PS Lessons Learned From Recent CCS Well Construction Projects*

A. Duguid[1], Jim Kirksey[2], George Koperna[3], and David E. Riestenberg[4]

Search and Discovery Article #80656 (2018)**
Posted November 26, 2018

*Adapted from poster presentation given at AAPG 2018 Annual Convention & Exhibition, Salt Lake City, Utah, United States, May 20-23, 2018
 DOI:10.1306/80656Duguid2018

[1]Battelle, Columbus, OH, United States (Duguid@battelle.org)
[2]Loudon Technical Services, Charleston, WV, United States (jkirksey1@loudontechsvcs.com)
[3]Advanced Resources International, Arlington, VA, United States
[4]Advanced Resources International, Knoxville, TN, United States

Abstract

Carbon Capture and Storage (CCS) wells are constructed using standard oilfield equipment and generally supervised by oilfield personnel; however, the goals of CCS wells are much different from a typical oil and gas well. The standard to which wellbore integrity is held in CCS wells is higher than the standard for a conventional oil and gas well because they are regulated by the US EPA as part of the Underground Injection Control (UIC) program. The methods used for evaluation are more sophisticated as well including detailed logging and integrity characterization. From the initial well planning and all the way through well construction process it has to be emphasized that the goal of the well drilling is to drill a hole that will facilitate a successful cementing operation; i.e., as straight and as close to gauge as possible. A slight change in penetration rate or different pump pressures can adversely affect the borehole as well as the cement integrity for the entire well.

Recent experience with CCS well construction highlights challenges. Three CCS monitoring wells were constructed recently as part of a project called “Establishing an Early Carbon Dioxide Storage (ECO2S) Complex in Kemper County, Mississippi” (Project ECO_2S). UIC requirements specify that the long-string casing be cemented to surface, to simplify cementing operations each well was cemented in a single stage. Single-stage cementing required balancing the slurry properties and density with set cement properties and CO_2 resistance. The integrity of each of the wells was assessed considering the geologic setting using open-hole logs, the hole conditions, casing setting and centralization details, cement pumping data, and cased-hole integrity logs.

Two wells had cement returns surface. One well lost much of the cement to the surrounding formations (no returns to surface). Technical contributions of this work include how detailed logging can be used to identify contaminated cements, how cement operations and hole conditions can be designed reduce poor cement outcomes, how to balance operational needs for successful cementing with long term requirements of the well and how cultural differences in planning and operations between oil and gas and CCS can affect integrity. Overall, the results of the Project ECO_2S well integrity assessment provides lessons learned to construction of CCS and other wells that may need to be constructed to withstand CO_2 exposure including CO_2-EOR wells.

LESSONS LEARNED FROM RECENT CCS WELL CONSTRUCTION PROJECTS

A. Duguid[1] (Duguid@battelle.org), Jim KIrksey[2], George Koperna[3], David E Riestenberg[3]

[1]Battelle, [2]Loudon Technical Services, [3]Advanced Resources International

INTRODUCTION

Injection wells for carbon capture and storage (CCS) projects have strict construction requirements as part of the US Environmental Protection Agency (US EPA) Underground Injection Control (UIC) Program. To date, all wells (injection and monitoring) associated with commercial-scale projects have been constructed to US EPA UIC Program Class VI injection well specifications using CO_2 resistant cements and materials. UIC requirements call for detailed logging and integrity characterization after construction of project wells which creates data that can provide feedback on well construction practices and be used to inform other CO_2 projects that contemplate storage. Recent experience with the construction of three CCS monitoring wells highlights challenges with cement slurry design and placement. Three CCS monitoring wells have been constructed in Northeast Mississippi as part of a project called "Establishing an Early Carbon Dioxide Storage Complex in Kemper County, Mississippi" (Project ECO_2S).

BACKGROUND

Project ECO_2S is funded under Phase 2 of the United States Department of Energy's Carbon Storage Assurance Facility Enterprise (CarbonSAFE) Program. The objective of the program is to develop commercial carbon storage projects capable of storing CO_2 by 2025. Project ECO_2S is demonstrating that the subsurface adjacent to the Kemper County Energy Facility has the potential to economically store commercial volumes of CO_2 within the regional deep saline aquifer system.

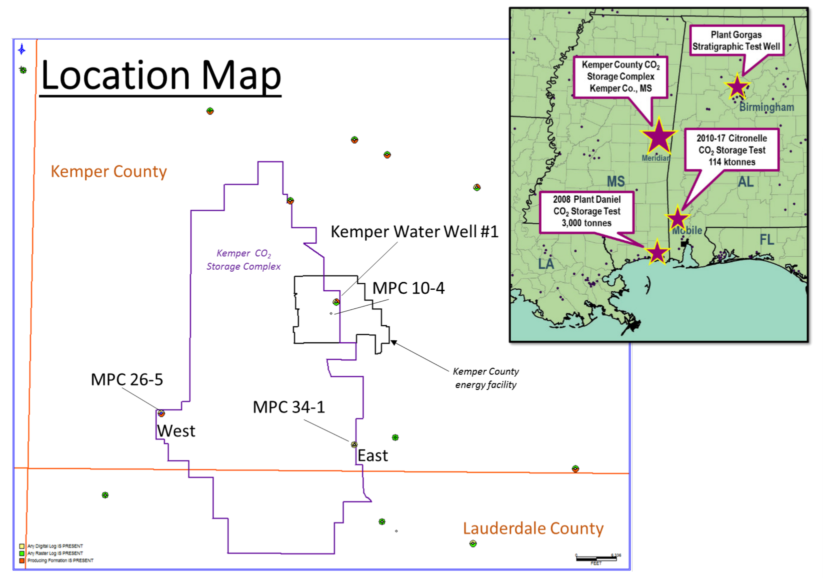

Figure 1 Project ECO_2S map showing the location of all three monitoring wells

The US EPA Class VI requirements require monitoring to ensure that stored CO_2 behaves as expected in the subsurface and does not pose a risk to underground sources of drinking water (USDW). Three wells, MPC 26-5, MPC 34-1, and MPC 10-4, were drilled to allow detailed characterization of the subsurface at the site. The wells were then completed as monitoring wells following the UIC regulations (Part 146 in the US Code of Federal Regulations) for construction of Class VI injection wells. The UIC Class VI regulations calls for casing, cement, and other materials to be compatible with stored CO_2 and subsurface conditions. The casing and cementing program must prevent movement into or between USDWs. A cement isolation log must be run to radially evaluate the location and quality of cement after construction.

MONITORING WELL DESIGN AND CONSTRUCTION

The wells were designed to meet the UIC Class VI construction requirements with both the surface and long string casings cemented to surface. The long string sections of the well were designed with chrome casing and CO_2 resistant cement across the potential storage zones and through the caprock. The wells were drilled to approximately 5400 to 5700 ft.

To simplify cementing operations each well was cemented in a single stage. Single-stage cementing required balancing the slurry properties and density with set cement properties and CO_2 resistance. The integrity of each of the wells was assessed considering the geologic setting using open-hole logs, the hole conditions, casing setting and centralization details, cement pumping data, and Schlumberger's ultrasonic Isolation Scanner Cement Evaluation Service. The Isolation Scanner provided radial maps of the casing and cement to assess quality and placement.

The results of the cementing varied greatly between the wells. Two wells successfully had cement returns surface. One well lost much of the cement to the surrounding formations with no returns to surface. The well integrity assessment using all available data showed each well has integrity across the storage formation. The assessment identifies the likely reasons related to hole conditions, casing location, and slurry density that cement failed to reach the surface in one well. It also identifies cement contamination and microannulus other wells and identifies the likely causes.

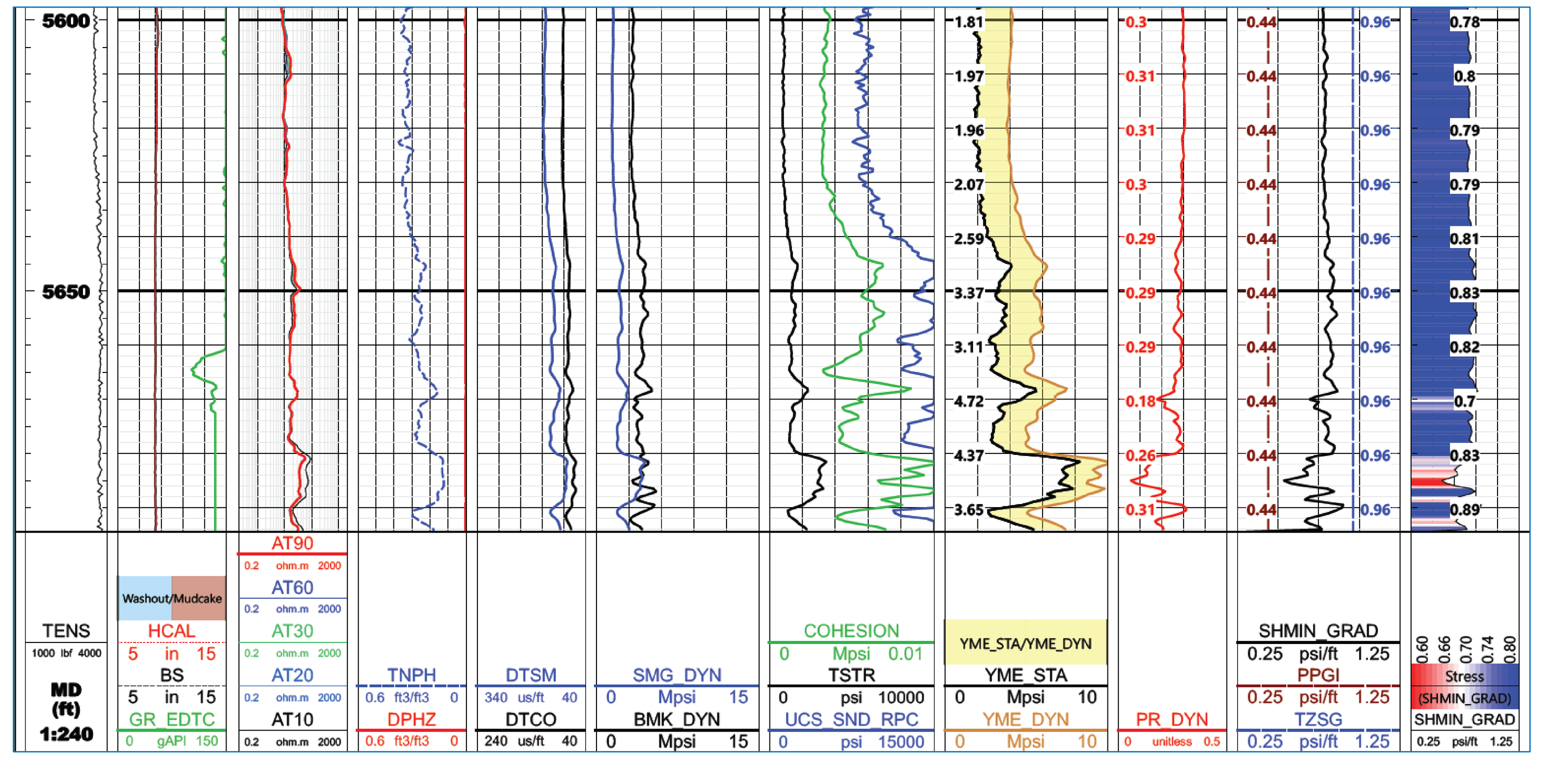

Figure 2 Open hole log data from MPC 34-1 showing low fracture gradient below the Paleozoic unconformity

Table 1 Well construction details for each well

Well	MPC 26-5	MPC 34-1	MPC 10-4
Surface Hole Size	12.25''	12.25''	13.5''
Surface Hole Depth	2500 ft	2500 ft	2500 ft
Surface Casing	12.25" Open hole with 9 5/8'' 40# LTC J-55 set at 2489'. Cemented to surface	12.25" Open hole with 9 5/8'' 40# LTC J-55 set at 2495'. Cemented to surface	13.5" Open hole 10 3/4''45.5# BTC J-55 set at 2505'. Cemented to surface
Surface Cement	50 bbls 10.5 ppg Spacer	30 bbls 10.5 ppg Spacer	30 bbls 10.5 ppg Spacer
	Lead: 210 bbls 65/35 cmt-poz 6% gell 1.97 cu.ft/sk 12.4 ppg	Lead: 246 bbls 65/35 cmt-poz 6% gell 2.1 cu.ft/sk 12.0 ppg	Lead: 233 bbls 65/35 cmt-poz 6% gell 2.1 cu.ft/sk 12.0 ppg
	Tail Cement: 69 bbls Class A 1.18 cu ft/sk 15.6 ppg	Tail Cement: 59 bbls Class A 1.18 cu ft/sk 15.6 ppg	Tail: 65 bbls Class A 1.18 cu ft/sk 15.6 ppg
	Displaced with 9.6 ppg mud	Displaced with 9.6 ppg mud	Displaced with 9.6 ppg mud
	Logging confirmed cement to surface	Logging confirmed cement to surface	Logging confirmed cement to surface
Long String Hole Size	8.5''	8.5''	9.875''
Total Depth	5877 ft	5748 ft	5440 ft
Mud Weight	9.4 ppg	9.4 ppg	9.1 ppg
BHST	135 F	140 F	128 F
Long String Casing	5 1/2''17# Cr13-85 JFE-Bear 5865'-3002' and 5 1/2'' 17# L-80 LTC 3002-surface	5 1/2''17# Cr13-85 JFE Bear 5705'-2846' and 5 1/2'' 17# L-80 LTC 2846'-surface	7" 29# Cr13-85 JFE Bear 5440'-2792' and 7" 26# N-80 LTC 2792'-surface
Centralization	Centralization: One centralizer every joint for first 66 joints (3140'), every other joint to 2435' and every third joint to surface	Centralizer every joint for first 68 joints (2906'), every other joint to 2287' and every third joint to surface	Centralizer every joint for first 65 jts (2792'), every other joint to 2531' and every third joint to surface
Primary Cement	well cemented to surface in one stage	well cemented to surface in one stage	well cemented to surface in one stage
	50 bbls 11.0 ppg Spacer	50 bbls 10.5 ppg Spacer	60 bbls 11.0 ppg Spacer
	Lead: 65/35 cmt-poz 6% gell 1.92 cu ft/sk,12.7 ppg	Lead: 160 bbls 65/35 cmt-poz 6% Gell 1.95 ccu ft/sk 12.5 ppg	Lead: 327 bbls LiteCRETE lead at 11.5 ppg,
	Tail Cement: NeoCEM 1.13 cu ft/sk, 14.5 ppg	Tail Cement: 182 bbls 50/50 cmt-poz, 1.27 cu ft/sk, 14.5 ppg	Tail: 155 bbls 50/50 Cmt-Poz 1.27 cu ft/sk 14.5 ppg
	Displaced with 134 bbls fresh water	Displaced with 131 bbls fresh water.	Displaced with 202 bbls fresh water
	Note: Mixability problems with tail cement causing rates to be very low, poor mud removal as result.	Note: Lost returns after droping the plug. Final lift pressure 800 psi	Note: Full returns. 140 bbls mud-cement mix and 60 bbls good cement to surf
	Held 500 psi on casing while logging	Held 500 psi on casing while logging. Log indicated cement top at 3100 top of tail at approximately 4100 ft	Held 500-1000 psi on casing while logging. Held 1500 whle logging inside surface casing
Remedial Cement		Perforated 2939'-40' with 4 shots. Broke circulation	
		Cemented through tubing below retainer with: 50 bbls	
		50 bbls Mud Flush	
		Lead: 110 bbls 65/35 cmt-poz 1.95 cu ft/sk, 12.5 ppg	
		Tail 55: bbls 50/50 cmt-poz, 1.27 cu ft/sk, 14.5 ppg and 10 bbls Class A, 1.18 cu ft/sk, 15.8 ppg	
		Circulated 20 bbls to surface	
		logging confirmed cement to surface	

LESSONS LEARNED

MPC 26-5

The cementing service provider recommended a new system for use in CCS wells. Physical makeup was proprietary. Lab testing prior to the cementing the well indicated that the system was very viscous and could pose mixing problems. The service provider altered the system and improved the mixability so that the lab report rated it fair. On the actual job the system was very hard to mix and the pump rate had to be slowed to an average rate of 2.3 bpm to achieve proper density control. This low and varied rate had a negative effect on mud removal so sections of the well appear to have mud contamination issues.

Lesson learned: Lab testing is very important and results should be monitored closely. Vendor and cement system selection should be taken with care and ensure simplicity and full understanding for field operations.

MPC 34-1

This well experienced a loss of returns during cementing just as the leading edge of the spacer system was entering the surface casing and pumping was shut down to launch the wiper plug. The hole likely bridged to the point that the equivalent circulating density was raised enough to break down the natural fracture system encountered just below the Paleozoic Unconformity (Figure 2). As a result, the cement top was lower than expected as required by Class VI requirements (Figure 3). This well was successfully remediated some months later by perforating the casing and circulating cement to surface and then squeezing the perforations.

Lessons learned: Good hole cleaning practices and surface execution are very important in obtaining a good cement job. Another lesson learned is that with good planning a well that has a compromised cement top can be successfully repaired.

MPC 10-4

The drilling contractor was changed prior to drilling this well. A larger hole was drilled (13.5") and larger casing was run (7"). A caliper log run in the well indicated severe washouts and hole enlargement over a large portion of the open hole. Although the spacer volume was increased and the pipe well centralized mud removal was compromised due to the number of washouts. This was detected during the cementing operation when cement contaminated mud was encountered at the surface very early in the cementing process. Pump rates were maximized and the lower section of the well has good bonding but inside the surface casing and in the area just below there is evidence of mud contamination.

Lessons learned: Close attention is required during drilling to achieve adequate penetration rates and good hole cleaning without encountering hole enlargement. It is virtually impossible to obtain good mud removal in a highly washed out wellbore.

CONCLUSIONS

The construction of the monitoring wells for Project ECO_2S provided an opportunity to identify and document problems that may affect the construction of CCS wells at any project. Each of the wells had sections of the cemented annulus capable of providing isolation sufficient for a CO_2 storage project. Each of the wells encountered problems that are common within conventional oil and gas wells.

CCS wells are constructed using standard oilfield equipment and generally supervised by oilfield personnel; however, the goals of CCS wells are much different than a typical oil and gas well. The standard to which wellbore integrity is held in CCS wells is higher than the standard for a conventional oil and gas well. The methods used for evaluation are also generally more sophisticated as well. From the initial well planning and all the way through well the construction process it has to be emphasized that the goal of the well drilling is to drill a hole that will facilitate a successful cementing operation; i.e., as straight and as close to gauge as possible. A slight change in penetration rate or different pump pressures can adversely affect the borehole as well as the cement integrity for the entire well. As a result, successful well planning requires attention to the cultural issues as well as the technical issues.

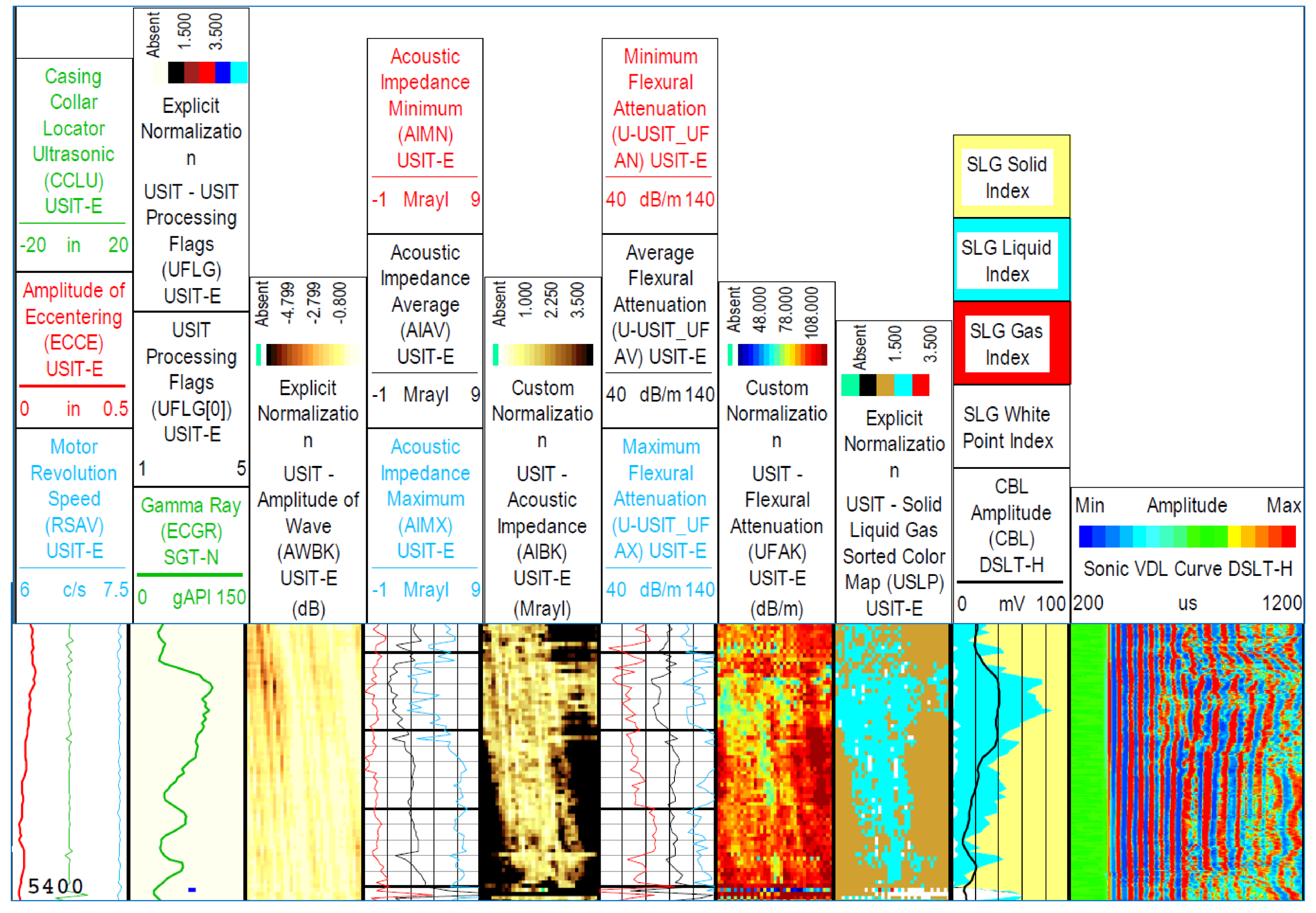

Figure 3 Isolation Scanner log section showing mud contamination in MPC 26-5

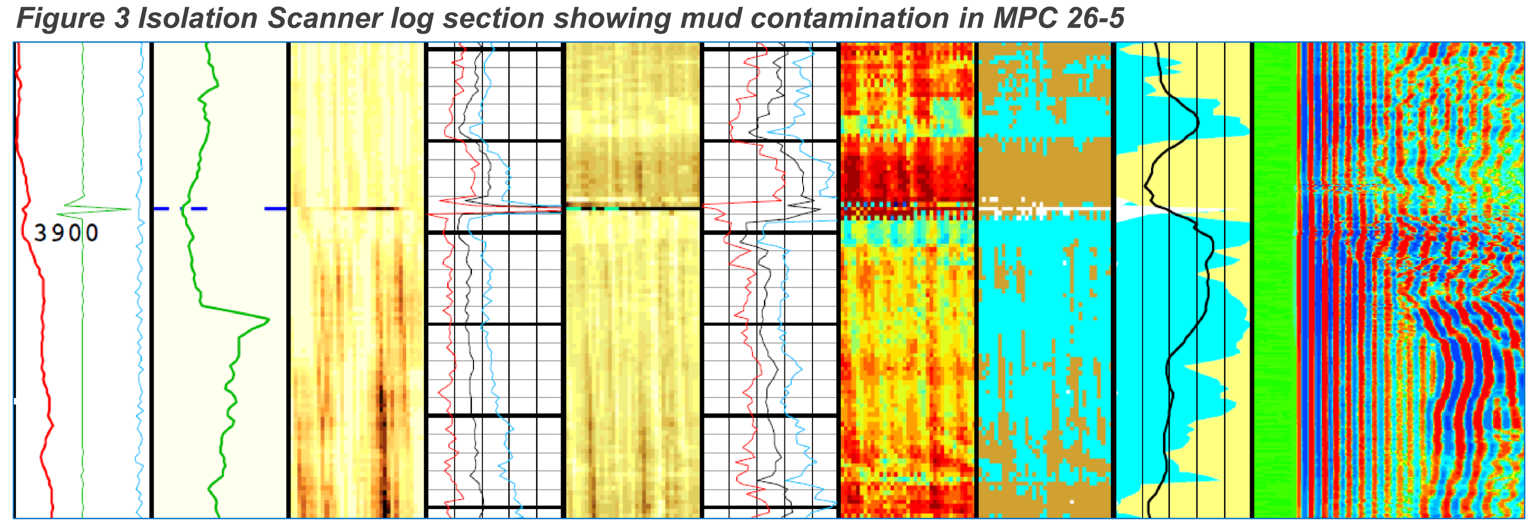

Figure 4 Isolation Scanner log section showing patchy cement near the top of the original cement in MPC 34-1

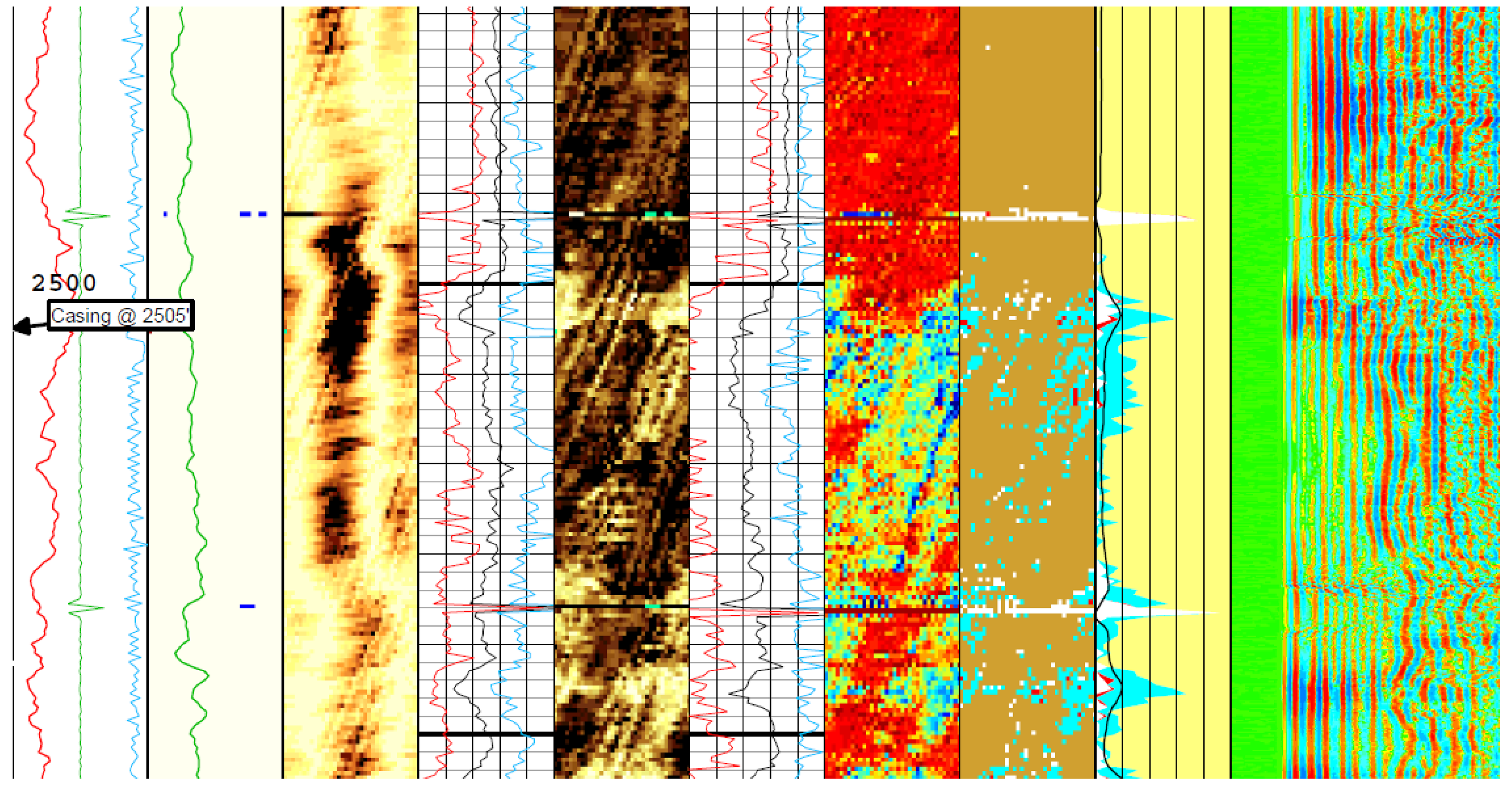

Figure 5 Isolation Scanner log section showing mud contamination just below the surface casing in MPC 10-4

AAPG ACE 2018
May 20 – 23, 2018. Salt Lake City, Utah

This work was funded by DOE NETL (DE FE 0029465)