isomorphic substitution, Deprotonation of the clay sheets. How the clay charges are related to flocculation, and mobilization of clay particles. A standard procedure to coat silicon/glass micromodel with clay minerals has been identified to mimic the pore chemistry of a clay-rich shale in microscale.
- Two industrial visits to: Stim Laboratory a subsidiary of core laboratory in Duncan Oklahoma and PropTester Inc in Cypress Houston, that are specialized in proppant embedment have been undertaken with an aim of understanding the proppant embedment process. (Appendix B) Evaluating the possibility of purchasing the equipment and determining how long the installation and training would take. Laboratory evaluation of protocol for shale characterization begun with the use of SEM, EDS and SE processes however the use of the XYLON CT scan has not yet yielded good enough scans because the instrument hasn't yet been configured to show good enough scans. Literature review on proppant embedment and rock fluid interaction in shale reservoirs is ongoing.
- As part of analyzing the overall economics and rate of return (ROR) analysis in the strategic field development plan for the Caney Shale we have done a preliminary analysis of the two previous Continental Resources (CLR) Caney wells stimulation and production. (see Appendix C - Task 8)

Caney Shale Meetings			
Meeting type	Attendents	Subject	Date
DOE Kick off meeting	DOE - Project team	PPT Project Presentation	28/10/2019
1st Meeting	Project Team members	1st Month Progress plan	13/11/2019
2nd Meeting	Project Team members	Progress for end of 2019 & Q1 wrap	11/12/2019

Table 1 Caney Shale Project Progress Update Meetings

Tasks Subtasks	Y1 Q1	Y1 Q2	Y1 Q3	Y1 Q4	Y2 Q1	Y2 Q2	Y2 Q3	Y2 Q4	Milestone Deliverables Completed
Task 1.0 Project Management Plan PMP	√							Phase 1	PMP 27-11-19
Kickoff Meeting/PPT	√							Report	PPT 28-10-19
Task 2.0 Work Force Readiness Plan WFP									Ongoing
Task 3.0 Data Management Plan DMP	√								DMP 18-12-19
Task 4.0 Geological Characterization									Ongoing
Core Description & Sampling									Not started
Core & Cuttings - Geophysical log calibration									Not started
Pore System Analysis									Not started
Core and Well log Analysis									Not started
Task 5.0 Geomechanics									Ongoing
Drilling Data Analysis									Ongoing
Core-based rock mechanics characterization									Not started
Geomechanical stress model									Not started
Task 6.0 Geochemistry & Microstructure of Rock-Fluid Interactions									Ongoing
Hydraulic fracturing rock/fluid design, charact.									Ongoing
Core flow-through experiments									Not started
Geomaterial Microfluidics									Ongoing
Solid-Oil Water/Gas Interfacial Properties									Not started
Task 7.0 Multiphase Fluid Flow Modeling									Not started
Modeling of tasks 5&6									Not started
Modeling of Fracturing & Production									Not started
Selection of Final Model									Not started
Task 8.0 Caney Economical Field Baseline									Ongoing
Simulation and production of existing wells									Ongoing
Completion optimization and cost analysis									Not started
Drilling optimization and cost analysis									Not started
Task 9.0 Well Candidate Selection									Not started
Decision will be based on Data Integration from Tasks 4-8									Not started

Table 2 Caney Shale Phase 1 Gantt Chart of completed & ongoing tasks

2.3. Opportunities for Training and Professional Development.

Nothing to report in First Quarter.

2.4. Dissemination of Results to Communities of Interest

Nothing to Report in First Quarter.

2.5. Plan for Next Quarter

- Complete outcrop sampling and correlate outcrops to subsurface section in the vicinity of the new core being acquired in Section 35, T.02S., R.04W. by the drilling of the Continental Resources Tomaney 1-35-34-27 well.
- Correlate existing cored sections to outcrops and subsurface Caney Shale where new core being acquired in Section 35, T.02S., R.04W.
- Understand different ways of altering wettability of Caney (or a representative) shale formation and identify and evaluate the most suitable wettability alteration method for Caney based on its petrophysical and geochemical properties
- Evaluate swelling potential of clay at different brines and salinities
- Continue to develop a detailed economic baseline model linking drilling, stimulation and production in a rate of return model for the Caney shale.

2.6. Summary of Tasks for Next Quarter

Task 4:

- Describe existing core and pilot hole core provided by Continental Resources
- Acquire samples as needed from these cores and outcrops
- Acquire survey geochemical data using handheld XRF
- Refine correlation of outcrop data, especially gamma-ray, to gamma-ray profile for the acquired Caney Shale core.

Task 5:

- Run the necessary characterization tests on the shale samples and begin setup of geomechanical stress models. The specifics of the testing method used for the provided shale samples will be determined using cement samples. This will allow for troubleshooting of any potential equipment limitations without sacrificing the field samples. Once the methodology has been perfected, the field samples will be used for testing.
- Unless directed otherwise, samples will be prepared and tested based on relevant ASTM standards (ex: D7012).
- Initial setup of the geomechanical stress models will take into account results from the initial literature review and will implement results from laboratory testing. Updates will continue to be provided in the bi-monthly team meetings, reporting relevant results and addressing any questions which occur during testing and model development.

Task 6:

- Complete ongoing analysis of the Caney outcrop and legacy well-core samples, for microstructural (CT, SEM/EDS/BSE), compositional (XRD), micro-geomechanical (Micro/Nano Indenter) and petrophysical properties (porosity, permeability).
- Obtain same set of data on samples from the test well Caney core.
- Experimental design for Fracture/Proppant Permeability testing on samples from test well Caney core
- Continue literature review on the tasks for the Caney Shale Rock-Fluid interactions will

be done and it is aimed to be submitted to a journal by the end of Q2.

- Continue study on zeta potential and wettability alteration that will not compromise the permeability of a clay-rich Caney formation.
- Understand the degree of formation damage, the swelling potential of the dominant clay present in Caney with different brines and salinities will be evaluated in our laboratory

3. PRODUCTS

Nothing to report in First Quarter

4. PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS

Caney Shale Participants	
PI	Post Doctoral Fellows & Students
M.Radonjic; G. Hareland; P. Bakina - OSU Petroleum	
	Post Doctoral Fellow - G. Luo
	Graduate Student - A. Katende
	Graduate Student - H. Kolmer
	Graduate Student - C. Cunningham
	Graduate Student - R. Bhattacharjee
J. Puckette; J. Pashin; M. Grammer - OSU Geology	
	Post Doctoral Fellow - Y. Wang
	Graduate Student - C. Wethington
	Graduate Student - I. Cox
	Graduate Student - C. Hart
	Graduate Student - J. Cains
A. Seyedolali; B. Cardott; Geologist F. Suriamin - OKGS	
J. Rutqvist; C. Doughty - LBNL	
A. Bunger - Univ. Pitt	
	Graduate Student - M. Benge
A.Rihn; C. Duff; D. Elliott - Continental Resources	
Industry Technical Advisor - G. King	

Table 3 – Caney Shale Participants

5. IMPACT

Nothing to report in First Quarter.

6. CHALLANGES/PROBLEMS

- Landowner permission to visit the three principal outcrops of the Caney Shale was secured, but sampling prior to the winter break was not completed as a result of (1) landowner concern regarding sampling during deer hunting season (Philips Creek) and (2) high water in streams associated with the sections along South Jack Fork Creek at the Hass G section.

- Core belonging to BNK Petroleum was not made available as a result of BNK properties being offered for sale.

7 SPECIAL REPORTING REQUIREMENTS

Nothing to report in First Quarter.

8 BUDGETARY INFORMATION

Summary of the first quarter budgetary information of the project are provided in Table 4 showing the Original Cost Plan, Actual Incurred Costs and Variance for both Federal and Non-Federal Shares.

DE-FE0031776	Oklahoma State University							
	Budget Period 1							
Budget Reporting Quarter	Q1		Q2		Q3		Q4	
	10/1/2019-12/31/2019		1/1/2020-3/31/2020		4/1/2020-6/30/2020		7/1/2020-9/30/2020	
	Q1	Total to Date	Q2	Total to Date	Q3	Total to Date	Q4	Total to Date
Budget Cost Plan								
Federal Share	$595,060.50	$595,060.50	$595,060.50	$1,190,121.00	$595,060.50	$1,785,181.50	$595,060.50	$2,380,242.00
Non-Federal Share	$30,000.00	$30,000.00	$1,235,800.00	$1,265,800.00	$30,000.00	$1,295,800.00	$30,000.00	$1,325,800.00
Total Planned	$625,060.50	$625,060.50	$1,830,860.50	$2,455,921.00	$625,060.50	$3,080,981.50	$625,060.50	$3,706,042.00
Actual Incurred Costs								
Federal Share	$57,742.37	$57,742.37						
Non-Federal Share	$0.00	$0.00						
Total Incurred Costs	$57,742.37	$57,742.37	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Variance								
Federal Share	$537,318.13	$537,318.13						
Non-Federal Share	$30,000.00	$30,000.00						
Total Variance	$567,318.13	$567,318.13						

Table 4 Budgetary Summary for Q1

9 PROJECT OUTCOMES

Nothing to Report in First Quarter

10 APPENDIX

Appendix A - Task 5

In this period, the preliminary geomechanical logs are evaluated from key inputs such as depth, time, RPM, WOB, pump pressure, gamma ray, bit & BHA parameters, and final survey report from the daily drilling report of the Wynell 1-31-6XH well penetrating the Caney formation from 11,000 feet to 20,521 feet and inputted into the D-Rock and D-WOB software. The variables were then subject to quality assurance and from there, the drilling coefficient of friction was found. From this, the output drill file of down hole weight on bit (DWOB) was then entered into D-Rock to find the unconfined compressive strength, Young's Modulus, porosity, and permeability of rock characteristics along the wellbore. Initially assuming a sheave efficiency of 97.5% and a hook weight of 35 klbf (using these values, we were able to include friction along the lateral and incorporate a more accurate software output), the very preliminary results are below:

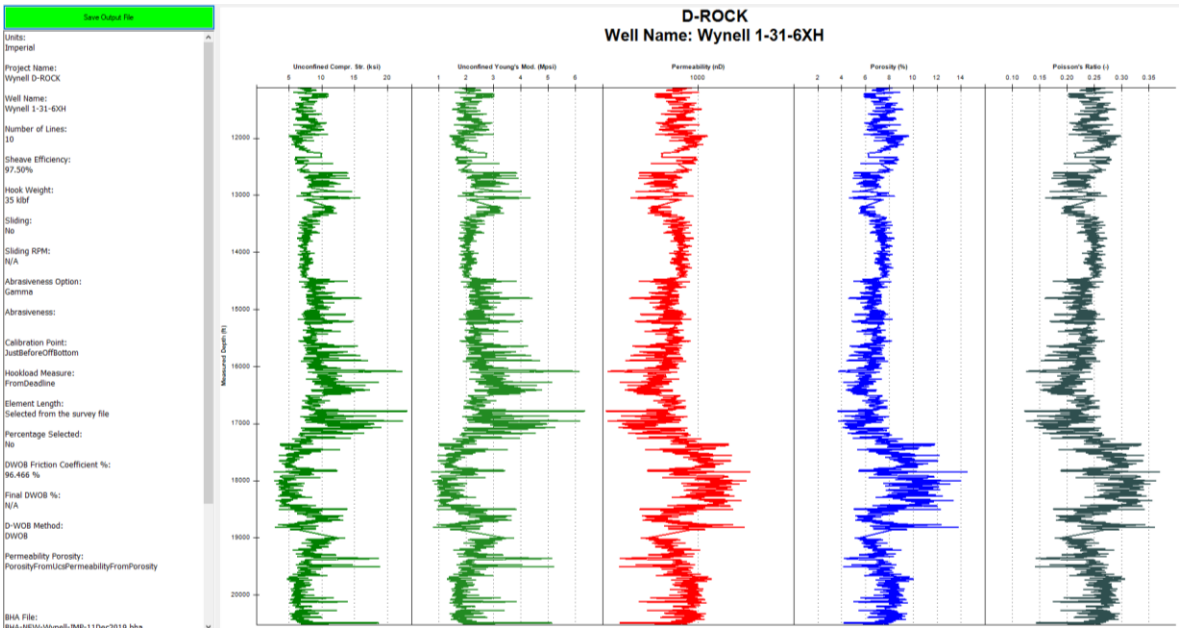

Figure 1 - Rock characteristics analyzed between 11,000 feet and 20,521 feet

Explanation of Variance: The formation identity used for preliminary software evaluations were rock permeability and porosity coefficients consistent to that of the Eagle Ford shale formation. Preliminary assumptions have also been made on the rig drawworks design and efficiency. Thus, characteristics will continue to be preliminary until a core sample can identify those distinct characteristics.

Appendix B – Task 6

The difference between Stimlab and PropTester Inc lies in the fact that both companies execute somewhat similar tasks however, there are several differences between these two companies as shown in the table below:

Stimlab in Duncan Oklahoma	PropTester Inc in Cypress Houston
Cost of Equipment is High if purchased	Cost of equipment is lower than Stimlab
Costs $22, 000 per four stack of testing proppant embedment at their premises	Costs $18, 000 per four stack of testing proppant embedment at their premises
Wait time is dependent on the que and varies between 1 to 2 months.	Wait time is dependent on the que but less than 1.5 months

Table 5 – Comparison of Stimlab & PropTester Inc

Preliminary characterization and testing of laboratory protocols that are suitable for Caney Shale:

We obtained samples from the core drilled from a legacy well DAVY JONES, WILD CAT MARSHALL. 095-20485-RES. From depths from around 7152(top Caney). Wells were drilled in 2007, samples ~12 years old. The thermal gradient is 1 deg F/100ft and at 9625ft, the temperature is 152 deg F. Core is held in OSU Geology Core facility, pictured below Figure 2. 1 Sample cut 0º to the bedding; 2 Sample cut to 90 º 3Sample cut at 45º to the bedding plane.

Figure 2 Core from legacy well DAVY JONES, WILD CAT MARSHALL, 095-20485-RES; orientation of SEM samples

500x 1000x 5000x

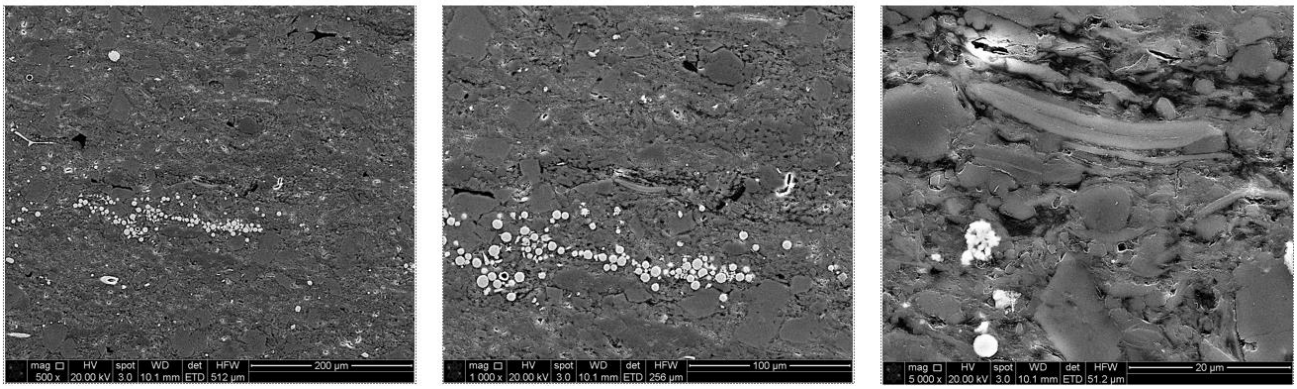

Figure 3: Caney Shale medium-high magnification orientation 3- Back Scatter Electron Imaging

From this existing Caney Shale samples were cut in three orientations as shown in the drawing on the right. This is was done to check whether the samples are homogeneous or heterogeneous. From Scanning Electron Microscope (SEM) Figure 3 there is heterogeneity in the sample and this will greatly affect the rock fluid interaction and proppant embedment.

Appendix C – Task 8

In the initial evaluation of CLR Caney Shale project, general oilfield completion metrics were evaluated to begin the planning and optimization process. The metrics evaluated were: Completed lateral length, cluster spacing, sand volumes (#/ft), fluid volumes (BBLS/ft), proppant size, and initial production (first 2 years). As shown in Table 6, both wells were stimulated nearly identically when metrics such as #/ft, bbls/ft, and cluster spacing are considered. Although the treatment for the wells was nearly identical, the oil production was not. The Wynell 1-31-6XH outperformed the Garrett 1-36H with over

double the oil volumes in the first two years of production.

		Garrett 1-36H	**Wynell 1-31-6XH**
	Stages	19	31
Perf Interval			
FT (MD)	Top	11339	10891
FT (MD)	BTM	17033	19481
FT	Total	5694	8590
FT	Cluster Spacing	72	66
LBS	Sand	4829180	8277840
LBS/Stage	Sand/ stage	254167	267027
LBS/FT	Sand/ ft	848	964
	Sand Type	40/70&30/50	40/70&30/50& 20/40
BBLS	Fluid	264108	375433
BBLS/STG	Fluid/STG	13900	12111
BBLS/FT	Fluid/ft	46	44

Table 6: Completion Metrics on CLR Caney Shale Wells

It is important to note that the Wynell Well is a 1.5 mile lateral and the Garrett is a 1.0 mile lateral, but this does not explain the difference in production considering that the two wells are with a ½ mile distance of each other. In deeper investigation it was found that the oil cut in the Wynell 49% and the Garrett oil cut was 23%.

Explanation of Variance: This is part of establishing the economic baseline for the previously completed Caney wells.

Appendix D – Maps