Welcome to the first issue of Caney News, where we will try to share our project progress during the summer of 2020 and enable you to stay connected to the team members and the work being done. We have been able to not only stay on target and deliver on projected tasks planned for year 1 of the project, but we also added some extra work, thanks to kind support from the National Energy Technology Laboratory (NETL) researchers.

The journey we have taken so far, from selecting the Caney shale to the successful drilling and retrieval of the 650ft core in Oklahoma, to CT scanning the entire core in Morgantown, WV, is truly exciting and required a lot of effort from our industry partners, the Department of Energy (DOE) and NETL and everyone who was involved in this project. To be able to obtain a rock from 14,000ft and see through it as we prepare to test and model Caney formation is every researcher’s dream.

I am honored to lead this project and I am grateful to all of you who contributed to the success of our project. I am looking forward to more exciting news as we continue this caney journey.

With thanks, Mileva Radonjic, June 2020, OSU

**NETL Support of Caney Project**

**Crandall**

When the researchers and technicians in the Computed Tomography (CT) facility of the Research and Innovation Center at NETL were able to return to operations this late spring, our primary desire was to utilize our skills and equipment for a worthwhile project.

The arrival of 650 feet of core from the Caney Field Project in mid-May for non-destructive scanning was a welcome challenge, and one we are happy to report is nearing completion. At the time of this publication, all the core has been CT scanned and roughly 1/3 of the core has been processed in NETL’s multisensor core logger. In addition, over 100 sub-cores have been imaged prior to further analyses at Oklahoma State University and the University of Pittsburgh. Data analysis and processing is underway, with the goal of publishing a publicly available technical report on this unique Caney shale well by the end of 2020. Prior to that, the full data sets are available on NETL’s Energy Data Exchange and a workshop is planned for the late summer to inform project participants on how to access and utilize these data streams.

Examples of caney core CT scans from the ongoing analysis at NETL’s CT scanning facility.
The Mississippian Caney Shale play in southern Oklahoma is an emerging unconventional hydrocarbon play. For this study, core samples from two wells provide an opportunity for integrated reservoir characterization. Core description, thin section petrography, and scanning electron microscopy are utilized for analyzing facies and pore architecture. A suite of mixed carbonate-siliciclastic facies are identified such as mudstone, calcareous siltstone and silty carbonate, reflecting various depositional environments. Porosity is dominantly micrometer to nanometer in size, with a variety of different types, implying that microporosity is a critical factor in affecting reservoir quality.

Ongoing work includes detailed analysis of facies, sequence stratigraphy, pore architecture, natural fractures, and rebound hardness.

We are establishing a regional organic matter content and thermal maturity regime for the caney shale in Anadarko, Ardmore and Arkoma basins. An isothermal map has been generated for the Ardmore basin and is awaiting statistical validity checking when VRo measurements are completed for several available cores. Organic petrography of the Davy Jones core is also complete and work is in progress on the organic petrography of the samples of the Tomaney core.

Completed work includes the regional Ardmore basin structure mapping, regional Ardmore basin gross thickness mapping and the local – Tomaney Area – gross and internal parasequence structure mapping. Advanced study includes the Ardmore basin thermal maturity (VRo%) regional map (Figure 5), Ardmore basin average %TOC regional map, local Tomaney area – %TOC estimations with density, GR curves and the local Tomaney area – total porosity estimations with density and neutron curves.

Portions of the Caney project in the early stages include: the Ardmore basin regional structure mapping, the Arkoma basin regional gross thickness mapping, the Arkoma basin VRo% estimations – Regional mapping, the Arkoma basin average %TOC estimations – Regional mapping, the Arbuckle Wilderness outcrop section of the stratigraphic and sedimentological characterization of the Caney Shale (~270 ft section ) and outcrop samples collected for organic petrography for multiple areas in the Arbuckle Mountains southern part of Oklahoma.

The EPMA and XRD studies of several Caney cores are in progress. Ultra-thin sections have been made and several whole thin sections have been scanned.
Work is under way in the characterization of the Davy Jones and the Tomaney cores. EPMA and organic petrography analyses on the outcrop samples of the Philips Creek and some of the Davy Jones core samples are also completed (e.g., figures 6 and 7). The remaining Davy Jones samples are in progress along with the image analysis of the resultant images.

• A procedure has been developed to functionalize microfluidic chips with Illite clay mineral, as it is the most dominant clay mineral of Caney Shale

• Using the procedure, glass capillary tubes have been coated with Illite (Fig. 9 a, b)

• SEM & EDS analysis on the coated capillary tubes are currently being carried out to verify the coating density, coverage, and elemental analysis in order to make any required adjustments in the procedure (Fig. 10)

• Standard operating procedures for IFT and contact angle measurements have been developed

• The IFT and contact angle data will be used for two phase flow modelling by LBNL

Caney Shale core plugs have been CT scanned by NETL and are now at the University of Pittsburgh. The laboratory reopened on June, 10 2020. All safety protocols are now satisfied to resume testing and equipment is prepared (Figure 11) with testing commencing on June, 19 2020. Testing is beginning with triaxial shear strength at 90 deg C, which is near the log temperature of the Caney formation in the Tomaney Well. Tests will begin with 1500 psi
confinement and will proceed to 5000 psi, with a final test either lower or higher than this range depending upon analysis of the first two test results. With pore pressures allowed to dissipate during these tests ("drained" conditions), the effective stress states considered will span the actual stresses thought to exist in the caney.

With pore pressures allowed to dissipate during these tests ("drained" conditions), the effective stress states considered will span the actual stresses thought to exist in the caney.

The first sample tested is shown in Figure 12. It shows a little parting-type damage that is common in shale core specimens. It is not expected to be problematic once the specimens are subjected to large confining stresses.

The experiments were conducted on a very soft and ductile Green River shale sample by Marco Voltolini at LBNL as part of an ongoing DOE funded shale project. The upper right figure shows an X-ray image with some preliminary modeling results to the right. The modeling performed by LBNL's Jonny Rutqvist as part of the caney ductile shale project, is conducted to replicate some of the micro-mechanical responses observed in the X-ray tomography, such as tensile fracturing along bedding and the formation of shear bands. These results are relevant to learn about the mechanisms and key parameters for proppant embedment in ductile shale, such as the caney shale.

The Lawrence Berkeley National Laboratory (LBNL) has conducted model development and testing for modeling micromechanics as observed from high resolution synchrotron X-ray imaging during micro-indentation measurements.

The drilling team has been working on extracting key parameters such as UCS, porosity, permeability, and brittleness to find the stimulation index factor (STIX). The STIX will be able to assist the team in identifying the most accessible and optimal perforation placement as well as key information for decreasing cost and increasing drilling speed. Currently, the team is identifying various formations that the Garrett and Wynell wells have drilled through to enhance the D-Series software and increase the accuracy of the output. We are currently using the formation constants extracted from the Eagle Ford formation until the testing on the Tomaney core is available.
Below is a preliminary graph showing the effect of UCS on STIX for the Garrett of lateral length 10,000’ to 16,881’.

The STIX is an indicator that is obtained from drilling data and core testing and analysis. The STIX accounts for formation stiffness, porosity, permeability and UCS, which are weighed for specific reservoirs with the goal of determining the optimal selective stimulation cluster intervals and intervals where the STIX is higher which are suggestive locations for selective stimulation. In the figure below, the STIX has been calibrated based on presumptive weighing of the STIX parameters in the Caney. The final weighing of the input parameters in the STIX will be determined in discussion with Continental Resources.

The completions team has been converting the Tomaney well logs into a lithology profile for GOHFER simulator (Figure 14). From the generated lithology, a reservoir dip angle is generated that is reflective of the Caney formation. The Wynell well was placed in the Caney “A” portion of the simulated reservoir (Figure 15). An initial stimulation was conducted in GOHFER and the reservoir parameters are currently under development to create a pressure response that matches that of the field data collected during the Wynell stimulation (Figure 16). Once the reservoir parameters are set, various stimulation designs can be simulated to determine optimum proppant volume, concentration, size, etc. The new stimulation design will be a cornerstone project of determining the economics of the Caney development project.

Oklahoma State’s Drilling and Completion Team’s new team member, Mitchell Craig, has been brought up to speed on the mechanics of GOHFER software and the development of the Caney reservoir grid. Mitchell will provide critical insight on the optimized stimulation design.

**Geochemistry and Microstructure of Rock Fluid Interactions**

**OSU Petroleum: Katende, Luo, Radonjic**

Hydraulic fracturing is vital in the evolution of shale reservoirs. However, proppant embedment, clay swelling, mineral dissolution and precipitation significantly reduces the conductivity of fractures, and encourages the formation of shale flakes that move around and obstruct fracture networks. To target these issues, our research focuses on rock microstructure, geochemical and geomechanical characterizations.

**Microstructure analysis:** Microstructure includes framework rock composition and fabric, diagenetic alteration of the fabric, organic content, and pore structure. These factors affect the brittleness of sedimentary rocks as well as their ability to store and transmit hydrocarbons and to be effectively fractured.
Minerology: The minerology and Poisson’s ratio is shown, in Figure 17. Quartz and clay dominantly distribute in the core samples from the target well, whereas carbonate appears locally in carbonate rich zones.

Meanwhile rock with high quartz and carbonate contents is related to low Poisson’s ratio (brittle), and rock with high clay content shows higher Poisson’s ration (Ductile).

Fabric and natural fractures: SEM images show evidence of natural fracture and heterogeneity. Clay swelling, mineral dissolution and precipitation are known to affect the fracture conductivity. Caney formation shows high clay content, and sample XRD shows the appearance of scale minerals (Figure 19).

Geomechanical Characterization of Caney Formation Through Indentation

Work to delineate mechanical properties of the Caney Shale utilizing the Davy Jones formation is ongoing with an aim of providing insight into proppant embedment. This work will utilize indentation techniques to study how different properties like Young’s Modulus and hardness vary along the different bedding orientations. The mechanical properties from Davy Jones core are compared with other formations shown in Figure 20.
**Scholarly Contributions**


**Recommended Reading**

Roadside Geology of Oklahoma by Neil H. Suneson

**Caney Shale Participants**

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<tr>
<th>PI</th>
<th>Post Doctoral Fellows &amp; Students</th>
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A. Rihn; A. Haecker; B. Dean - Continental Resources
J. Renk III; Z. Stevens - Department of Energy
L. Williams - Project Administrative Manager
M. Radonjic - Project Director

**Thank you to the following for their contributions!**

**Continental Resources:** Andy Rihn, Adam Haecker, Barry Dean.

**Chesapeake Reservoir Technology Center Team:**
Led by Kyle Bradford & Eric Cline for core handling, sample prep and testing.

**Schlumberger:** Nasar Khan, Wayne Rowe

**NETL:** Dustin Crandall and the Lab Team.

**CoreLab:** Ben Anderson, Lisa O’Connel, Kathy Abney.

**Oklahoma State University:** Jamie Westmoreland, Jennifer Mansell, Sandy Earls, Ben Champlin, Lisa Withworth, Brent Johnson, Patrick Wheeler.

**University of Oklahoma:** R. Nygaard, A.Cedola and J. Wise of the Petroleum Engineering Department for their contribution to Caney proposal writing.

**Webinar speakers:** George King, Eric Cline.

And Thank You to All Project Team Members for their contribution towards this first Caney Newsletter!

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netl.doe.gov/node/9335