Oil & Natural Gas Technology

DOE Award No.: DE-FE0024297

Quarterly Research Performance

Progress Report (Period Ending 12/31/2019)

Marcellus Shale Energy and Environment Laboratory (MSEEL)

Project Period (October 1, 2014 – March 30, 2021)

Submitted by:
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Office of Fossil Energy

Executive Summary
Quarterly Progress Report

October 1 – December 31, 2019

The objective of the Marcellus Shale Energy and Environment Laboratory (MSEEL) is to provide a long-term field site to develop and validate new knowledge and technology to improve recovery efficiency and minimize environmental implications of unconventional resource development.

Plans developed for MSEEL Phase 3 were executed at the Boggess Pad just west of Morgantown, WV. The Boggess pad consisting of six wells that were drilled and fracture stimulated. Production started on 18 November 2019. We monitored the distributed acoustic sensing (DAS) and distributed temperature sensing (DTS) from initial production until 23 November. DTS monitoring has continued through the report period and will continue through subsequent quarters of the project.

This quarter's work focused on monitoring initial production from the MSEEL Phase 3 wells at the Boggess Pad. As of this report (1/28/2020), total production ranges from 720 to 936 MMcf. Two wells were geometrically completed, two wells were engineered by a private consultant and two wells were engineered using software developed by the MSEEL team. While it is earlier it appears that the wells engineered using software developed by the MSEEL team may be some of the better wells on the pad. A paper on the MSEEL completion approach is being prepared.

Research on machine learning for improved production efficiency with LANL was continues and we have provided data and consultation and have contributed to a paper on use of artificial intelligence for a better understanding of reservoir properties.

We continue to process the 108 terabytes of data from the downhole microseismic sensors and the fiber-optic data to better understand geomechanical properties and slow slip events during hydraulic fracture stimulation. Several manuscripts were published and are listed in this report.

Project Performance

This report summarizes the activities of Cooperative Agreement DE-FE0024297 (Marcellus Shale Energy and Environment Laboratory – MSEEL) with the West Virginia University Research Corporation (WVURC) during the first quarter of FY2020 (October 1 through December 31, 2020).

This report outlines the approach taken, including specific actions by subtopic. If there was no identified activity during the reporting period, the appropriate section is included but without additional information.

A summary of major lessons learned to this point of the project are provided as bullet points and will be added to as research is completed. New lessons listed below are:

Phase 3 Plans

Phase 3 of MSEEL has moved forward with completion/stimulation completed and production initiated during the reporting quarter. Six 10,000+ foot horizontal Marcellus Shale wells off a single pad (Boggess) are near the initial MIP pad (Figure 1.1). The pad has one permanent fiber optic (FO) cable installed in the Boggess 5H lateral provided digital acoustic sensing (DAS) during stimulation, and was monitored during initial production. Distributed temperature sensing (DTS) was monitored during stimulation and continues during initial and long-term production. We acquired DAS data for the entire 5H well, but the FO failed around stage 30 and we do not have long-term DTS data below that stage to the toe. We will have data from the upper stages through the heel. Deployable FO systems were proposed (Boggess 1H and 17H), but due to the fiber failure in the 5H the fiber was not placed in the 17H. However, we acquired significant DAS and DTS and microseismic data from the 5H and 1H that provided insight of stimulation effectiveness in near real-time and the 100's of terabytes of data to evaluate and model the reservoir across each individual stage, and at individual clusters within stages for the 5H, which will be used for all Boggess wells.

We have developed technique to use the permanent DAS and DTS monitoring in the 5H along with the logging while drilling (LWD) image and geomechanical logs to design an improved methodology to complete wells. This methodology uses computed Sh_{min} from the downhole drilling and logging while drilling data and avoidance of fracture locations to complete the 1H and 3H wells. The new methodology appears to improve completion efficiency. As the wells have come on production, it appears that 1H and 3H wells have a higher gross production efficiency that either the geometrically completed wells (9H and 17H with identical 200 feet stages with identical number of clusters in each stage) or the commercial design provided which only used the geomechanical logs and ignored the imaged fractures (5H and 13H) (Figure 1.2). On a net production efficiency controlling for variable lateral length (Mcf/1000') outside wells (1H and 17H) are better than interior wells, but engineered wells had a slower ramp-up but are gaining on their counterparts (Figure 1.3). We also need to control for the amount of sand per stage since the shorter 17H received significantly more sand per stage. We plan to monitor the 5H DAS for several days during initial flow-back and the long-term DTS during production. The production is very early and the picture could very easily change.

We are undertaking detailed analysis of the cored and logged vertical pilot well to develop a high-resolution geomechanical model (stratigraphy) to type each 6 inches of the Marcellus. Logging while drilling (LWD) logs in each of the six laterals provided similar geomechanical logs and image logs to geomechanically type each foot of the laterals as the horizontal laterals move stratigraphically up and down through the Marcellus. This approach permitted direct coupling and evaluation of cost-effective LWD technologies to the relatively high-cost permanent FO data and the basis for engineering stages in all wells. It was applied to two of the Boggess wells.

We used the LWD and permanent FO in the one well (extremely large big data) and the LWD and microseismic only (relatively “thin” data) in two other wells to engineer stage and cluster spacing. Coupled with production data from all the wells including the control wells, this will provide the basis to evaluate the reservoir through modeling and direct monitoring to develop a first ever, publicly available, multi-well unconventional fractured reservoir simulation.

We are gathering fiber optic and production data from the Boggess wells to compare across each of the six wells, and with the two wells at the MIP pad (MSEEL 1) and use these data to form the basis for robust big data modeling. One aspect will be to compare zipper fracturing to sequential fracture treatment and the use of recycled water in the Boggess wells to the 100% fresh water in the MIP wells. The MIP wells generated almost 10 terabytes of data and created approaches and capabilities to handle and process big data sets (i.e., volume, variety, velocity and veracity) from a single well to address the spacing between laterals and stage length, the importance of modeling at multiple scales from nanopores in kerogen to healed fractures spaced along the lateral, and the approaches to engineering stage and cluster design and stimulation processes. The multiple wells at Boggess Pad using the new generation high resolution fiber and LWD tools provided 108 terabytes of data in a series of similar wells under controlled conditions to test and enhance the understanding of shale reservoirs. We moved the data from Houston to the servers at West Virginia University (15 December 2019). MSEEL will test new technologies and approaches to provide robust models that can be modified in near real-time using “thick” relatively high-cost data sets limited to science wells, or when calibrated more cost-effective “thin” data sets that could be used in broader field development and basin evaluation.

Figure 1.1: Boggess Pad with new generation permanent fiber in the central well (Boggess 5H, red star)) and deployable fiber in adjoining wells skipping one (orange stars). We will be able to monitor in near-real time fracture stimulation in the central 3 wells (3H, 5H and 9H). A vertical pilot will be drilled, cored, and logged.

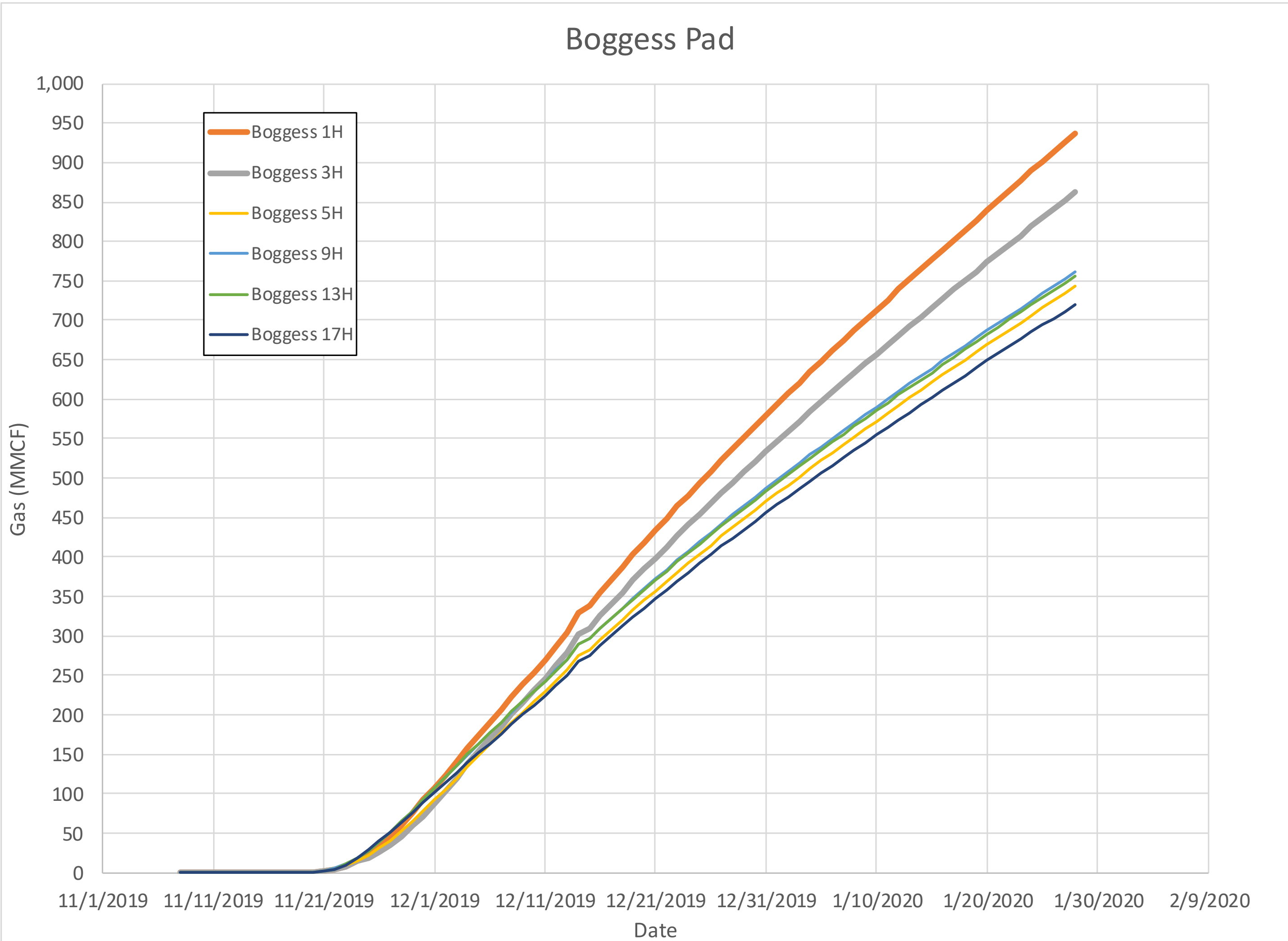

Figure 1.2: Initial daily gross production from the Boggess Pad. The wells engineered using the MSEEL software are highlighted with thicker lines (1H and 3H). Wells have different lateral lengths that need to be evaluated to derive a better evaluation of production efficiency. Also outside wells typically perform better than interior wells due to reduced competition. The production is very early and the picture could very easily change.

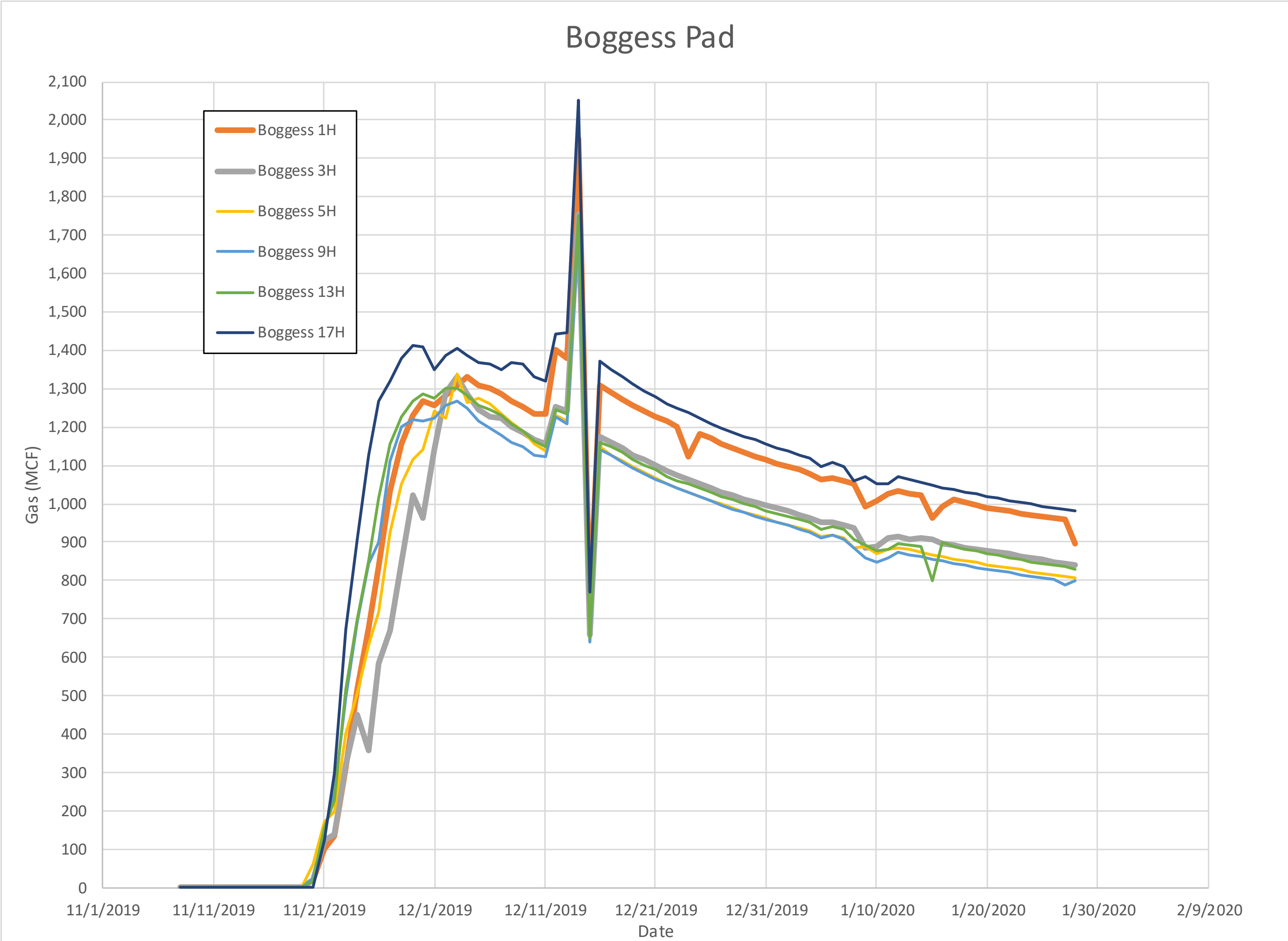

Figure 1.3: Initial daily net production from the Boggess Pad adjusted for Mcf per 1000' of completed lateral. The wells engineered using the MSEEL software are highlighted with thicker lines (1H and 3H). As you can see outside wells (1H and 17H) perform better than interior wells due to reduced competition. Also wells engineered using the MSEEL approach got off to a slower start but have narrowed the gap in daily production and in the case of the 3H, it is producing more than any other interior well. In the case of the 17H more sand was used per stage and we need to adjust for sand per foot. The production is very early and the picture could very easily change.

Project Management Update

Approach

The project management team will work to generate timely and accurate reporting, and to maintain project operations, including contracting, reporting, meeting organization, and general oversight.

Results and Discussion

The project team is tracking eight (8) milestones in this budget period.

	Task	Milestone	Status	Due Date
1.	3.2.1	Methane Audit 12 Completed	Audits 10, 11, 12 completed. Audit 13 scheduled for January 2020.	12/31/2019
2.	3.2.1	Sample collection and analysis of horizontal drill cuttings and drilling mud	Complete 139.2' of core and core plugs were collected from the vertical 17H pilot well. Drilling fluids collected.	6/30/2019
3.	3.2.1	Sample collection and analysis of makeup water and frac fluids	Samples will be collected from Boggess Wells	Ongoing/Complete
4.	3.2.1	Eddy Covariance Methane Detection Deployed at Wellsite (MIP)	Deployed in November 2019 after short delay. Continuing to operate and collect data.	9/30/2019
5.	3.1.3	Boggess wells turned in.	Complete 12/2019	Oct-19
6.	3.1.2	Characterization of organic matter - Total Organic Carbon and Pyrolysis Experiments Complete	Complete. Characterization of samples from Boggess wells. 41 Core samples from Boggess 17 H were collected and analyzed.	12/31/2019
7.	3.1.2	Isotopic characterization of produced water and gases - sampling and analysis complete	Complete. Produced water from Boggess wells 1H, 3H, 5H, 9H, 13H, 17H were collected on Day 1, and from wells 9H and 17H on day 7 and day 14. The produced gases Gas was sampled Boggess wells 1H, 3H, 5H, 9H, 13H, 17H were collected on Day 1, Day 3, Day 5 and Day 9.	12/31/2019
8.	3.1.3	Provide final DAS/DTS data from completion activities to researchers (Boggess)	Final DAS/DTS data from well completion is available to researchers. We do have a challenge of data volume which will be addressed	12/31/2019
9	3.2.1	Sample collection and analysis of	Complete. Analytical results have been received for muds, cuttings, and	12/31/2019

		flowback/produced water	samples have been collected for water from Boggess Pad.	
10	3.2.1	Energy Audit System Deployed with Patterson Rig (Boggess)	DAQ system required significant modification. WVU team has been working with Patterson extensively. Systems now ready for deployment – currently planning for installation in January.	12/31/2019
11	3.4.1	Statistical Analysis of production stages complete	Initial data analysis for Machine Learning Tasks. We have submitted an abstract to SPE annual meeting	12/31/2019

Topic 1 – Geologic Engineering

Approach

In addition to advances in improving our understanding of chemical evolution of produced water, methane emissions, microbiology and rock-fluid geochemistry, we worked to better understand the microseismic monitoring by downhole geophones, surface seismic, fiber-optic distributed acoustic sensing (DAS), and distributed temperature sensing (DTS) observations made during the hydraulic fracture stimulation of the MIP-3H well. DAS and DTS data measure the fiber strain and temperature, respectively, along a fiber-optic cable cemented behind the casing of the well. We recorded numerous microseismic events (Figure 1.4) and saw significant variations in DAS response between stages (Figures 1.5 and 1.6).

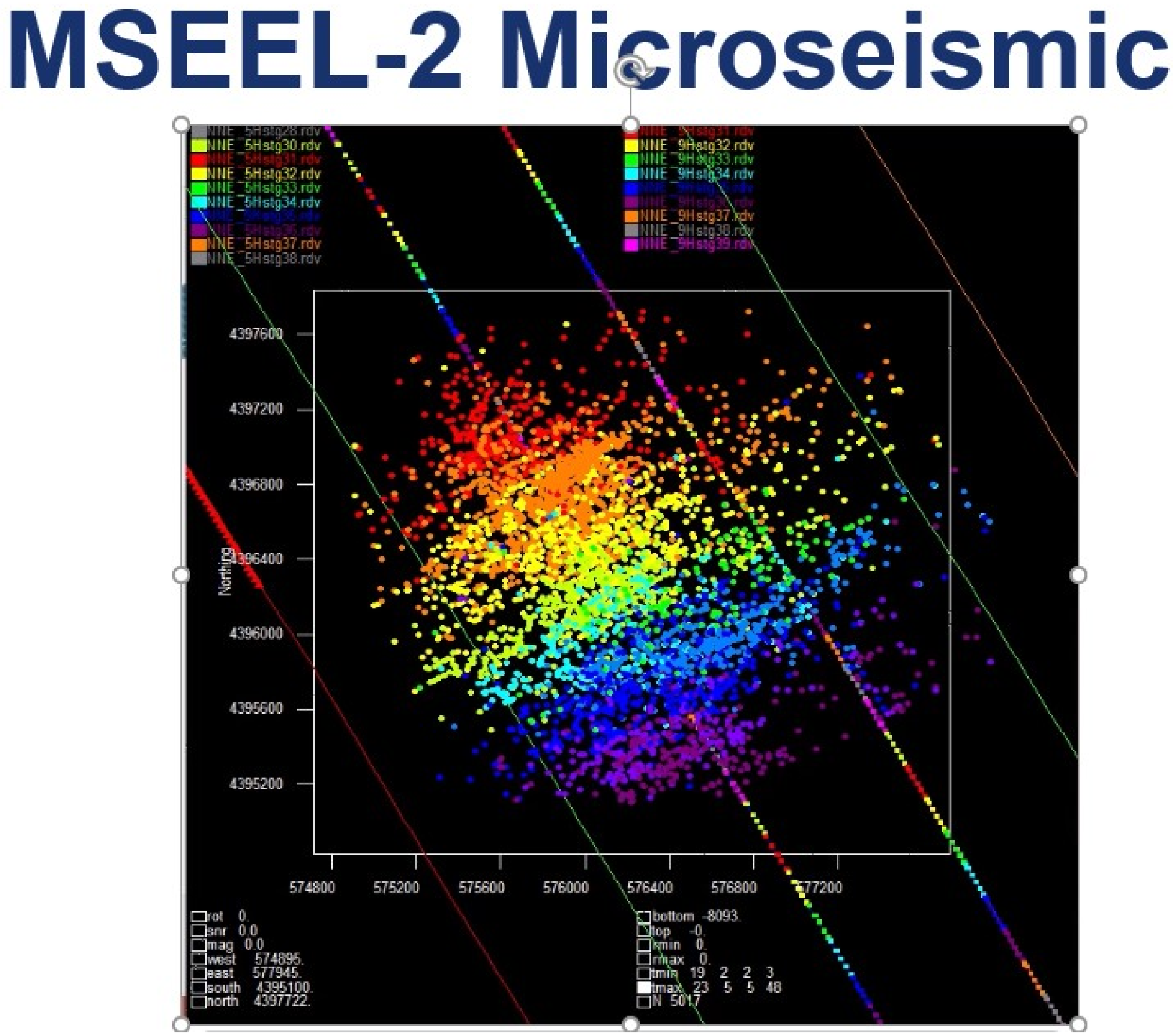

Figure 1.4: Microseismic events for eight stages of the Boggess 5H well showing the large number of events recorded using the permanent fiber in the 5H and the deployable fiber in in the 1H. Colors are by stages.

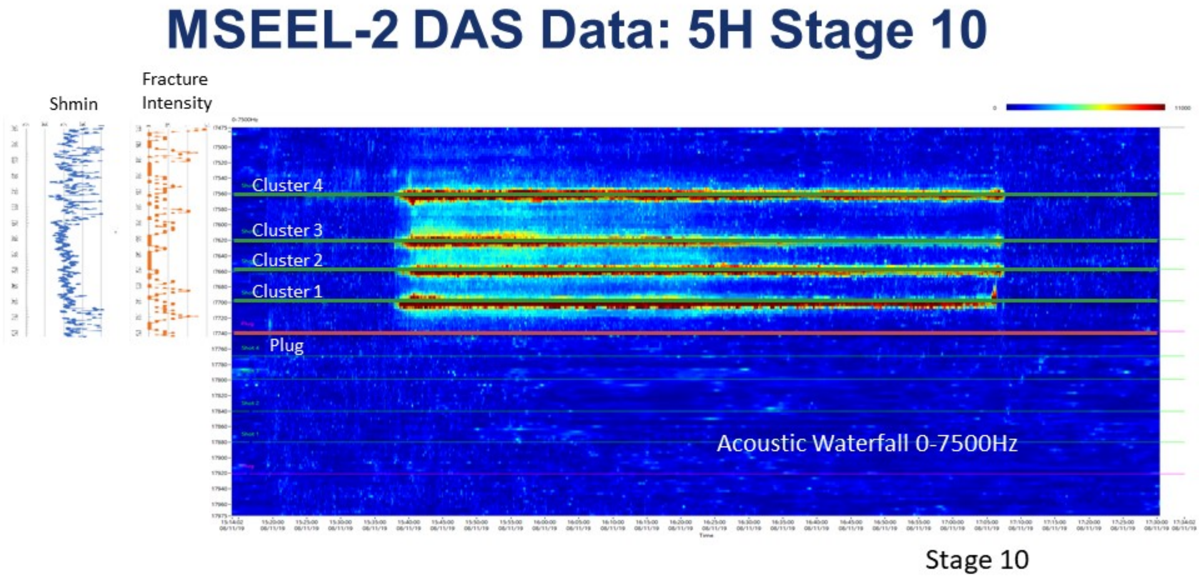

Figure 1.5: DAS data for Stage 10 showing four clusters and a consistent completion between clusters as indicated by acoustic amplitude recorded by the DAS.

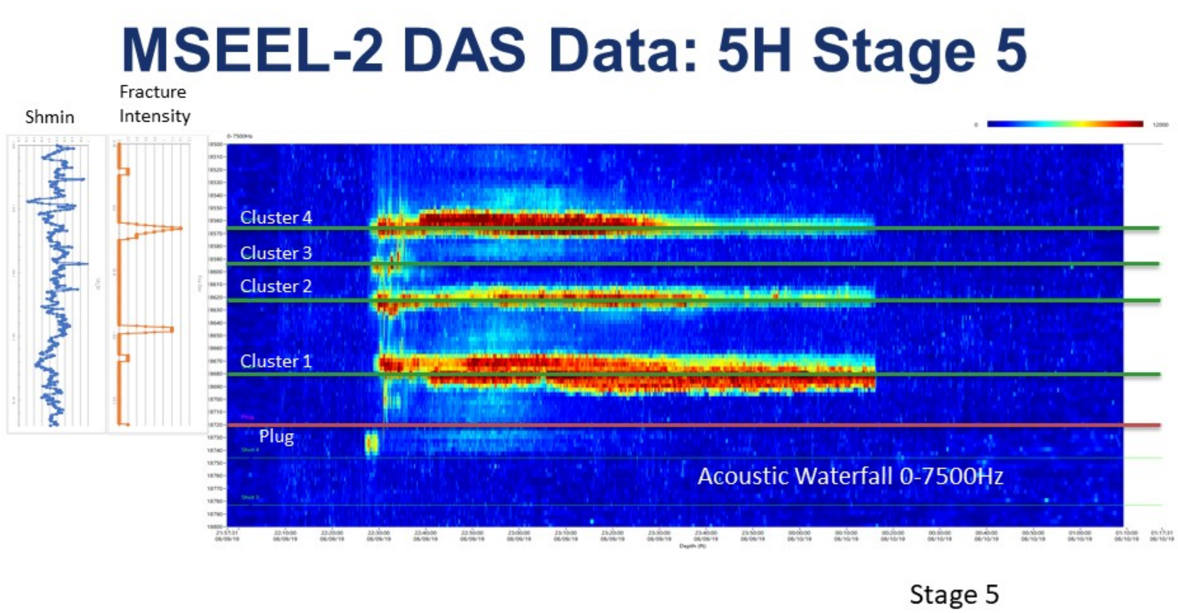

Figure 1.6: DAS data for Stage 5 showing four clusters and an uneven completion between clusters as indicated by acoustic amplitude recorded by the DAS. Cluster 3 received almost no stimulation and even cluster 2 is different than cluster 1 which received most of the sand and water.

Results and Discussion

We have developed a completion approach that we applied in the Boggess 1H and 3H that shows significant promise (Figure 1.6). We use a semi-automated process that makes use of the downhole accelerometers to derive minimum horizontal stress (Sh_{min}) and the LWD borehole viewer to image the numerous fractures. We target consistent Sh_{min} and avoid fractures. This approach uses machine learning to derive Sh_{min} and then manual adjustment to avoid fractures. We are working to fully automate the process. An abstract is being prepared for the annual meeting of the Society of Petroleum Engineers (SPE).

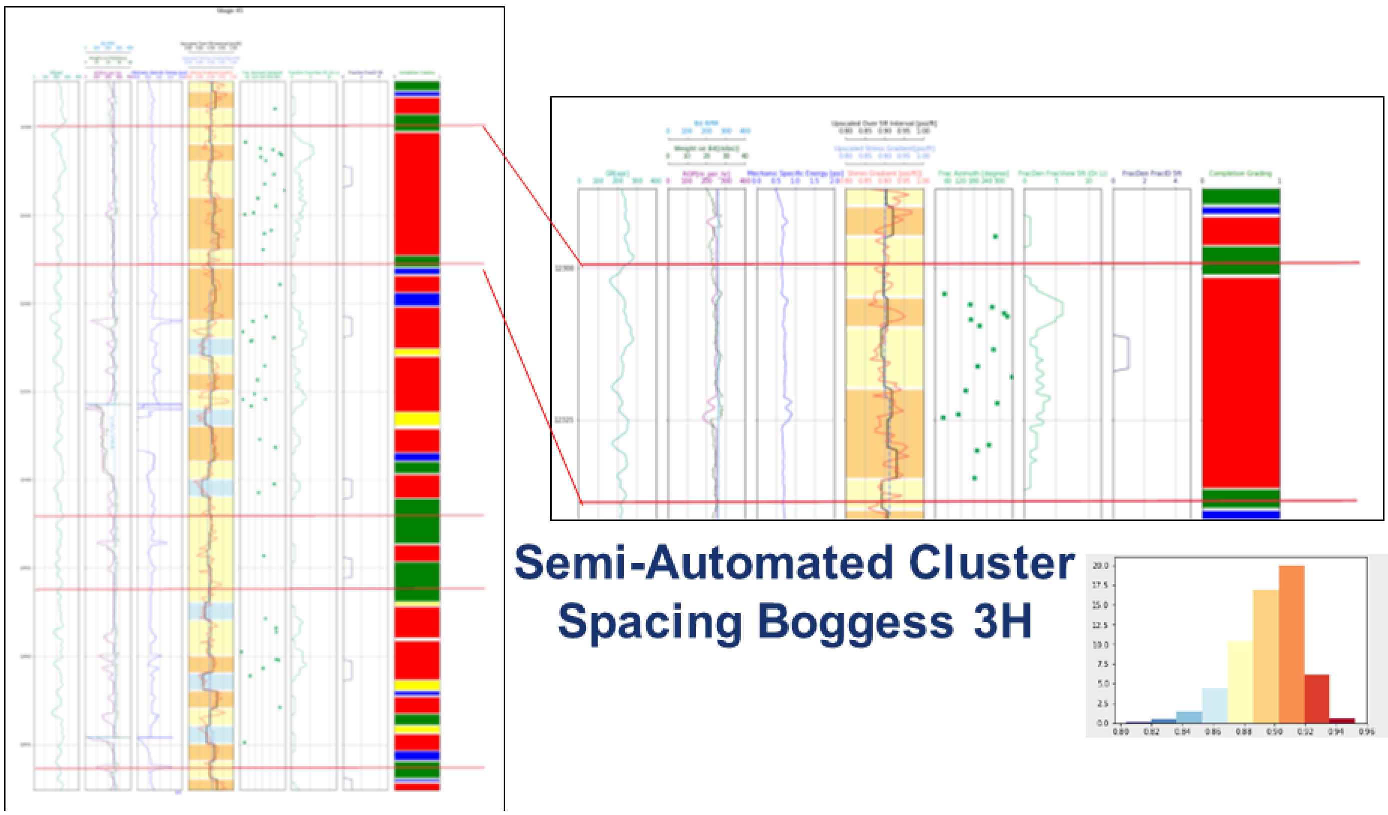

Figure 1.6: Display of a single stage of Boggess 3H showing Sh_{min} derived from accelerometer data in track 4 and color coded and grouped by Sh_{min} bin. Track 6 shows the number of fractures per foot from the LWD image logs. The rightmost track is a risk grading from high risk (red) to low risk (green). The five clusters were adjusted to target the green areas with a consistent Sh_{min} and avoid fractures.

Products

A beta process that uses several pieces of software.

Plan for Next Quarter

We are working to improve and integrate the software for targeting clusters for completion and to generate an abstract for submission to SPE.

Topic 2 – Geophysical & Geomechanical

Approach

Geophysical and Geomechanical

We are working with Los Alamos National Lab (LANL) to understand the influence of a discrete fracture network on the growth of hydraulic fractures was investigated using numerical modeling. The numerical model updated in a previous quarter was used to compute hydraulic fracture dimensions for stage 26 through stage 30 of well MIP-5H.

During this quarterly period, the influence of a discrete fracture network on the growth of hydraulic fractures was investigated through the use of numerical modeling. All numerical modeling results were synthesized along with microseismic data results.

The match between numerical model calculated fracture heights and lengths and microseismic estimated height and length data is not currently considered to be excellent. The current modeling study will be continued to evaluate the influence of geomechanical properties on fracture geometries in comparison to microseismic estimates. A statistical methodology is being explored to better reconcile numerical model calculated fracture heights and lengths, and microseismic height and length estimates.

Results & Discussion

We have worked with LANL to generate a conference paper for the spring meeting of the Association for the Advancement of Artificial Intelligence (March 23-25) at Stanford University. The paper is entitled Physics-informed Machine Learning for Real-time Unconventional Reservoir Management

Plan for Next Quarter

We will employ our new investigator Brian Panetta to begin to develop a reservoir model for the Boggess Pad.

Topic 3 – Deep Subsurface Rock, Fluids, & Gas

Sharma Group

1. Characterization of organic matter - Total Organic Carbon and Pyrolysis Experiments Complete. 41 Core samples from Boggess 17 H were collected and analyzed in Source Rock Analyzer (SRA) at IsoBioGem lab to determine total organic carbon (TOC), free amount of hydrocarbons (S1), kerogen bound hydrocarbons (S2), free CO2 (S3), thermal maturity (Tmax and calculated VRo). The TOC values ranged between 1.0 to 9.7 wt.%, S1 ranged between 0 to 0.92 mg HC/g, S2 ranged from 0.16 to 1.58 mg HC/g, S3 ranged between 0 to 0.62, Tmax values ranged from 517 to 567.3 °C and VRo values ranged from 2.2 to 3.1.

2. Isotopic characterization of produced water : Produced water from Boggess wells 1H, 3H, 5H, 9H, 13H, 17H were collected on Day 1, and from wells 9H and 17H on day 7 and day 14. The $\delta^{13}C$ of dissolved inorganic carbon (DIC) from all these produced water samples have been analyzed. The O and H isotope analysis is currently under process

3. Isotopic characterization of produced gases. The produced gases were sampled in Boggess wells 1H, 3H, 5H, 9H, 13H, 17H were collected on Day 1, Day 3, Day 5, and Day 9. There was no difference in carbon isotopic composition of gases between different wells and also no variation was observed between Day1 and Day 9 samples. The $\delta^{13}C$ values for all the gas samples ranged between -37 to -38 ‰ w.r.t. V PDB.

Papers Published:

1. Thai P., Hakala A. and Sharma S. 2020, Application of isotopic and geochemical signals in unconventional oil and gas reservoir produced waters toward characterizing in situ geochemical fluid-shale reactions. *Science of Total Environment*: *doi.org/10.1016/j.scitotenv.2020.136867*
2. Sharma, S., Agrawal, V., & Akondi, R. N. 2020. Role of biogeochemistry in efficient shale oil and gas production. *Fuel,* 259, 116207.

Wrighton's Lab (OSU-CSU); Wilkins Lab (OSU-CSU)

Milestone 1 We will investigate how microbial strains persist and co-exist in the shales.

Deliverable 1: A manuscript was published on new strains of bacteria in the deep subsurface

The manuscript from Nixon et al. was published in mSphere.

S.L. Nixon, R.A. Daly, M.A. Borton, L.M. Solden, S.A. Welch, D.R. Cole, P.J. Mouser, M.J. Wilkins, K.C. Wrighton. Genome-resolved metagenomics extends the environmental distribution of the *Verrucomicrobia* phylum to the deep terrestrial subsurface.
mSphere. **DOI:** 10.1128/mSphere.00613-19

It is available at the following link:

https://msphere.asm.org/content/4/6/e00613-19

Mouser Lab (OSU-UNH)

Approach

The last 6 months have involved preparations for field sampling at MSEEL II, carrying out sampling, publishing papers from Evan's dissertation, and beginning new experiments with MSEEL II samples.

Results & Discussion

The following progress has occurred for the milestones outlined in the Mouser lab.

Milestone 1: Characterization of intact polar lipids in MSEEL core and fluid samples.

This paper is still in the final stages of editing based on co-author feedback. We are finalizing experiments/data to include in this publication.

Milestone 2: Characterization of dehalogenation pathways in MSEEL fluid samples.

This paper was published in Oct 2019.

Milestone 3: OSU student associated with MSEEL project (Evans) to defend thesis 2019.

Evans defended her dissertation on 4/8/2019. Evan's dissertation is available here:
Microbial transformations of organic chemicals in produced fluid from hydraulically fractured natural-gas wells. Morgan Volker Evans, 2019.

Available at: https://etd.ohiolink.edu/pg_10?::NO:10:P10_ETD_SUBID:179338

PUBLICATIONS & PRESENTATIONS

Peer Reviewed Publications associated with MSEEL:

1. Evans MV, Sumner A, Daly RA, *Luek JL, Plata D, Wrighton KC, Mouser PJ. Hydraulically fractured natural-gas well microbial communities contain genomic (de)halogenation potential. (2019). *Environmental Science & Technology* Letters, 6, (10), 585-591.

Papers in Review/Preparation

We have two additional paper revision/preparation that involve MSEEL related samples/topics:

Luek J, Murphy C, and **Mouser PJ.** Detection of antibiotic and metal resistance genes in deep shale microbial community members.

Aghababaei M, Luek J, Mouser PJ. Temporal Toxicity in Hydraulic Fracturing Wastewater from Black Shale Natural-Gas Wells in the Appalachian Basin

Presentations

None to report for this quarter but several planned for early 2020.

Plan for Next Quarter

Mouser is working with a two post-doc students (F. Colosimo; J. Adhakari) to conduct bioreactor experiments with MSEEL II fluids. The students are also analyzing field samples for polar lipids, microbial community, and microbial activity. We have new papers in the pipeline from a 2018 DOE EPSCoR grant involving MSEEL related samples.

Cole Lab (OSU)

Deliverable 2: SAW, JMS, and DRC are drafting a paper comparing the geochemistry of flowback fluids from the Utica/Point Pleasant (UPP) to the geochemistry of fluids from the MSEEL site, and relating the differences in water composition to long term geological and short term geochemical processes that have occurred in the subsurface. This manuscript couples flowback geochemistry to the distribution of major and trace elements in hydraulic fracturing targets: (Lower Marcellus and UPP).

Flowback fluid signals from the Appalachian Basin: Focus on the Marcellus and Utica-Point Pleasant. Susan A. Welch, Julia M. Sheets, Rebecca A. Daly, Andrea J. Hanson, Anthony Lutton, John Olesik, Shikha Sharma, Tim Carr and David R. Cole (for *Applied Geochemistry*)

To this end, integration of fluid chemistry with rock mineralogy and bulk geochemistry of the UPP and MSEEL target formations collected from the same wells.is ongoing.

Fluid Chemistry and Water-Rock Interaction.

We are currently revising a paper detailing flowback fluid geochemistry in concert with the formation geochemistry and mineralogy from both the MSEEL site and the Utica/Point Pleasant sites. The results of the water analysis show that the flowback/produced (FP) fluid compositions from the UPP and Marcellus formations are remarkably similar in spite of the different lithologies, however there are some differences in the water chemistry that reflect long term geologic processes as well as geochemical processes that are occurring in situ during the hydraulic fracturing, flowback and production. These differences are most apparent in the geochemistry of alkaline earth elements and dissolved sulfur species. The origin of the salts was interpreted using the isometric log ratio plots (ilr) described by Engle and Rowan (2014). This approach uses the normalized concentrations of Na-Cl-Br to determine the geochemical processes controlling these species, whether evaporation or halite dissolution, where-

$$z_1 = \frac{1}{\sqrt{2}} * \ln\left(\frac{Na}{Cl}\right)$$

and

$$z2 = \frac{\sqrt{2}}{\sqrt{3}} * ln\sqrt{(Na)(Cl)}\ /Br$$

Results of water analysis of both the UPP and Marcellus fluids show that they plot in the same region as Marcellus samples collected from other studies (Rowan and Engle, 2014), slightly above but parallel to the trend for modern seawater evaporation (Figure 3.1).

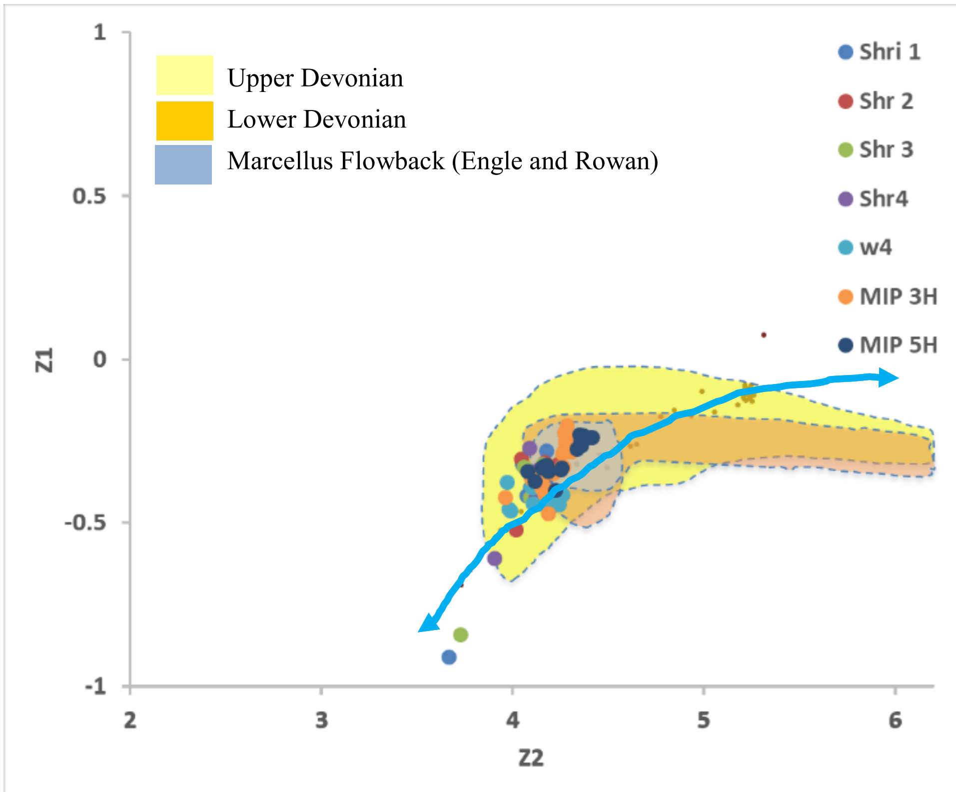

Figure 3.1 ilr plot (Na-Cl-Br) redrafted after Engle and Rowan (2014) with flowback fluids from both the MSEEL site (MIP 3H and 5H) and the UPP wells (Shr 1-4 and W4). The blue line represents modern seawater evaporation pathway. The data plot along a trajectory that is consistent with evaporated paleo seawater.

The strong correlations among most of the major constituents in the brines with conservative species such as Cl or Br, suggests that in situ brine composition in these formations is diluted by the relatively fresh input fluids used in hydraulic fracturing. This is overwhelmingly controlling flowback brine composition, and the large scale temporal changes can be described by diffusion of these brines in micropores to the larger fracture network generated by hydraulic fracturing (Balashov et al 2015).

However, there are distinct differences in the geochemistry of the brines that reflect geochemical processes that have occurred over geologic time, including dolomitization, sulfate reduction and ion exchange reactions as well as contemporaneous brine-rock interaction, either from the dissolution of primary rock, oxidation of reduced species or adsorption-desorption reactions in the subsurface. These differences are most apparent in the geochemistry of sulfur species and alkaline earth elements. Results show a progressive increase in both Sr and Ba with respect to other major ions, suggesting these larger ions are solubilized from either sulfate or carbonate minerals, or by ion exchange reactions with clay minerals. Both Sr and Ca increase with respect to Cl, suggesting dissolution of carbonate mineral in situ, however, Sr increases with respect to Ca, suggesting preferential release of the larger Sr ion from the carbonate mineral structure, or that Sr is sourced from another phase. Ba concentrations increase with respect to Cl, rapidly in the first few months of flowback, and then more slowly over time. This has been interpreted as ion exchange reactions with clay minerals, and is consistent with the small decrease observed for the Na/Cl ratios in the fluids. After approximately three months, the Ba/Sr ratios in the MSEEL and UPPS fluids are nearly constant, suggesting the same processes are controlling the release of these elements to the FP fluids.

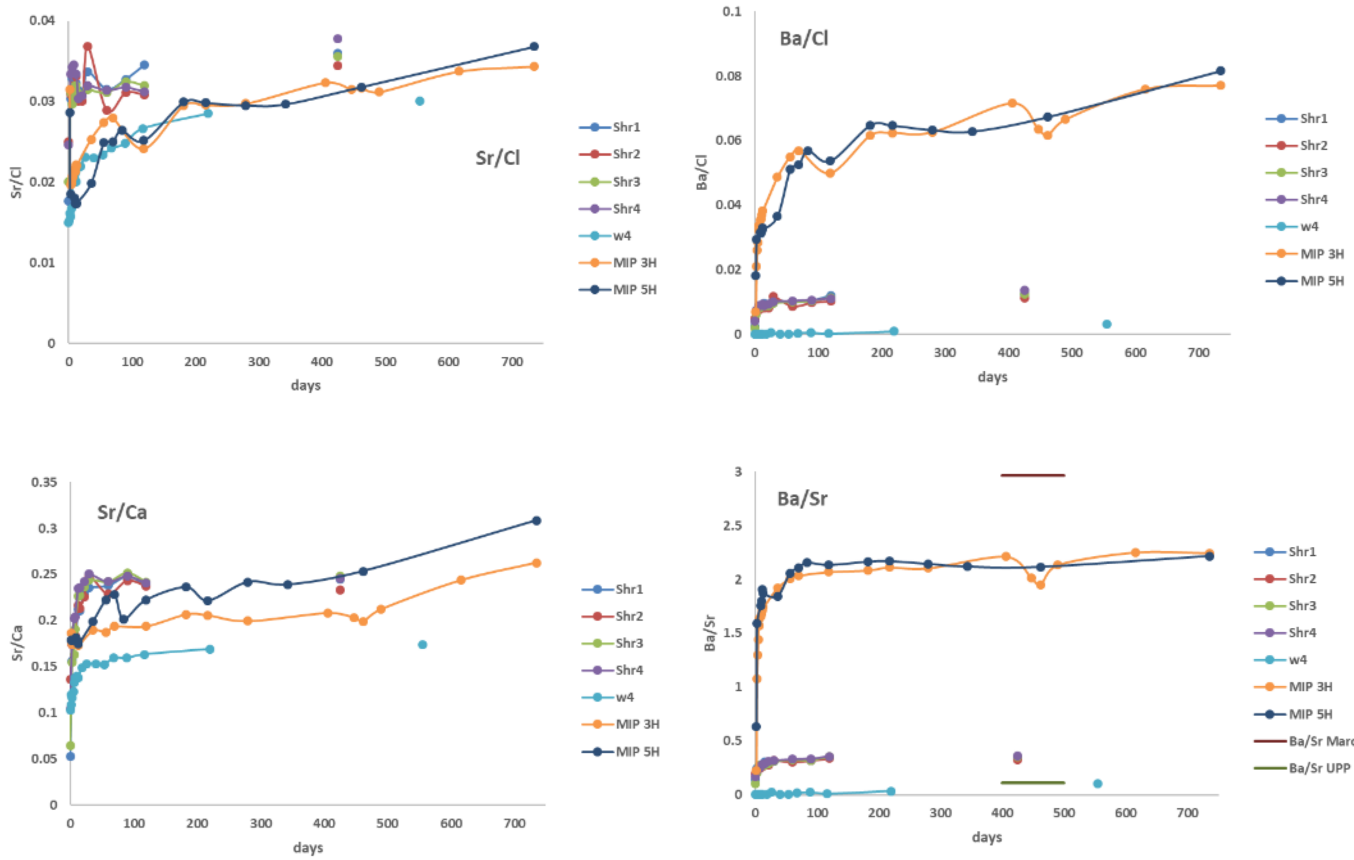

Figure 3.2 Elemental ratios for UPP and MSEEL fluids (wt:wt ratios). Top left Sr/Cl, bottom left Sr/Ca, top right Ba/Cl and bottom right Ba/Sr in flowback fluids from MSEEL and UPP wells showing and increase in the Ba/Cl and Sr/Cl ratios over time. The increase in alkaline earth elements compared to Cl reflects ion exchange reactions and dissolution of Sr and Ba bearing phases such as barite/celestite or gypsum, carbonates, or phosphate minerals.

Quantification of mineralogy for the UPP (Figure 3.3) and MSEEL (Figure 3.4) hydraulic fracturing target intervals continues. Figure 3.3a shows a QEMSCAN mineral map of the UPP target near the Belmont Harrison County line in Ohio, a core sample of Point Pleasant carbonate mudrock collected from an approximate depth of 8550 feet below the surface. Figure 3.4a shows the same for the MSEEL hydraulic fracturing target, depth 7543 feet, a silicate-rich core from the lower Marcellus (well MIP 3H, Morgantown, West Virginia. Rietveld quantitative analysis of powder XRD scans from the same core samples continues, with emphasis on improving the fitting of background, phase profile asymmetry and including preferred orientation functions for the phyllosilicates. This modeling attempts to minimize the differences between observed and calculated intensity profiles, while also trying to minimize the number of model parameters allowed to vary. Figures 3.3b and 3.4b show examples of these quantifications. Of particular note is the greater abundance of pyrite, barite, phyllosilicates, and quartz in the Marcellus target, as compared to the Point Pleasant target, which is dominantly calcite, mica/illite, and quartz.

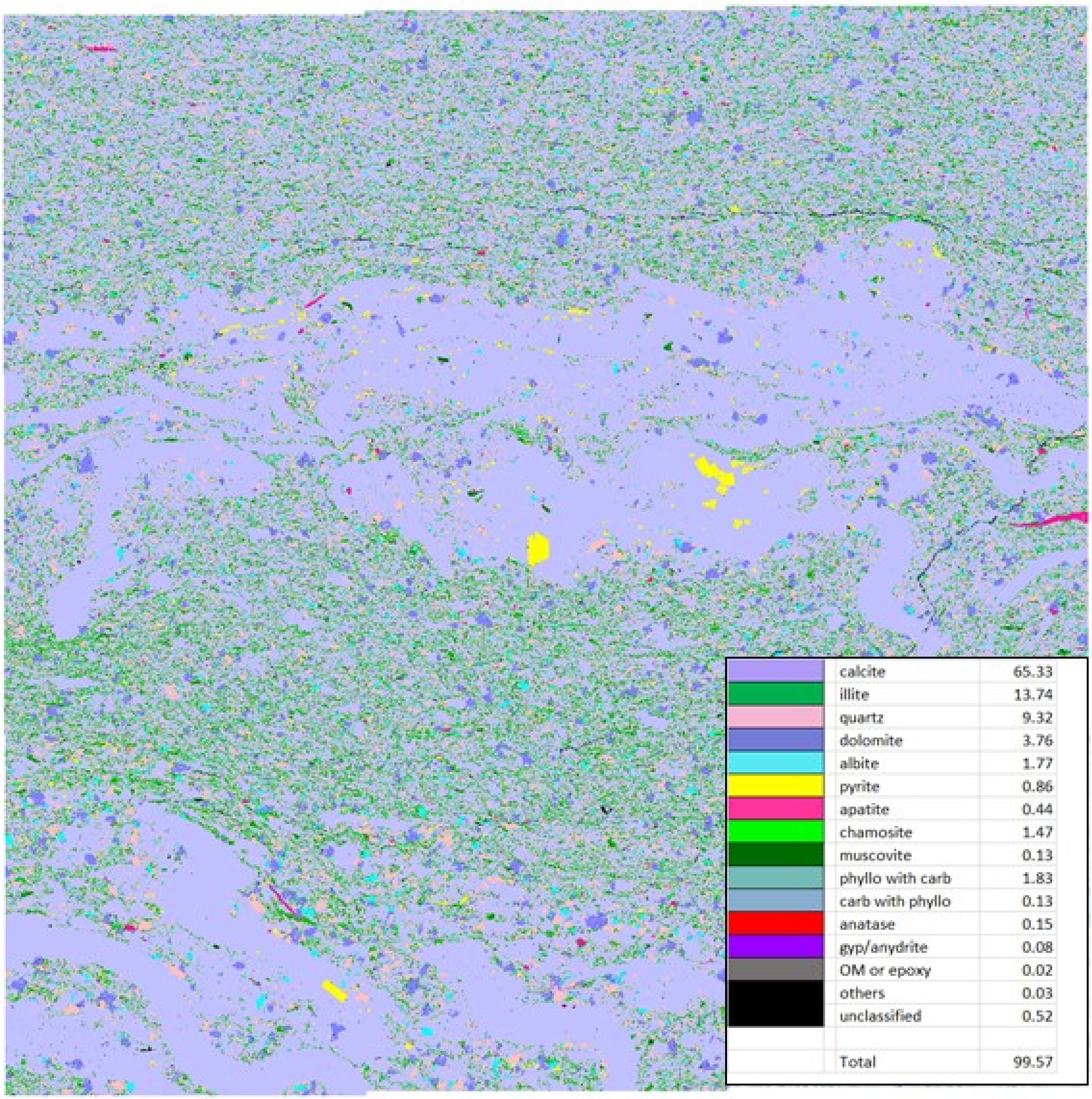

Figure 3.3a UPP QEMSCAN. QEMSCAN mineral map of ~3x3 mm^2 region of polished thin section of Point Pleasant hydraulic fracturing target (depth ~8550′). Lavender shades are calcite and dolomite (dark lavender), green shades are mainly illitic clay (with minor muscovite and chamosite), light pink is quartz, cyan is albite, yellow is pyrite, and fuchsia is apatite. Organic matter (OM, arrowed) is black; much of it is finely intercalated with illitic clay and too small to be resolved with QEMSCAN. Desiccation cracks also are black in this image.

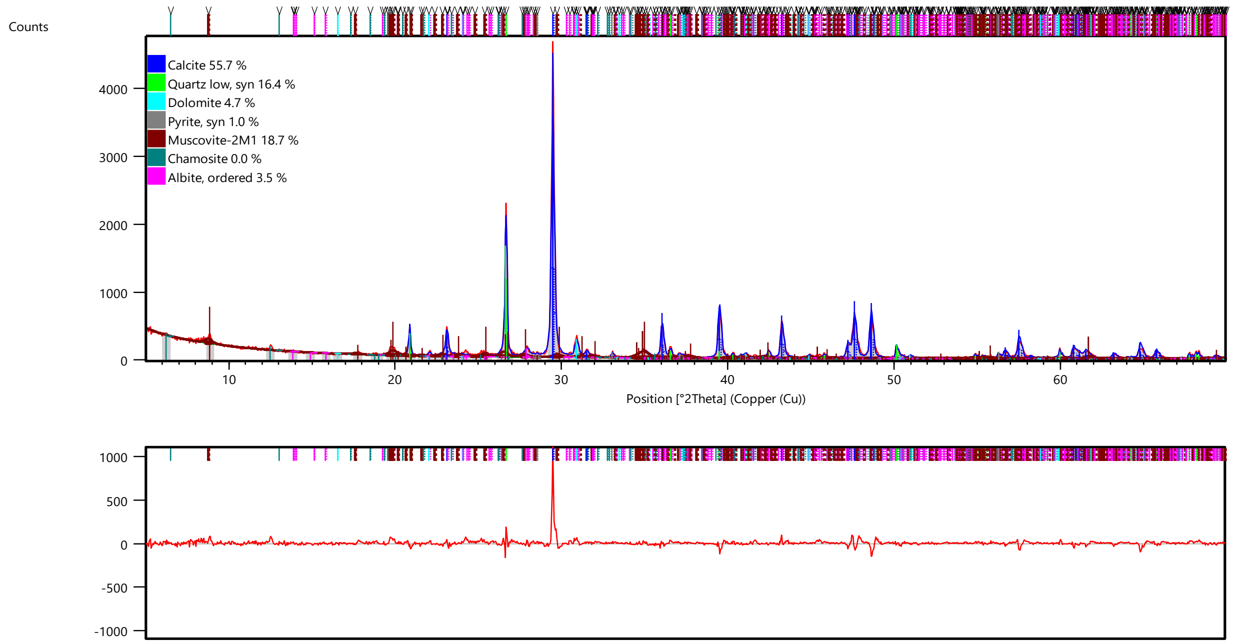

Figure 3.3b UPP Rietveld quantification of target formation, showing mineral composition in weight percent, and the difference plot derived from the whole pattern fitting.

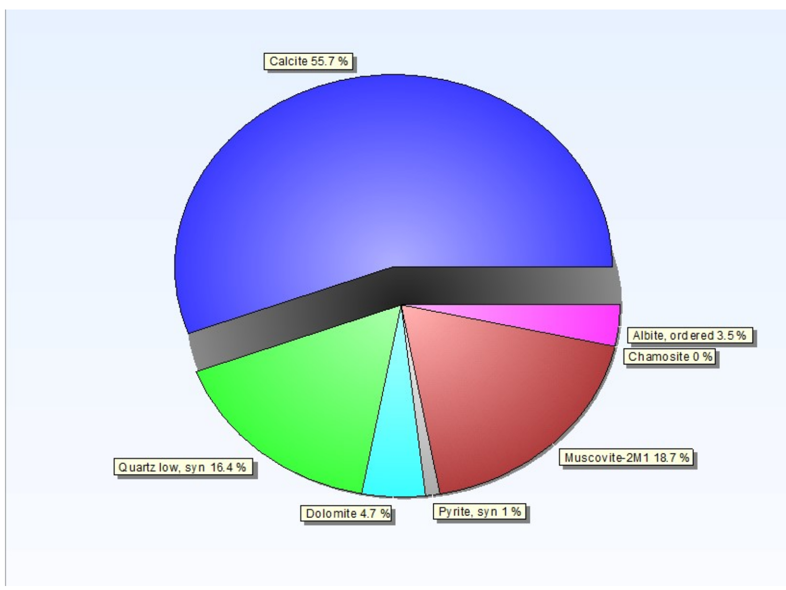

Figure 3.3c UPP Rietveld quantification of target formation as a pie chart, showing mineral composition in weight percent.

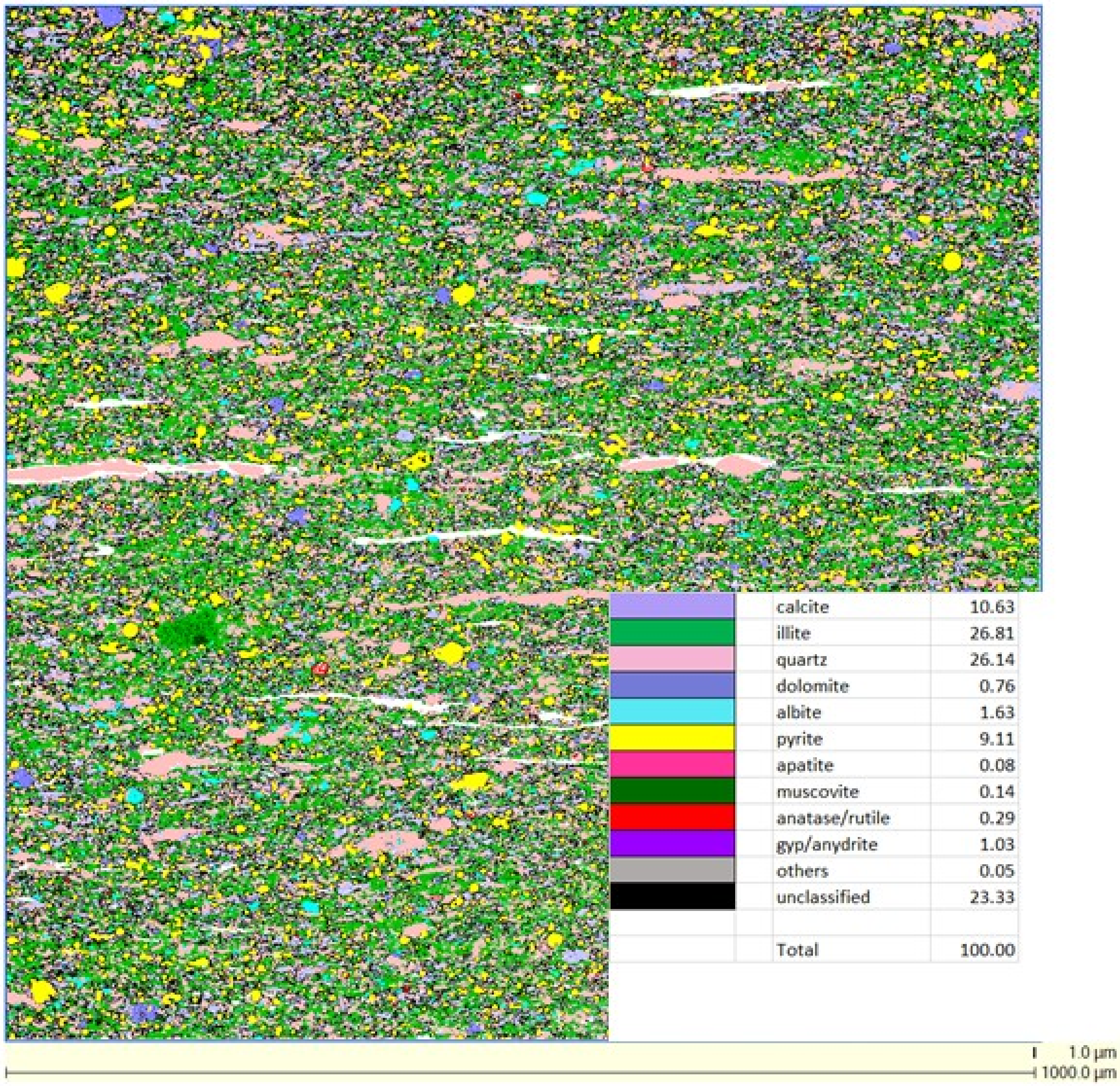

Figure 3.4a MSEEL QEMSCAN mineral map of ~1 mm^2 region of Lower Marcellus (depth 7543.0'). Compared to the Point Pleasant, this hydraulic fracturing target is very different in mineral composition and texture. The same general color scheme for minerals is used as in Figure UPP QEMSCAN. Green shades are illitic clay (25.7 %); light pink is quartz (25.2 %); black unclassified mixed pixels (22.5 %); light lavender is calcite (10.3 %); yellow is pyrite (8.8 %); cyan is albite (1.6 %); white is large OM macerals (3.4 %); purple is gypsum/anhydrite (1 %); dark lavender is dolomite (0.7 %). Remaining < 1% includes small quantities of mica as biotite, muscovite and glauconite, titania, Ca-phosphate, and K-feldspar. The black unclassified pixels represent the complex clay fraction, with the finest-grained OM intercalated with illitic clay, barite, pyrite, REE phosphates, sphalerite (ZnS) and a U-Ti phase, as identified by EDX spot analysis. This Lower Marcellus is a very OM-rich siliciclastic mudrock with minor carbonate; much of the large OM macerals are replaced by quartz to varying degrees.

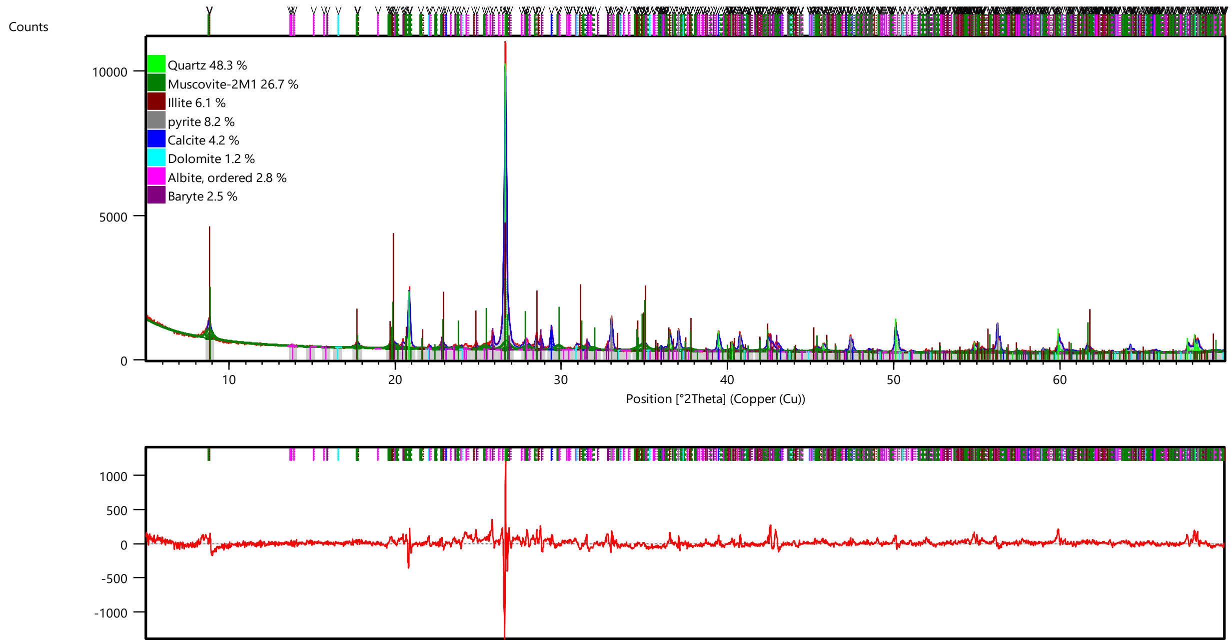

Figure 3.4b MSEEL Rietveld quantification of target formation, showing mineral composition in weight percent, and the difference plot derived from the whole pattern fitting.

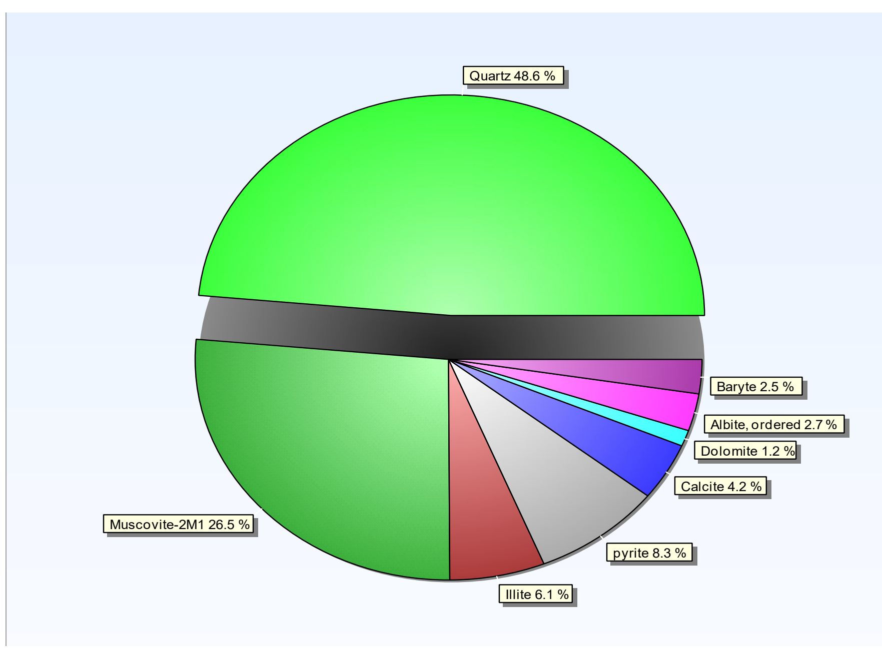

Figure 3.4c MSEEL Rietveld quantification of target formation as a pie chart, showing mineral composition in weight percent.

Integration of modal mineralogy with evolving flowback chemistry will help to better inform the water-rock interaction and the evolution of chemistry and porosity in the subsurface. A goal of this integration is to model the quantity of rock interrogated by hydraulic fracturing fluids.

References cited.

Balashov, VN, Engelder T, Gu X, Fantle MS, and Brantley SL, 2015, A model describing flowback chemistry changes with time after Marcellus Shale hydraulic fracturing. AAPG Bulletin, 90, 143-154.

Engle MA, and Rowan EL, 2014, Geochemical evolution of produced waters from hydraulic fracturing of the Marcellus Shale, northern Appalachian Basin, A multivariate compositional data analysis approach. International Journal of Coal Geology, 126, 45-56.

Darrah Lab (OSU)

Milestone 1: Completed characterization of all water and gas samples for noble gas (He, Ne, Ar, Kr, and Xe), fixed gas (N_2, H_2, CO_2) and hydrocarbon gas (C1-C5, C6+) composition (11 samples remain).

Deliverable 1: Manuscript entitled: The changing composition of hydrocarbon and noble gases during the early production of a Marcellus Shale Gas Well; Authors: T. Darrah, C.J. Whyte, D. Cole, S. Sharma, and T. Carr; Planned submission to *Geochimica et Cosmochimica Acta*

Deliverable 2: Manuscript entitled: Determining the residence time of natural gas produced from the Marcellus Shale using radiogenic noble gas isotopes. Authors: T. Darrah, C.J. Whyte, B. Lary, D. Cole, S. Sharma, and T. Carr; Planned submission to *Geochimica et Cosmochimica Acta*

Both manuscripts are nearing completion.

Topic 4 – Produced Water and Solid Waste Monitoring –

Approach

MIP Site

Over three years into the post completion part of the program, the produced water and solid waste component of MSEEL has continued to systematically monitor changes in produced water quality and quantity. During year one of the study, hydraulic fracturing fluid, flowback, produced water, drilling muds and drill cuttings were characterized according to their inorganic, organic and radiochemistries. In addition, surface water in the nearby Monongahela River was monitored upstream and downstream of the MSEEL drill pad. Toxicity testing per EPA method 1311 (TCLP) was conducted on drill cuttings in both the vertical and horizontal (Marcellus) sections to evaluate their toxicity potential. Sampling frequency has been slowly scaled back following well development.
Table 4.1 indicate that samples were not collected, due to lack of availability of produced water from the well(s).

Table 4.1. MIP sampling events are indicated with an "X".

Year	2015			2016											
Day/Month	10-Dec	17-Dec	22-Dec	6-Jan	20-Jan	3-Feb	2-Mar	23-Mar	20-Apr	18-May	2-Jul	17-Aug	21-Jun	19-Oct	16-Nov	14-Dec
3H	X		X	X	X	X		X	X	X	X	X	X	X		X
4H															X	X
5H	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
6H															X	X

Year	2017								2018					
Day/Month	13-Jan	14-Feb	13-Mar	7-Apr	5-May	12-Jul	3-Nov	20-Dec	22-Jan	23-Feb	16-May	2-Aug	16-Oct	15-Dec
3H	X	X	X	X	X	X	X	X	X	X	X	X		X
4H	X	X	X	X	X				X	X	X	X	X	X
5H		X			X			X	X		X		X	X
6H	X	X	X	X	X						X	X		

Year	2019							
Day/Month	24-Jan	5-Mar	6-May	13-Jun	18-Sep	21-Oct	21-Nov	30-Dec
3H	X	X	X	X	X	X	X	X
4H	X	X					X	X
5H	X	X	X	X	X	X	X	X
6H		X					X	X

Boggess Site

Two control wells; 9H and 17H were selected for solids and aqueous studies at the newly developed Boggess well site.

Tophole was completed in Feb 2019 for 9H and Jan 2019 for 17H. Samples of vertical drilling were not obtained due to completion prior to the start of the Boggess project.

Horizontals were initiated on 19 June 2019 for 17H and 20 May 2019 for 9H (Table 4.2). A drilling mud sample along with depth samples at 8,500ft; 10,000ft; 11,000ft; 13,000ft; and 15,000ft were collected and analyzed for parameters shown in Table 4.3.

Table 4.2. Sample depth and dates for collection of horizontal drilling mud and cutting samples.

Depth/Well	Mud 9H	8500 9H	10000 9H	11000 9H	13000 9H	15000 9H
Date	5/27/2019	5/27/2019	5/28/2019	5/29/2019	5/29/2019	5/30/2019

Depth/Well	Mud 17H	8500 17H	10000 17H	11000 17H	13000 17H	15000H
Date	7/1/2019	7/1/2019	7/1/2019	7/1/2019	7/1/2019	7/1/2019

Table 4.3. Solids analysis list.

Analysis	Analysis Method	Prep Method	Units	Parameter
Gasoline Range Organics by GC-FID	SW8015D	SW5035	ug/Kg	GRO C6-C10)
			% Rec	Surr: Toluene-d8
Volatile Organic Compounds	SW8260B	SW5035	ug/Kg-dry	Ethylbenzene
				m,p- Xylene
				o- Xylene
				Styrene
				Toluene
				Xylenes total
			% Rec	Surr: 1,2- Dichloroethane-d4
				Surr: 4-Bromofluorobenzene
				Surr: Dibromofluoromethane
				Surr: Tolouene-d8
Radionuclides	EPA 901.1	N/A	pCi/g	Potassium-40
				Radium-226
				Radium-228
	9310			Gross Alpha
				Gross Beta
Inorganics (note: metals analyzed as total metals)	SW9056A	Extract	mg/Kg-dry	Br
				Cl
				SO4
	SW9034	SW9030B		sulfide
	E353.2	Extract		nitrate
	E354.1			nitrite
	A2510M		µS/cm	EC
	SW9045D		units	pH
	A4500-CO2 D		mg/Kg-dry	alk bicarb
				alk carb
				alk t
	E365.1 R2.0			TP
	SW6020A	SW3050B		Ag
				Al
				As
				Ba
				Ca
				Cr
				Fe
				K
				Li
				Mg
				Mn
				Na
				Ni
				Pb
				Se
				Sr
				Zn
Moisture	E160.3M	N/A	%	Moisture
Chemical Oxygen Demand	E4104 R2.0	Extract	mg/Kg-dry	COD
Organic Carbon - Walkley-Black	TITRAMETRIC	N/A	% by wt-dry	OC-WB
Oil & Grease	SW9071B - OG	N/A	mg/Kg-dry	O&G

Flowback sampling was initiated on 18 Nov 2019 with weekly collection at 9H and 17H for the first four weeks (Table 4.4). Monthly sampling will begin following the initial weekly sampling effort.

Table 4.4. Boggess sampling events are indicated with an "X".

Year	2019			
Day/Month	18-Nov	25-Nov	2-Dec	10-Dec
9H	X	X	X	X
17H	X	X	X	X

Results & Discussion

MIP Site

Major ions – trends in produced water chemistry

While makeup water was characterized by low TDS (total dissolved solids) and a dominance of calcium and sulfate ions, produced water from initial flowback is essentially a sodium/calcium chloride water (Figure 4.1).

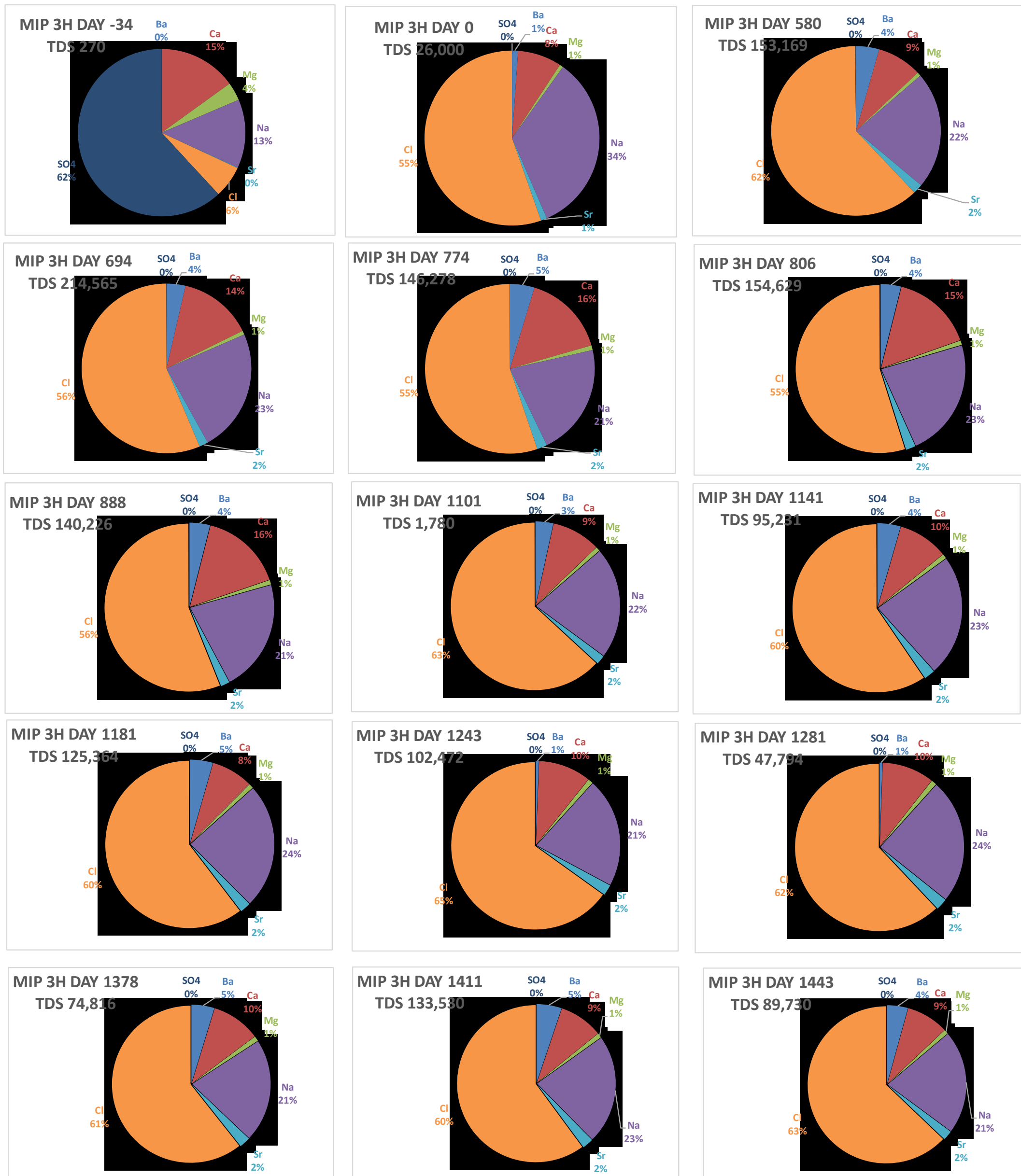

Figure 4.1. Changes in major ion concentrations in produced water from well MIP 3H. Top left Day -34 represents makeup water from the Monongahela River, top center is produced water on the first day (Day 0) and the remainder of pie charts show flowback and produced water on sampling dates through the 1443th day post completion.

In wells 3H and 5H, TDS increased rapidly over the initial 90 days post completion while TDS stabilized between 100,000 and 200,000 mg/L through day 1181(3H) (Figure 4.2). Note that 3H and 5H were both shut-in near day 966 and brought back online prior to sampling on day 1101. 3H and 5H are showing an upward trend following day through day 1243 (e.g. May 2019). Results from day 1281 (e.g. June 2019), TDS declined in both wells. It's uncertain if the wells were shut down between day 1243 and day 1281, which might explain the decrease in TDS.

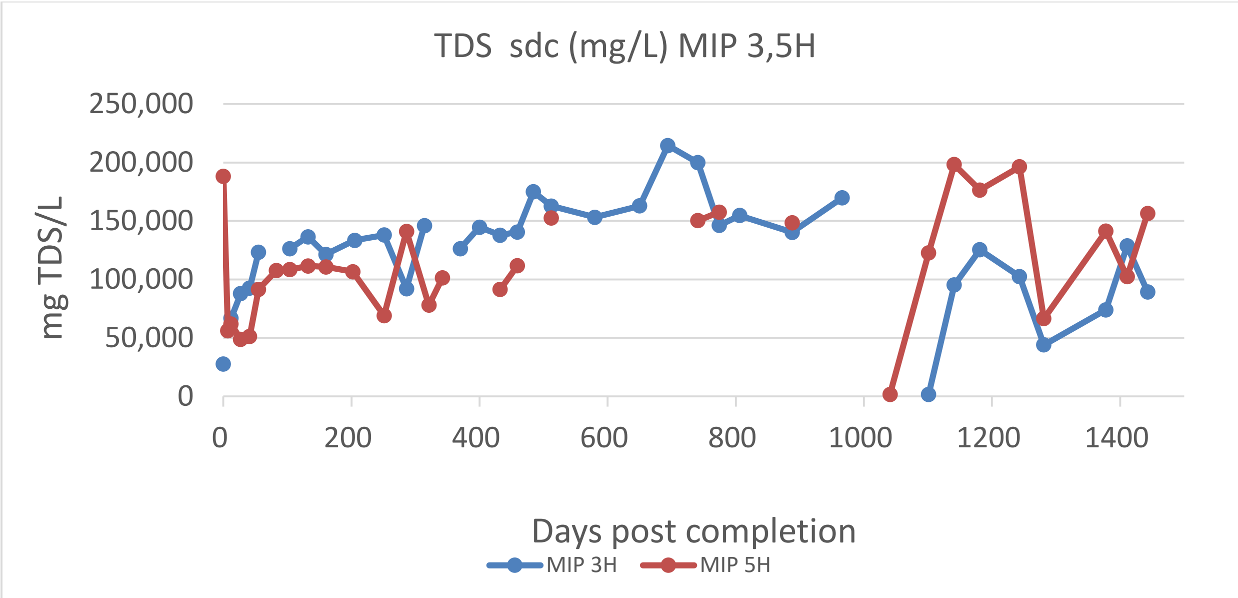

Figure 4.2. Changes in produced water TDS sdc (sum of dissolved constituents) through the first 1443 days post completion (3,5H).

The older 4H and 6H wells offer insight into the longer-term TDS trend. Those wells only came back on line during this quarter after a shut-in period of 315 days and those results vary but they are much lower than the current values for wells MIP 3H and 5H. Both 4H and 6H were shut down during late 2017. TDS was very low at MIP 4H during the first sampling event of early 2018. Calculated TDS was 2,455 mg/L and lab reported TDS was 2,300 mg/L. A similarly low TDS trend was noted when well 4H went back online around 1793 days post-completion (after being shut-in for 315 days) and again when 6H went online around day 2339, a rise in TDS subsequently follows the initial return to online status with TDS on an upward trend, reaching 160,000 for 6H. MIP 6H was shut down for 218 days between August 2018 and March 2019. Returning online at day 2632, MIP 6H has calculated TDS of 30,970 and 29,085 mg/L during the most recent sampling events (days 2632 and 2893, respectively) (Figure 4.3).

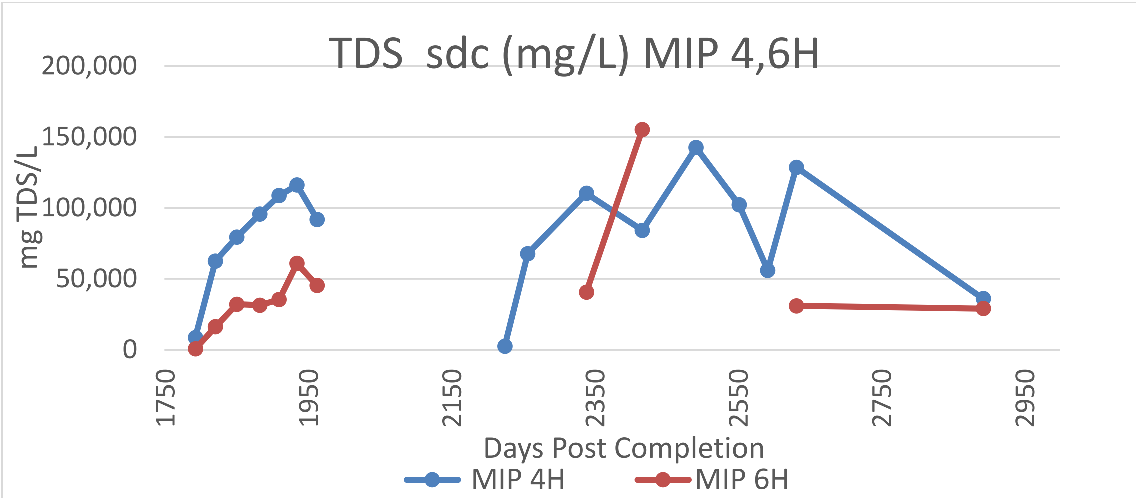

Figure 4.3. Changes in produced water TDS sdc (sum of dissolved constituents) through the first 1793 through 2893 days post completion (4,6H).

Water soluble organics

The water-soluble aromatic compounds in produced water: benzene, toluene, ethylbenzene and xylene were never high. With two exceptions at post completion day 321 and 694, benzene has remained below 30 µg/L (Figure 4.4). This seems to be a characteristic of dry gas geologic units. After five years, benzene has mostly declined below the drinking water standard of 5 µg/L. An exception to this was a measurement of 11 µg/L noted on day 1378 at 5H.

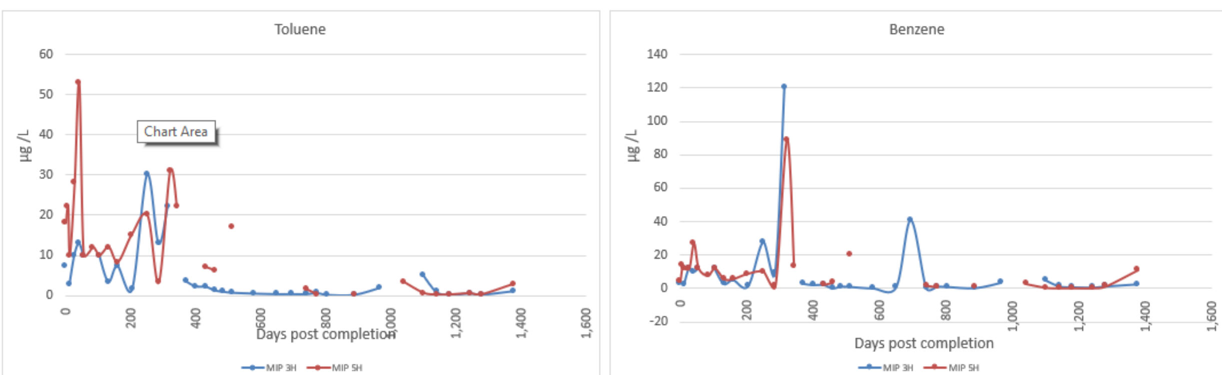

Figure 4.4. Changes in benzene and toluene concentrations. The figure shows data from well both 3H and 5H.

Radium isotopes

The radiochemical concentrations were determined by Pace Analytical in Greensburg PA, a state certified analytical lab. Radium concentrations generally increased through 800 days post completion at wells MIP 3H and 5H. Maximum levels of the radium isotopes reached about 21,800 pCi/L at the unchoked 3H well and around 17,800 5H. After returning online prior to day 966, both wells are on a generally upward trend through the most recent sampling event, except for 3H on day 1101. (Figure 4.5).

<u>Radioactivity in produced water</u>

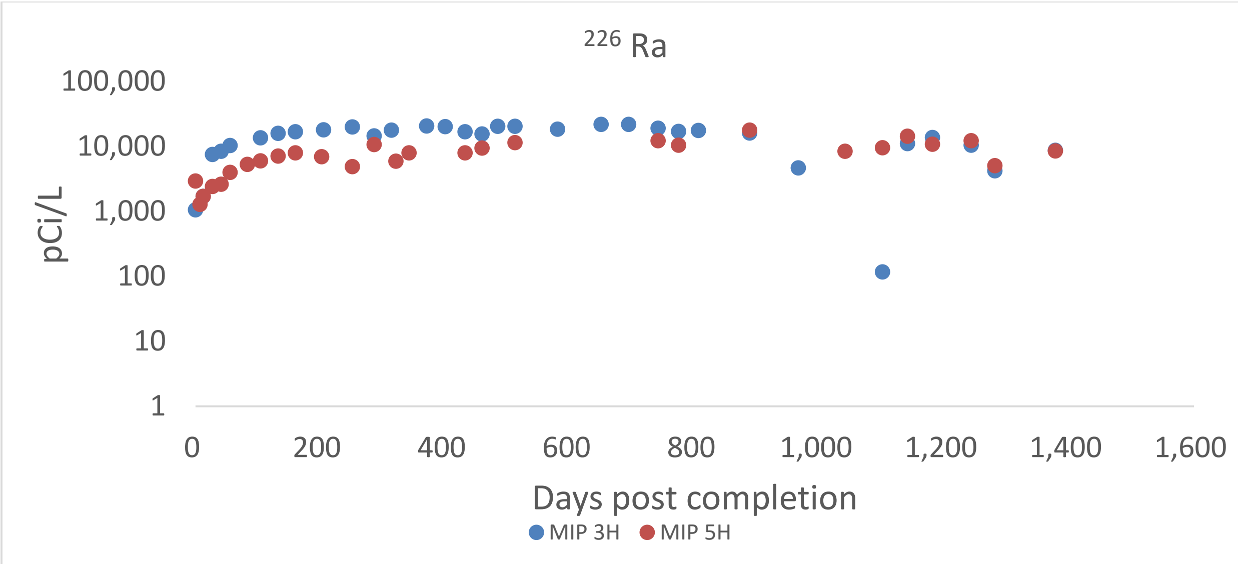

Figure 4.5. The radium isotopes are plotted against days post well completion. Well 5H was choked more periodically the 5H. 3H produced less water and lower concentrations of radium.

Radium concentrations at wells 4H and 6H were below 9,000 pCi/L during all sampling periods. Both wells were choked at day 1963. Well 4H was reopened at day 2225, radium was 58 pCi/L on the first sampling after the reopening and 3719 pCi/L at day 2257, a month later (Figure 4.6) peaked at 5,127 pCi/L then returned to 3,892 pCi/L. The same trend is noted at day 2492 when 4H returned online with 57 pCi/L then peaked at day 2632 with 8,197 pCi/L. Additional data is needed to capture long-term trends. 4H and 6H were not sampled during this reporting period.

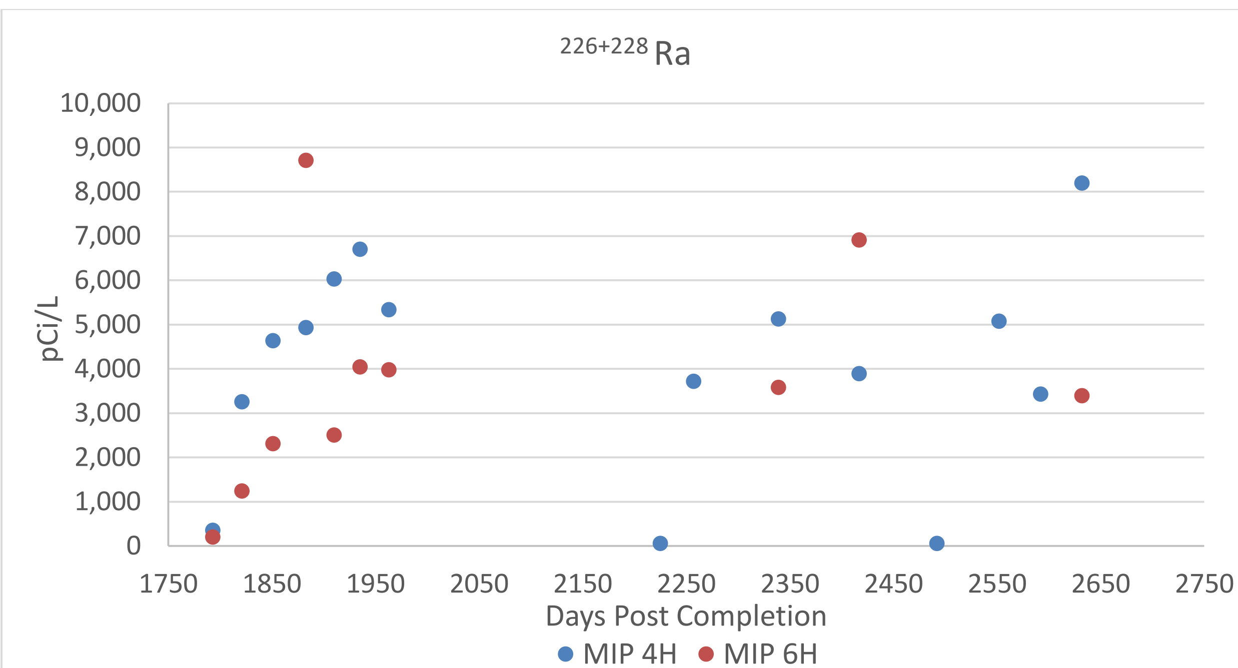

Figure 4.6. The radium isotopes are plotted against days post well completion. Well 4H and 6H were choked at day 1963. At day 2225, 4H was reopened showing a value of 58 pCi/L and reopened again at day 2492 showing a value of 57 pCi/L.

Figure 4.7 show the relationship between gross alpha and ^{226}Ra at 3H and 5H. Analysis for alpha was not conducted after day 1181.

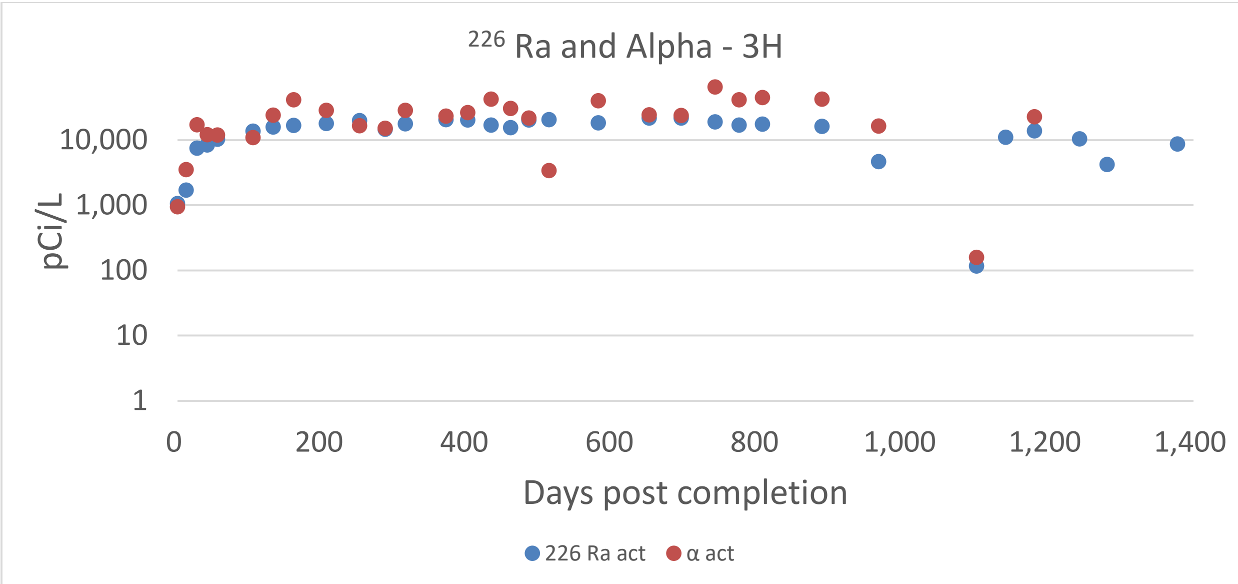

Figure 4.7. The relationship between gross alpha and ^{226}Ra as a function of time post completion at 3H. Note: analysis for alpha was not conducted after day 1181.

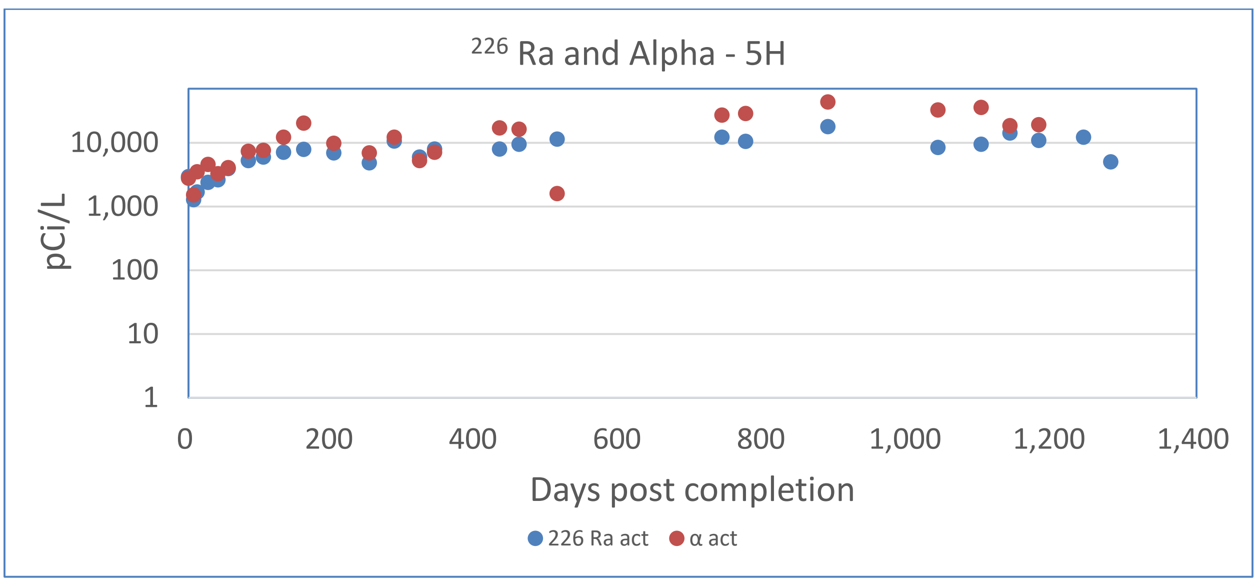

Figure 4.8. The relationship between gross alpha and ^{226}Ra as a function of time post completion at 5H.

The highest values reported in the older wells at 4H and 6H were 17,550 pCi/L gross alpha and 8,197 pCi/L ^{226}Ra. The relationship between gross alpha and ^{226}Ra for wells 4H and 6H are shown in figures 4.9 and 4.10. 4H and 6H were not sampled during this reporting period.

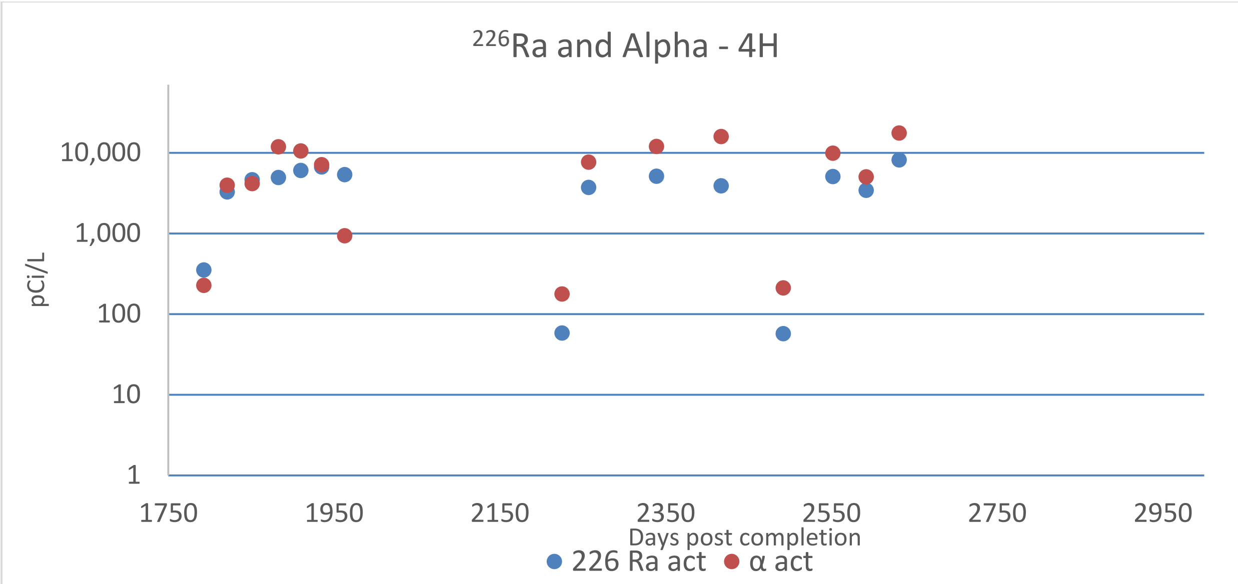

Figure 4.9. The relationship between gross alpha and ^{226}Ra as a function of time post completion at 4H.

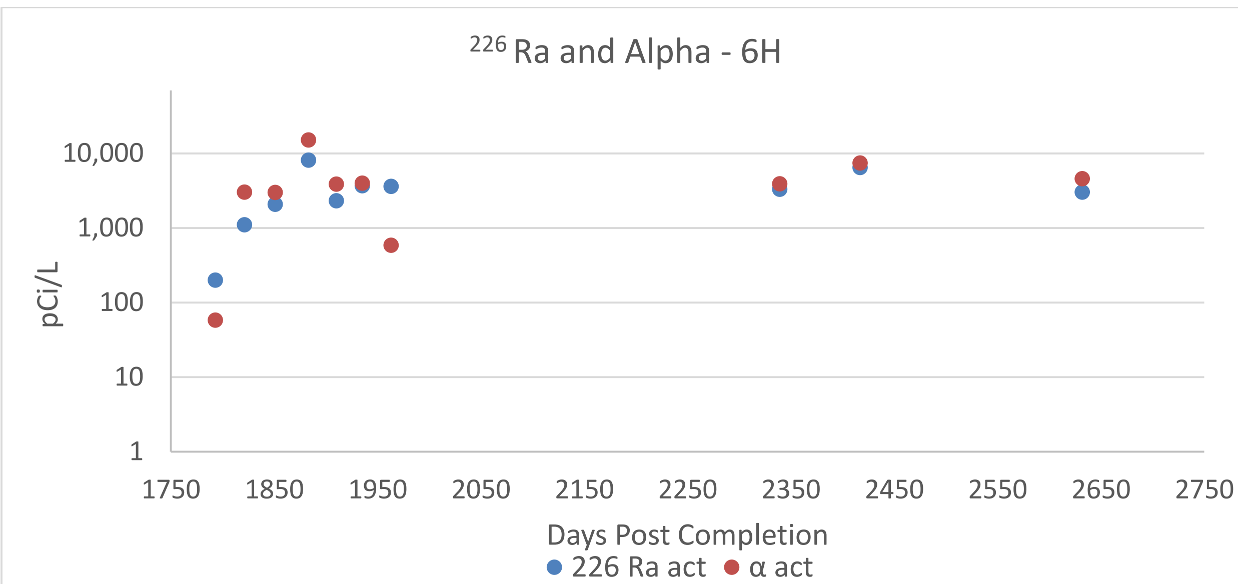

Figure 4.10. The relationship between gross alpha and ^{226}Ra as a function of time post completion at 6H.

Boggess Well

Solids

Analytical results have been received for drilling muds and cuttings collected at 9H at depth intervals of 8,500ft; 10,000ft; 11,000ft; 13,000ft; and 15,000ft. Anions (e.g. Br, Cl, and SO4) and Cations (e.g. Ba, Ca, Mg, Mn, Na, and Sr) are shown in Figure 4.11. Drill cuttings from 9H are predominately Calcium. The full list of solids parameters and methods are shown in Figure 4.3. Figure 4.12 depicts anions/cations of drilling mud and cuttings from 17H. Magnesium was more prevalent in the 8500 and 10000 depts for 17H in comparison to the same depths for 9H.

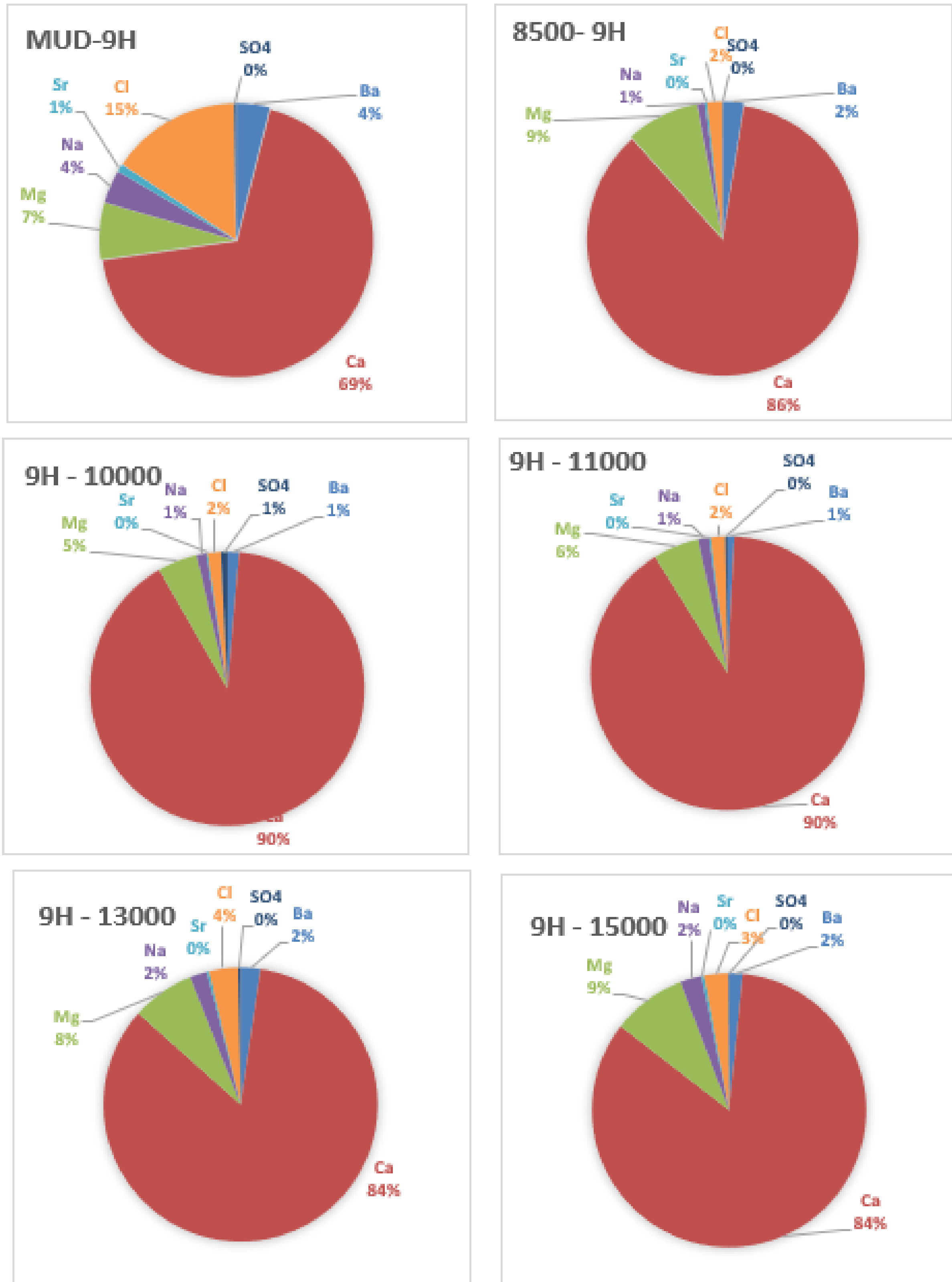

Figure 4.11. Anions/cations of drilling mud and cutting from 9H.

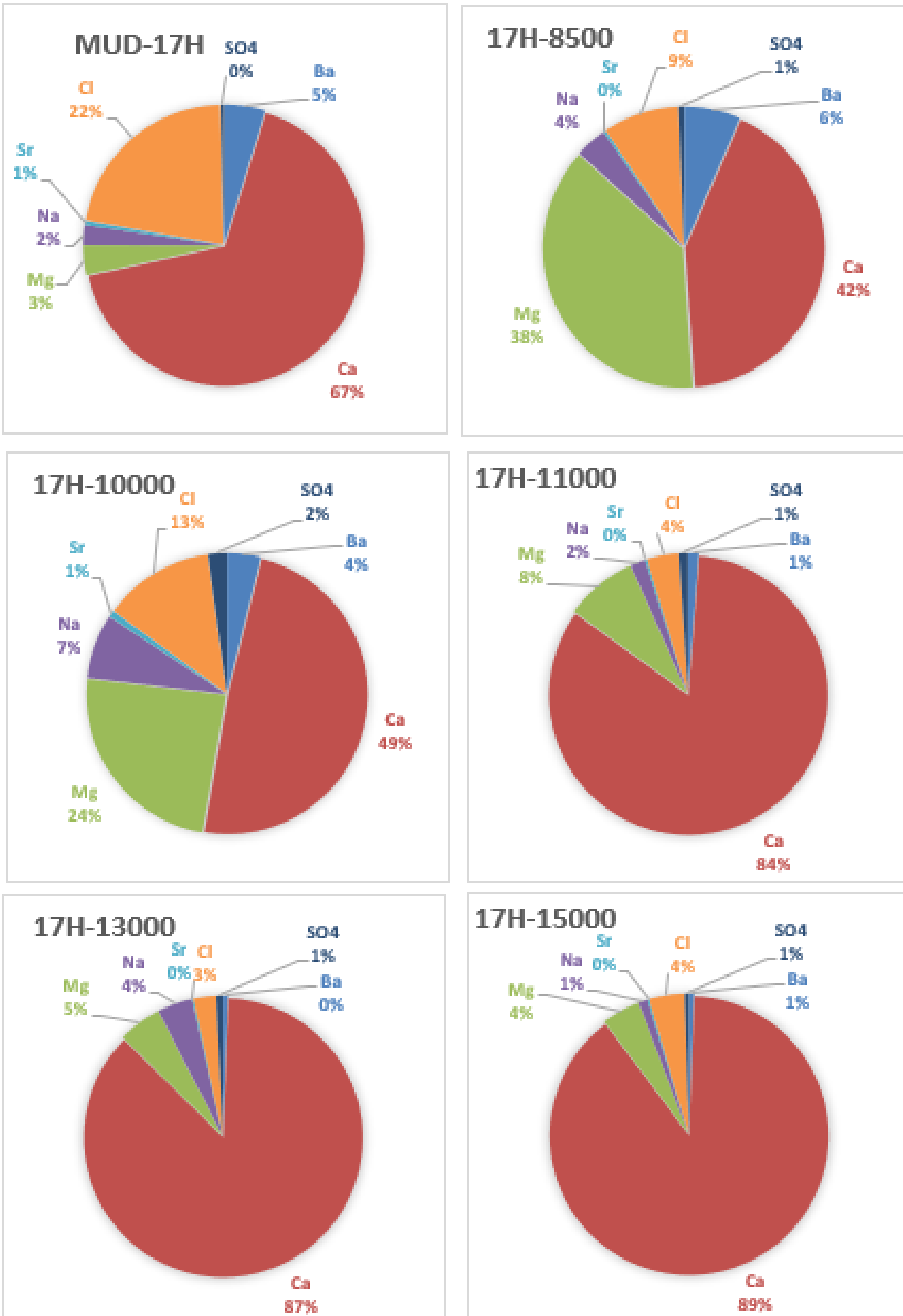

Figure 4.12. Anions/cations of drilling mud and cuttings from 17H.

Figure 4.13 and 4.14 depict combined radium 226 and 228 of solids in drilling mud and cuttings from 9H and 17H.

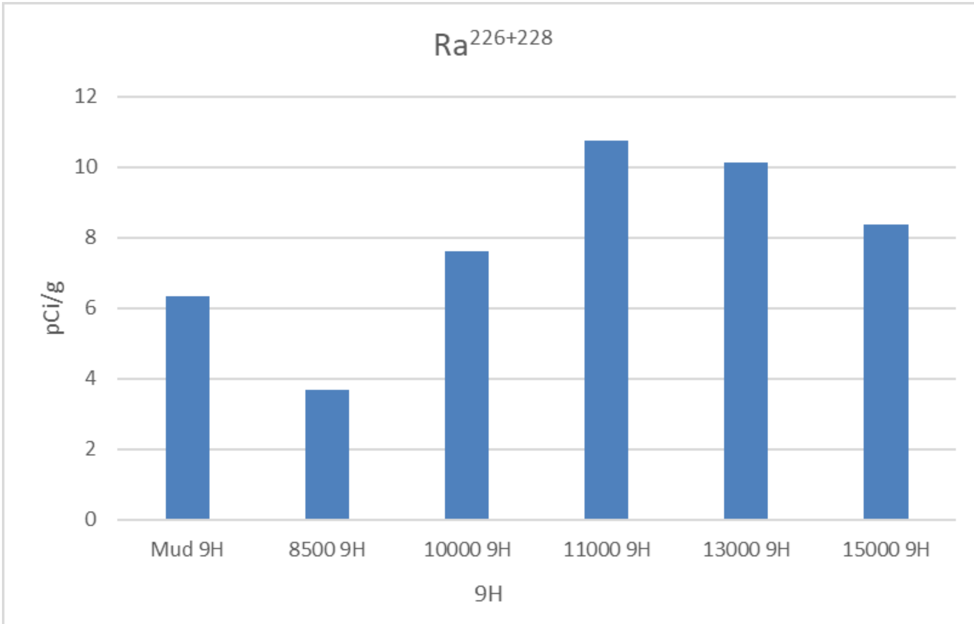

Figure 4.13. 9H Combined radium 226 and 228 for drilling mud and cuttings.

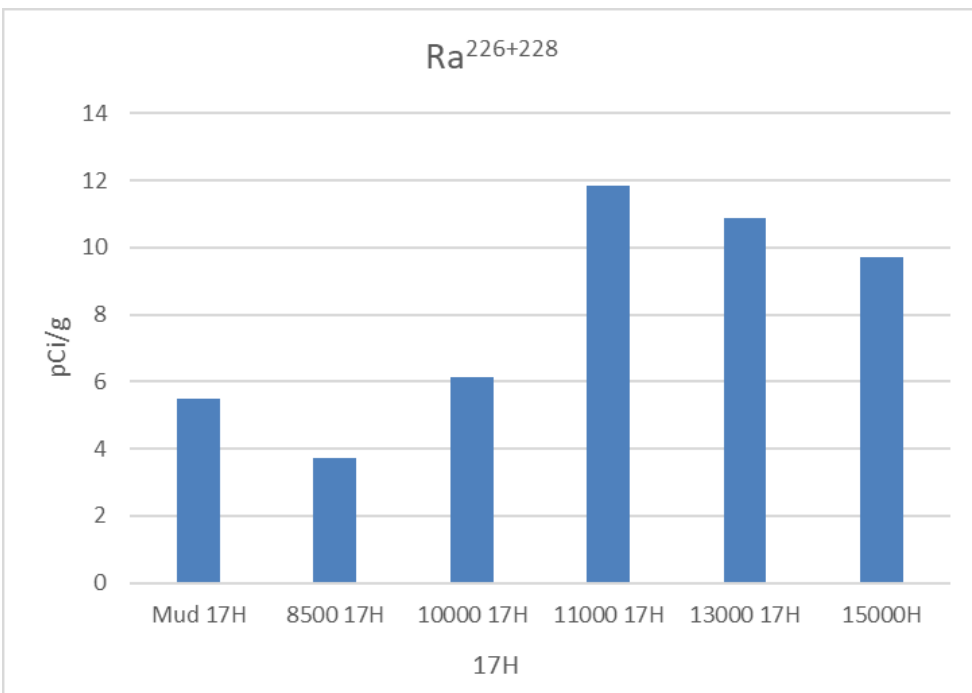

Figure 4.14. 17H Combined radium 226 and 228 for drilling mud and cuttings.

For comparison purposes, solids radium analysis from MIP 5H and 3H are shown in Figure 4.15 and Figure 4.16. In all wells analyzed, 3H and 5H from MIP along with 9H and 17H at Boggess, combined radium 226 and 228 remained below 12 pCi/g.

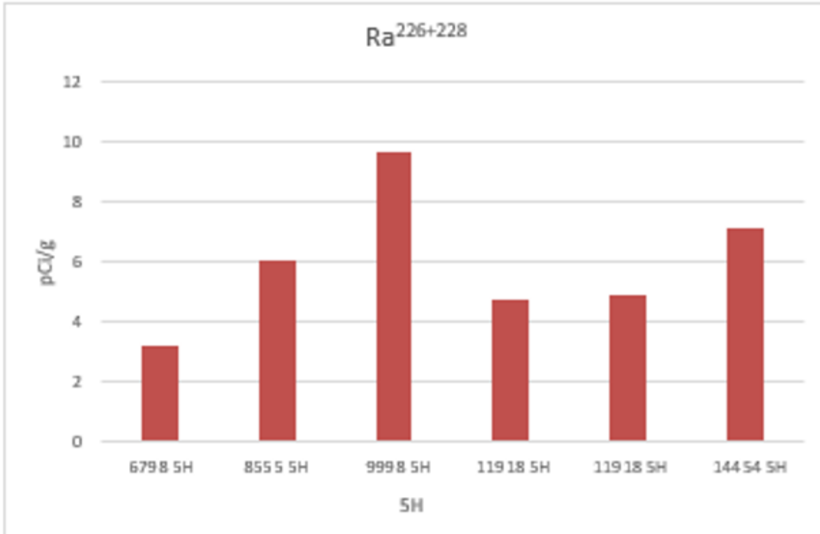

Figure 4.15. Combined Ra 226 + 228 for 5H MIP sites.

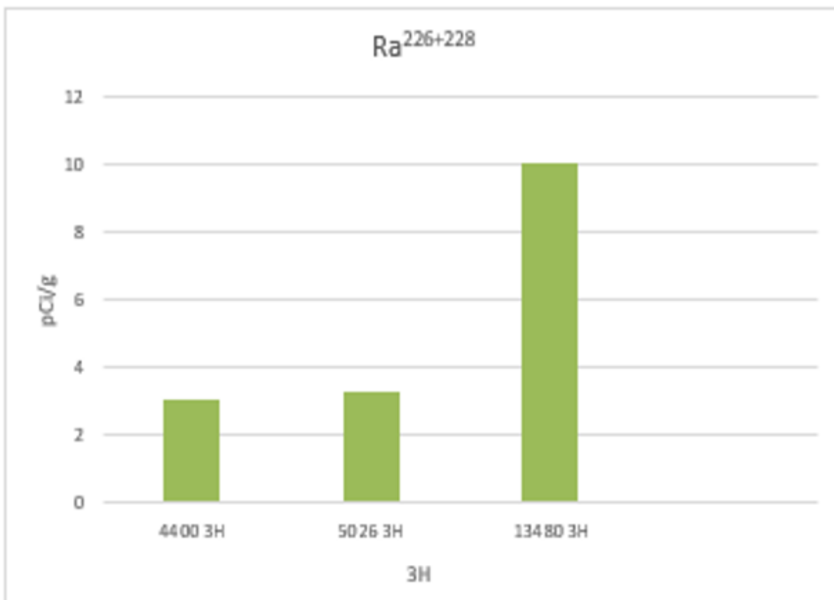

Figure 4.16. Combined Ra 226 + 228 for 3H MIP sites.

Major ions – trends in produced water chemistry

While makeup water was characterized by low TDS and a dominance of calcium and sulfate ions, produced water from initial flowback is essentially a sodium/calcium chloride water as noted in the earlier discussion regarding results from MIP. Preliminary results from days 0-14 at Boggess 9H and 17H are consistent with earlier results (Figure 4.17).

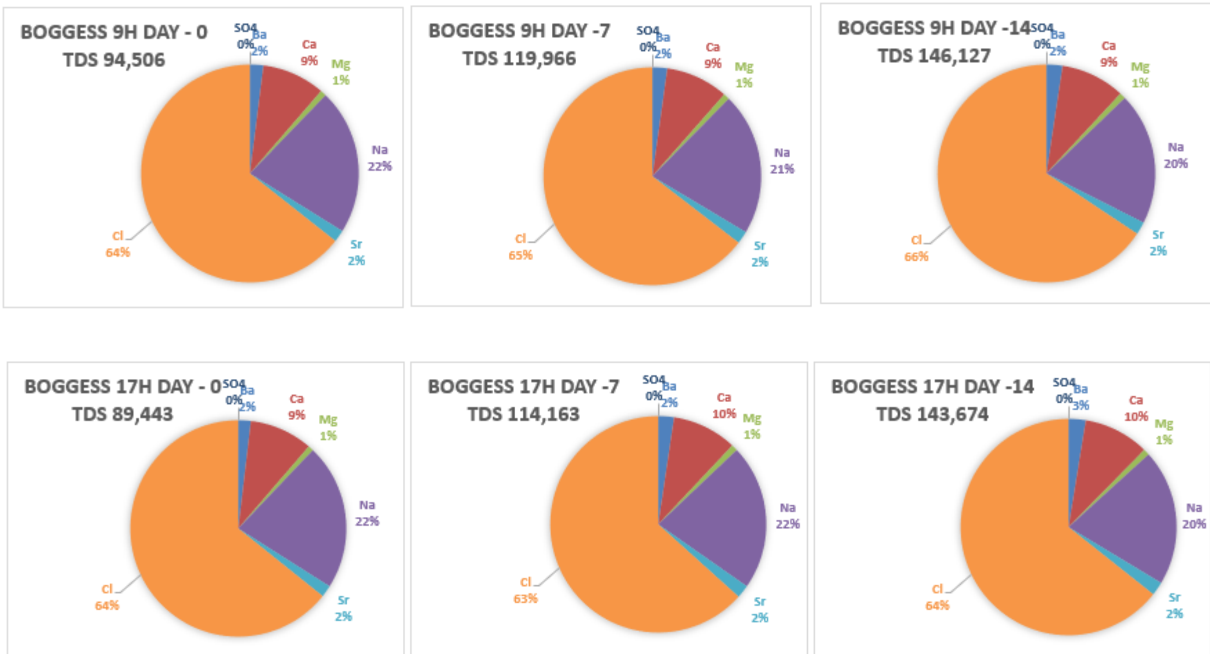

Figure 4.17. Major ion concentrations in produced water from wells BOGGESS 9H and 17H.

Preliminary TDS (sdc) at Boggess 9H and 17H show a slight upward trend between days 0 and 14 (Figure 4.18).

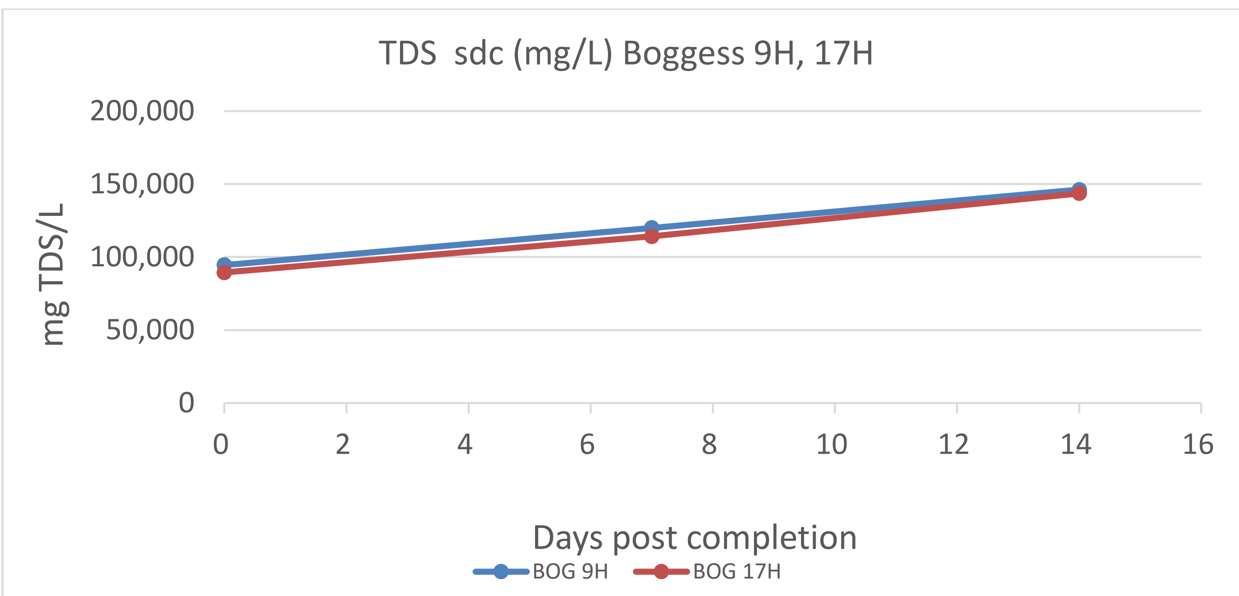

Figure 4.18. TDS (sdc) at Boggess 9H and 17H; days 0-14.

Water soluble organics and radio chemistries will be included in the next quarterly report. Results have not been received at the time of this report for days 0-14.

PUBLICATIONS & PRESENTATIONS

None for this quarter.

Plan for Next Quarter

We will continue monthly sampling at MIP and analyze flowback/produced water (FPW) from MIP 3H, 4H, 5H and 6H if they are online.

We will continue sampling at Boggess Pad control wells 9H and 17H. Plans include collection of flowback/produced water. Following the same protocols used at MIP wells, we will continue to characterize their inorganic, organic and radio chemistries.

Topic 5 – Environmental Monitoring: Air & Vehicular

Approach

Previously we reported on minor setbacks. We worked to overcome these issues and have completed the 12th audit in November of 2019. In addition, the complete OTM/Eddy Covariance Trailer Tower has been installed onsite (MIP) and has actively been collecting data since a week prior to Audit 12 See Figure 5.1 for location of the trailer tower with respect to major onsite components. The 12th audit included the use of the new fast methane/ethane analyzer.

Figure 5.1: Initial location of the eddy covariance trailer tower with respect to major components at MIP (MSEEL 1.0).

Preparation for energy audit continues. Previously we mentioned the use of CAFEE telemetry systems for data collection of primary engine activity. However, after multiple attempts to implement at the rig service yard, this method was abandoned. We have since reverted to refining the data collection system deployed in our previous efforts at MIP during development and those methods deployed across the country in our previous DOE program. The new DAQ includes 3 solid state computers equipped with WVU's CAFEE data acquisition software - Scimitar, a monitor, a mouse, a keyboard, 3 PCAN to USB connectors, 2 ICP COMs, and their respective power supplies and connections. Each primary engine will have its own dedicated computer to ensure robust data collection, see Figure 5.2. Scimitar has been modified to operate in an unmanned auto record mode. Once installed, the computers will collect engine activity data, temperatures from energy streams, and boiler fuel consumption on a predetermined period of 1-4 hours.

Figure 5.2: Final DAQ system for energy audits.

In addition, due to the sensitive nature of installing the fuel flow meters on an active boiler, we have updated the measurement circuits within the sensors to alleviate any fear of impacting operations. As such, the fuel flow meters were re-verified in the Engines and Emissions Research Laboratory. Standard diesel fuel was used and a 55-gallon drum was installed on a calibrated weight scale. A pump was installed in line with the recently updated fuel flow meter sensors. After collecting data from the test, the average flowrate of each of the flowmeters was calculated. And multiplied by the length in time of the test to obtain the total volume of fuel measured on each of the tests. Also, the fuel mass difference was measured from the scale and the volume of the fuel drained out from the container was calculated. Both flowmeters were compared to the mass-based calculated fuel volume and the largest percent difference found was 4.5%. For the second part of the test the maximum percent error was only 3.5%.

We are now working with Mr. Marcel Snider (Texas) and the local operators Mr. Stanley Dean and Mr. Travis Shirley on planning the install next quarter to complete the energy audit.

Results & Discussion

As presented above, the 12th audit was completed. The total average methane emissions were 619 g/hr. This reduced the arithmetic and geometric means of the MSEEL results to 5,691 and 987 g/hr., respectively. The arithmetic mean continues to be higher than expected due to Audits 7 and 8 which were due to excessive tank vent emissions. However, the geometric mean of the site is still within the bounds of the arithmetic and geometric means reported by Rella et al. As discussed before, we published a paper examining the first six audits with home to correlate methane emissions with site throughout of natural gas or produced water and will continue to examine this again now that the data set has doubled and will have quadrupled by the end of the program.

Regarding the ethane measurements, the ethane tended to be low as was expected due to previous gas analysis which showed produced gas consisted primarily of methane (>95%). We are working to recalibrate the ethane analyzer to hopefully improve the quality of simultaneous methane/ethane measurements.

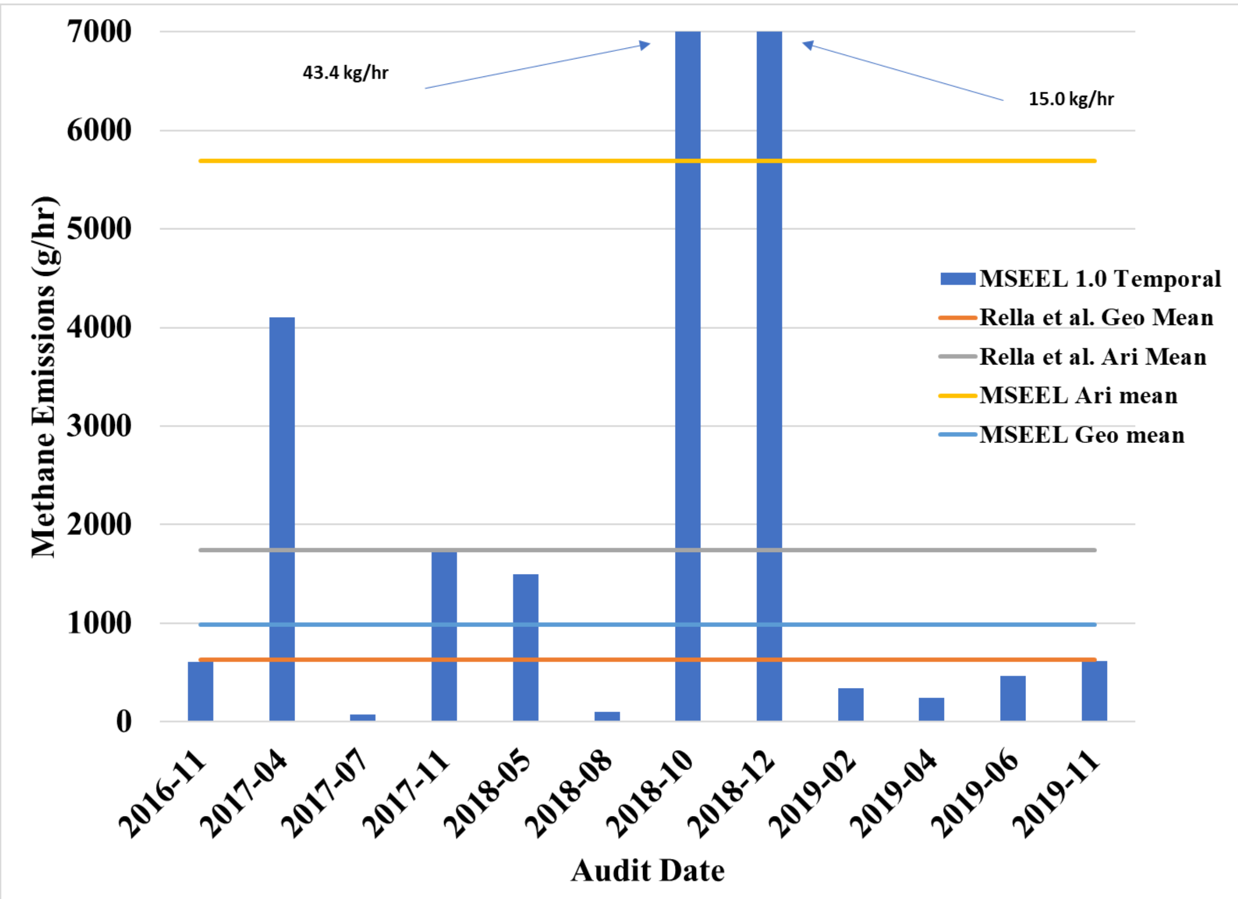

Figure 5.3: Results of Audits 1-12 at MIP (MSEEL 1.0).

PUBLICATIONS & PRESENTATIONS

Nothing to report.

Plan for Next Quarter

- Install energy audit system at active rig
- Collect energy data from the drilling of 1-2 wells.
- Begin QC/QA on energy audit data and continue with energy model development targeting combined heat and power system to replace boiler.
- Conduct Audit 13 at MIP (MSEEL 1.0).
- Begin data analysis from tower data.

Topic 6 – Water Treatment

This task is complete and will not be updated in future reports.

Topic 7 – Database Development

Approach

All MSEEL data is online and available to researchers (Figure 7.1 and 7.2). The website has been updated with the latest production beyond the end of the quarter (Figure 7.3). Work continues and we are adding data from MSEEL 3 Boggess Pad. We have improved the map interface for accessing well data.

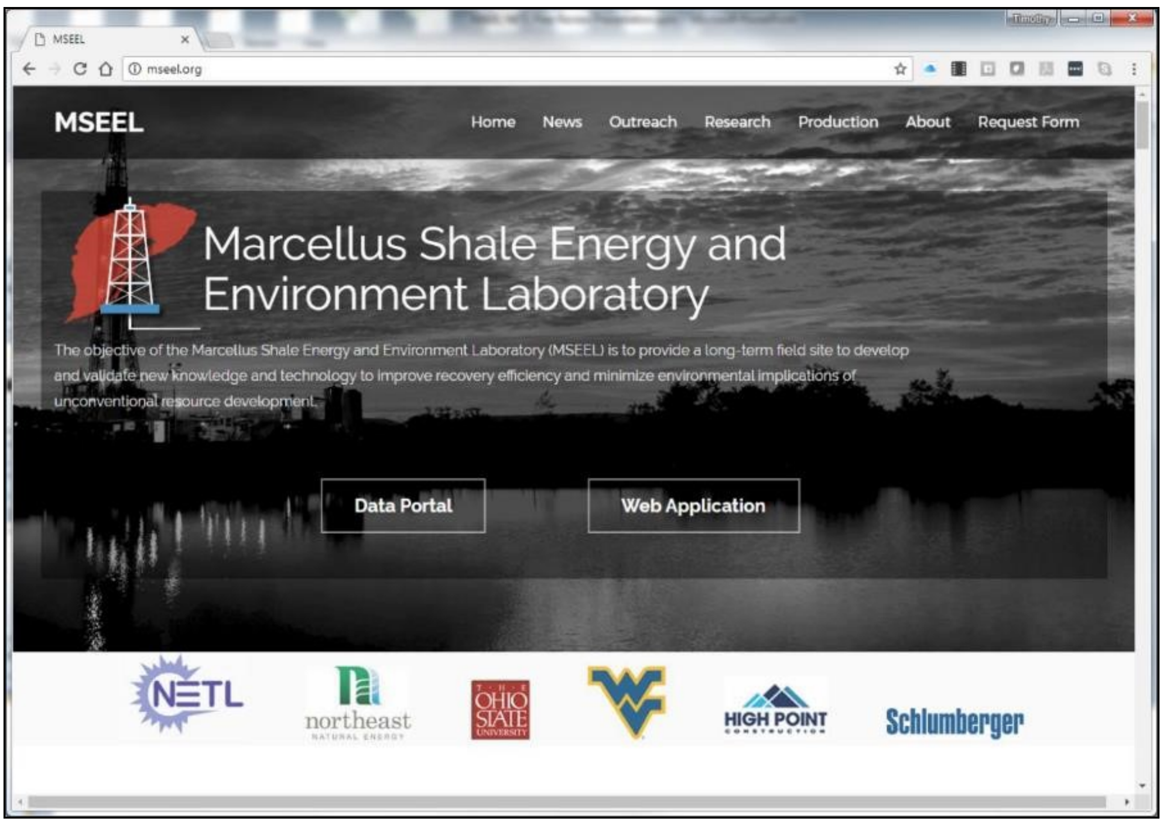

Figure 7.1: MSEEL website at http://mseel.org/.

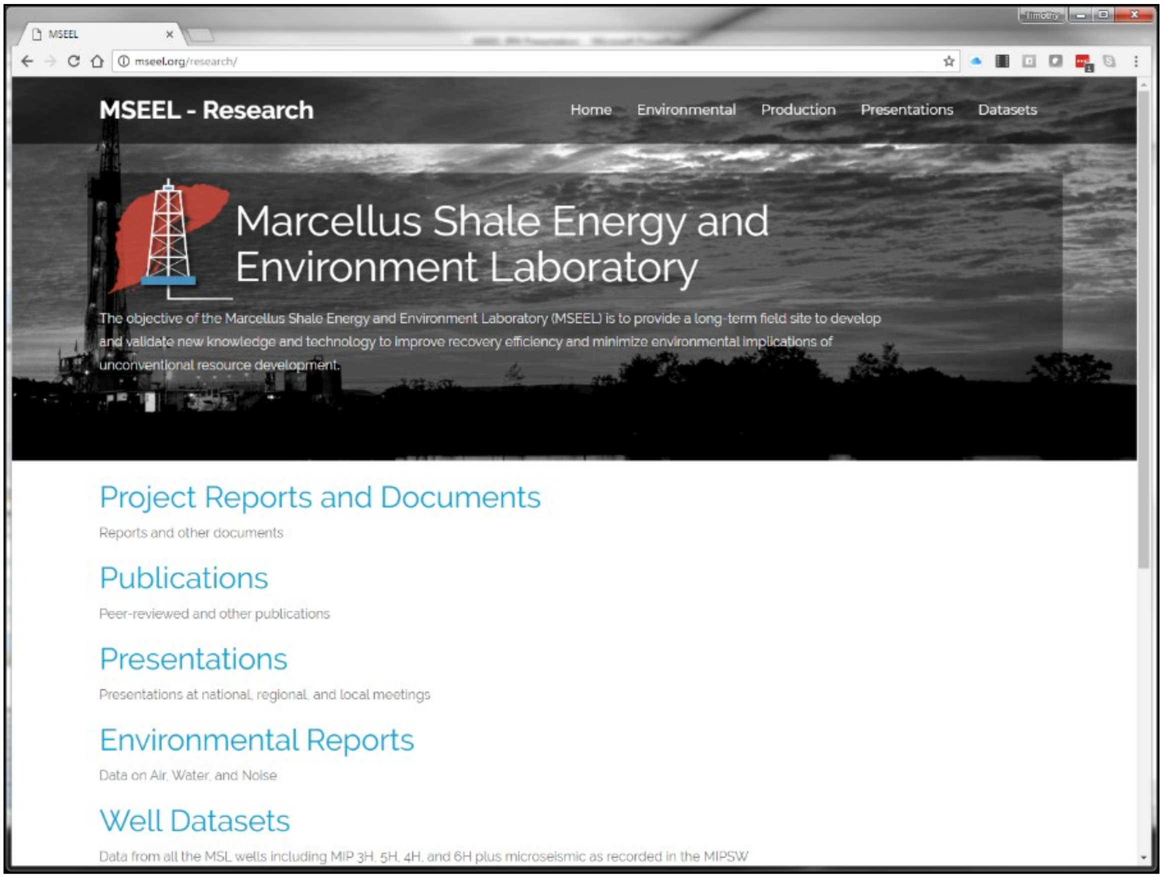

Figure 7.2: All data generated by the MSEEL project is available for download at http://mseel.org/.

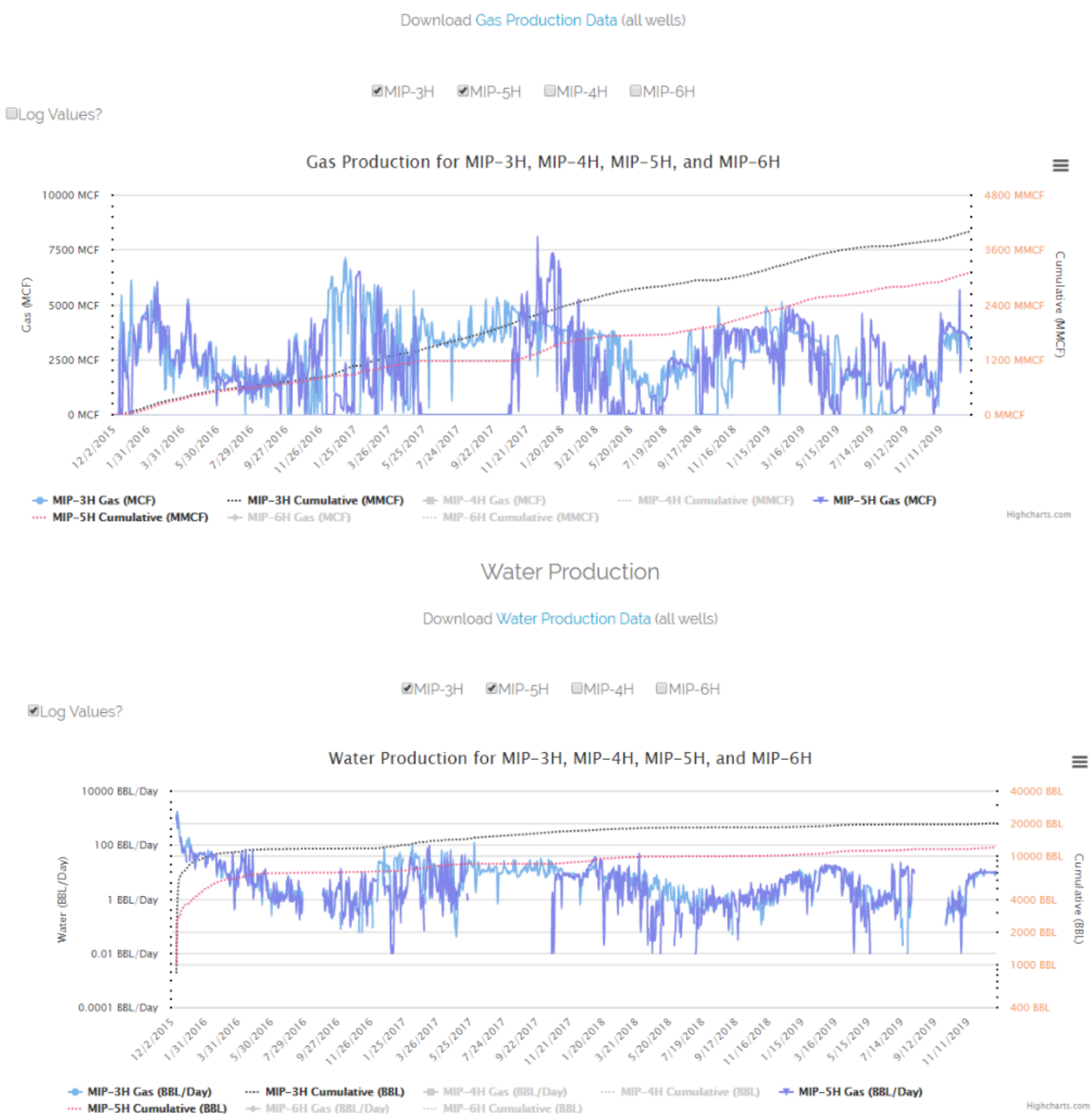

Figure 7.3: Gas and water production have been updated through the end of the quarter and are available at http://mseel.org/.

Results & Discussion

Data and publications are now available at http://mseel.org/.

Products

Web site enhanced and updated.

Plan for Next Quarter

Working to add data from the new Boggess Pad

Topic 8 – Economic and Societal

This task is complete and will not be updated in future reports.

Cost Status

Year 1

Start: 10/01/2014 End: 09/30/2019

Baseline Reporting Quarter

	Q1 (12/31/14)	Q2 (3/31/15)	Q3 (6/30/15)	Q4 (9/30/15)
Baseline Cost Plan	(From 424A, Sec. D)			
(from SF-424A)				
Federal Share	$549,000		$3,549,000	
Non-Federal Share	$0.00		$0.00	
Total Planned (Federal and Non-Federal)	$549,000		$3,549,000	
Cumulative Baseline Costs				
Actual Incurred Costs				
Federal Share	$0.00	$14,760.39	$237,451.36	$300,925.66
Non-Federal Share	$0.00	$0.00	$0.00	$0.00
Total Incurred Costs - Quarterly (Federal and Non-Federal)	$0.00	$14,760.39	$237,451.36	$300,925.66
Cumulative Incurred Costs	$0.00	$14,760.39	$252,211.75	$553,137.41
Uncosted				
Federal Share	$549,000	$534,239.61	$3,296,788.25	$2,995,862.59
Non-Federal Share	$0.00	$0.00	$2,814,930.00	$2,814,930.00
Total Uncosted - Quarterly (Federal and Non-Federal)	$549,000	$534,239.61	$6,111,718.25	$5,810,792.59

Start: 10/01/2014 End: 09/30/2019

Baseline Reporting Quarter

	Q5 (12/31/15)	Q6 (3/31/16)	Q7 (6/30/16)	Q8 (9/30/16)
Baseline Cost Plan	(From 424A, Sec. D)			
(from SF-424A)				
Federal Share	$6,247,367		$7,297,926	
Non-Federal Share	2,814,930		$4,342,480	
Total Planned (Federal and Non-Federal)	$9,062,297	$9,062,297.00	$11,640,406	
Cumulative Baseline Costs				
Actual Incurred Costs				
Federal Share	$577,065.91	$4,480,939.42	$845,967.23	$556,511.68
Non-Federal Share	$0.00	$2,189,863.30	$2,154,120.23	$0.00
Total Incurred Costs - Quarterly (Federal and Non-Federal)	$577,065.91	$6,670,802.72	$3,000,087.46	$556,551.68
Cumulative Incurred Costs	$1,130,203.32	$7,801,006.04	$10,637,732.23	$11,194,243.91
Uncosted				
Federal Share	$5,117,163.68	$636,224.26	$1,004,177.30	$447,665.62
Non-Federal Share	$2,814,930.00	$625,066.70	($1,503.53)	($1,503.53)
Total Uncosted - Quarterly (Federal and Non-Federal)	$2,418,796.68	$1,261,290.96	$1,002,673.77	$446,162.09

Start: 10/01/2014 End: 09/30/2019

Baseline Reporting Quarter	Q9 (12/31/16)	Q10 (3/31/17)	Q11 (6/30/17)	Q12 (9/30/17)
Baseline Cost Plan	(From 424A, Sec. D)			
(from SF-424A)				
Federal Share				$9,128,731
Non-Federal Share				$4,520,922
Total Planned (Federal and Non-Federal)				$13,649,653
Cumulative Baseline Costs				
Actual Incurred Costs				
Federal Share	$113,223.71	$196,266.36	$120,801.19	$1,147,988.73
Non-Federal Share	$0.00	$0.00	$0.00	$0.00
Total Incurred Costs - Quarterly (Federal and Non-Federal)	$113,223.71	$196,266.36	$120,801.19	$1,147,988.73
Cumulative Incurred Costs	$11,307,467.62	$11,503,733.98	$11,624535.17	$12,772,523.90
Uncosted				
Federal Share	$334,441.91	$138,175.55	$17,374.36	$700,190.63
Non-Federal Share	($1,503.53)	($1,503.53)	($1,503.53)	$176,938.47
Total Uncosted - Quarterly (Federal and Non-Federal)	$332,938.38	$136,672.02	$15,870.83	$877,129.10

Start: 10/01/2014 End: 09/30/2019

Baseline Reporting Quarter	Q13 (12/31/17)	Q14 (3/31/18)	Q15 (6/30/18)	Q16 (9/30/18)
Baseline Cost Plan	(From 424A, Sec. D)			
(from SF-424A)				
Federal Share				$11,794,054
Non-Federal Share				$5,222,242
Total Planned (Federal and Non-Federal)				$17,016,296.00
Cumulative Baseline Costs				
Actual Incurred Costs				
Federal Share	$112,075.89	$349,908.08	$182,207.84	$120,550.20
Non-Federal Share	$0.00	$31,500.23	$10,262.40	$4,338.00
Total Incurred Costs - Quarterly (Federal and Non-Federal)	$112,075.89	$381,408.31	$192,470.24	$124,888.20
Cumulative Incurred Costs	$12,884,599.79	$13,266008.10	$13,458,478.34	$13,583,366.54
Uncosted				
Federal Share	$588,114.74	$238,206.66	$55,998.82	$2,600,771.62
Non-Federal Share	$176,938.47	$145,438.24	$135,175.84	$832,157.84
Total Uncosted - Quarterly (Federal and Non-Federal)	$765,053.21	$383,644.90	$191,174.66	$3,432,929.46

Start: 10/01/2014

End: 09/30/2020

Baseline Reporting Quarter

	Q17 (12/31/18)	Q18 (3/31/19)	Q19 (6/30/19)	Q20 (9/30/19)
Baseline Cost Plan	(From 424A, Sec. D)			
(from SF-424A)				
Federal Share			$15,986,489	
Non-Federal Share			$9,180,952.00	
Total Planned (Federal and Non-Federal)			$24,867594.00	
Cumulative Baseline Costs				
Actual Incurred Costs				
Federal Share	$80,800.03	$133,776.98	$714,427.48	$1,136,823.21
Non-Federal Share	$4,805.05	$130,449.21	$4,099,491.20	$334,919.08
Total Incurred Costs - Quarterly (Federal and Non-Federal)	$85,605.08	$264,226.19	$4,813,918.68	$1,471,742.29
Cumulative Incurred Costs	$13,668,971.62	$13,933,197.81	$18,747,116.49	$20,218,858.78
Uncosted				
Federal Share	$2,519,971.59	$2,386,194.61	$5,864.202.13	$4,727,378.92
Non-Federal Share	$827,352.79	$696,903.58	$556,122.38	$221,203.30
Total Uncosted - Quarterly (Federal and Non-Federal)	$3,347,324.38	$3,083,098.19	$6,420,324.51	$4,948,582.22

Start: 10/01/2014

End: 09/30/2020

Baseline Reporting Quarter

	Q21 (12/31/19)	Q22 (3/31/20)	Q23 (6/30/20)	Q24 (9/30/20)
Baseline Cost Plan	(From 424A, Sec. D)			
(from SF-424A)				
Federal Share				
Non-Federal Share				
Total Planned (Federal and Non-Federal)				
Cumulative Baseline Costs				
Actual Incurred Costs				
Federal Share	$3,098,337.44			
Non-Federal Share	$3,163,776.74			
Total Incurred Costs - Quarterly (Federal and Non-Federal)	$6,262,114.18			
Cumulative Incurred Costs	$26,480,972.96			
Uncosted				
Federal Share	$1,629,041.48			
Non-Federal Share	-$2,942,573.44			
Total Uncosted - Quarterly (Federal and Non-Federal)	-$1,313,531.96			

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