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A Geotechnical Acoustic Survey to Address Well Abandonment Options for A Toppled Offshore Platform

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Abstract

In September 2004, within the Mississippi Canyon Area, a platform was toppled by a subsea mudslide that occurred during Hurricane Ivan. The platform was dragged off the station approximately 500 feet with all the associated well conductors buried under the sediment. Oil continues to flow through these conductors today, which is being collected subsea and sent to shore for recycling.

To permanently plug and abandon these wells using any top kill solution would require knowledge of the conductors' burial depth beneath the seabed. Standard geotechnical survey methodologies like ground penetrating radar could not determine the depth of conductor burial. An Acoustic Corer [1,2,3] survey was conducted to successfully identify the conductors' location, orientation, and depth of burial.

The Acoustic Core [2,3] device consists of a High-Frequency Chirp (HF), a Low-Frequency Chirp (LF), and a Parametric Source. The vertical position of linear features and anomalies is determined by converting acoustic reflection transmission-reception times to depth utilizing a velocity model representative of the survey site. Sixty-three focused Acoustic Corer scans were successfully acquired along four survey grid lines Post preliminary scan processing; the sixty-three Acoustic Core data sets were then individually topographically corrected and processed as a singular large area seismic volume encapsulating the whole regions of the four survey grid lines. The data collected

along the lines were combined, resulting in 3D views of the sub-seabed down to a depth of approximately 200 ft, and the conductors' presence, orientation, and depth of burial were highlighted with clarity. This paper will present the results of this survey and the implications of well abandonment options that will adhere to BSEE regulations.

Introduction and Background

Twelve miles off the coast of Louisiana, a low probability high consequence event occurred in September of 2004 during Hurricane Ivan, which resulted in a producing oil and gas platform being toppled over in approximately 470 ft of water and dragged off station approximately 500 ft. Twenty-eight oil and gas well conductors were buried beneath the mudline under sediment and have been discharging oil and gas into the Gulf of Mexico since the incident occurred.

In November 2018, the United States Coast Guard partially federalized the worksite and solicited oil spill response proposals to design, build, install and operate a system to capture the ongoing release of oil at the site. The subsea RRS (Rapid Response System) solution that was proposed and built included a subsea collection device supported by the downed jacket lying on the seabed. The collection device was placed on a porch suspended off the jacket leg directly above four hydrocarbon plumes emanating from the seabed. The collected hydrocarbons were routed to a patented subsea separator that separates the oil from the water and gas. Oil is sent to subsea oil containment vessels on top of the jacket and offloaded via a hydraulic pump every month to a surface vessel, where the crude is then transported to shore and recycled.[4]

To permanently plug and abandon these wells using any top kill solution would require knowledge of the conductors' burial depth beneath the seabed. Standard geotechnical survey methodologies like ground penetrating radar could not determine the depth of conductor burial. An Acoustic Corer [6] survey was conducted to successfully identify the conductors' location, orientation, and depth of burial beneath the mudline [5,6].

Acoustic Corer Technology

The Acoustic Corer (AC) is a 3-D sub-bottom imaging technology that uses multi-aspect acoustic imaging to delineate sub-seabed stratigraphies and buried geohazards such as boulders, complex layers, shallow gas, and abandoned seabed infrastructure (i.e. conductors buried beneath the midline).

The Acoustic Corer unit comprises two sonar heads attached to each arm of a 40ft (12m) boom. High-Frequency Chirp (HF), Low-Frequency Chirp (LF) and a Parametric Source are utilized. A tight grid of acoustic data is acquired as the boom rotates 180°, creating a 360° acoustic core [1,2,3]. Once data has been collected at a survey site, the device is moved to the following seabed survey location. For this application, the device was modified to deploy on a suction pile to allow for survey at the seabed over a soft, low load-bearing sediment.

The vertical position of linear features and anomalies is determined by converting acoustic reflection transmission-reception times to depth utilizing a velocity model representative of the survey site. The velocity model is determined via the semblance analysis of JYG-Cross data[1,2,3]. Compressional wave velocities increase with increasing depth from 1460m/s at the mudline to 1960m/s at full penetration depth. These velocity profiles are used in subsequent data processing to create extended p-models, which are 3-D volumes generated at each site to provide the coordinates of the imaging points that will be imaged. Vrms profiles are used for post-processing depth conversion.

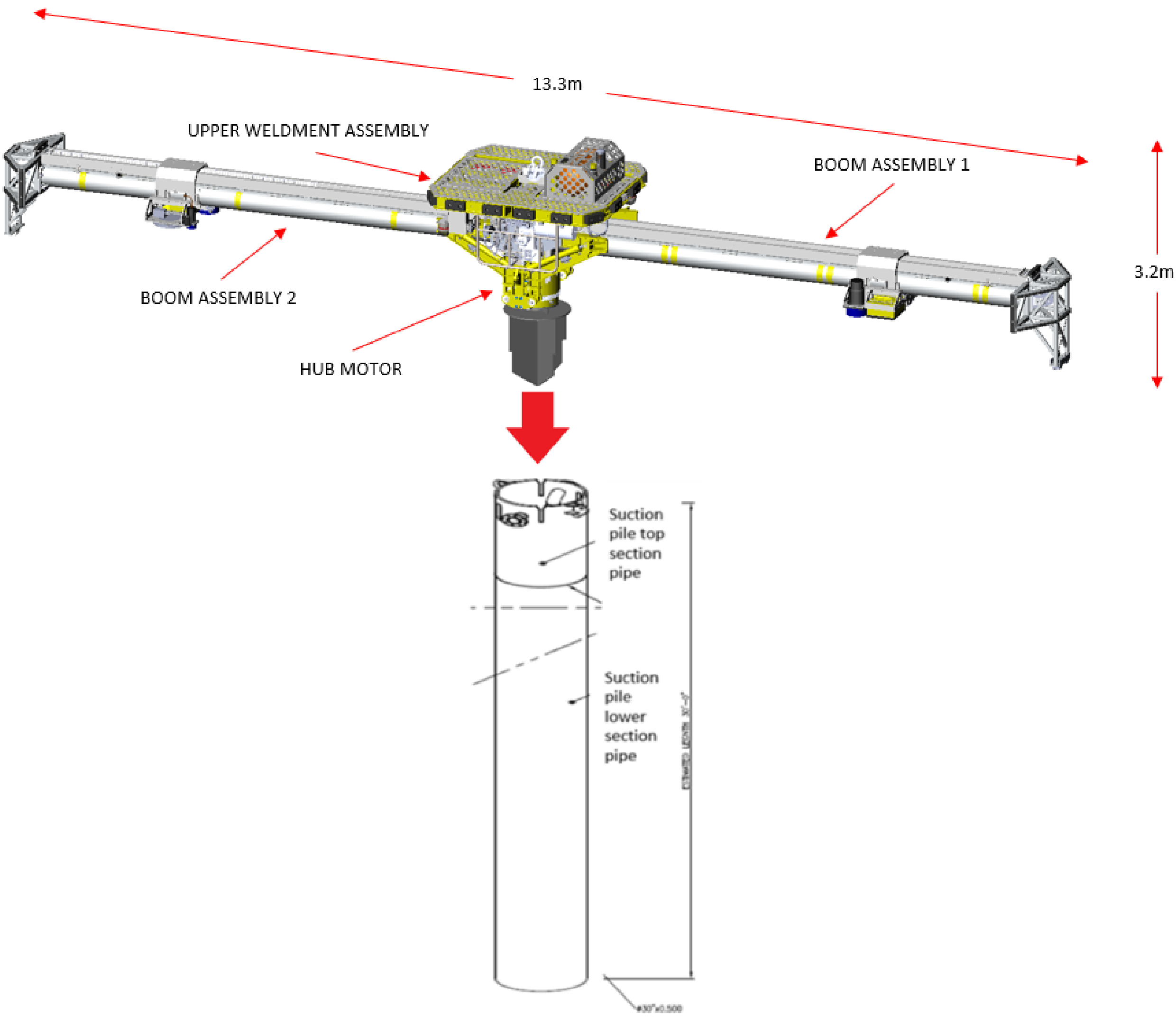

Figure 1: Illustration of the Acoustic Corer device and suction pile used to collect data in the deployment and retrieval stages.

Survey Methodology and Scope of Work

A total of sixty-three scans were conducted using the Acoustic Corer over the grid pattern shown below that extended from the original conductor bay to the Rapid Response Solution suspended off the downed jacket above the seabed that collects oil emanating from the buried conductors.

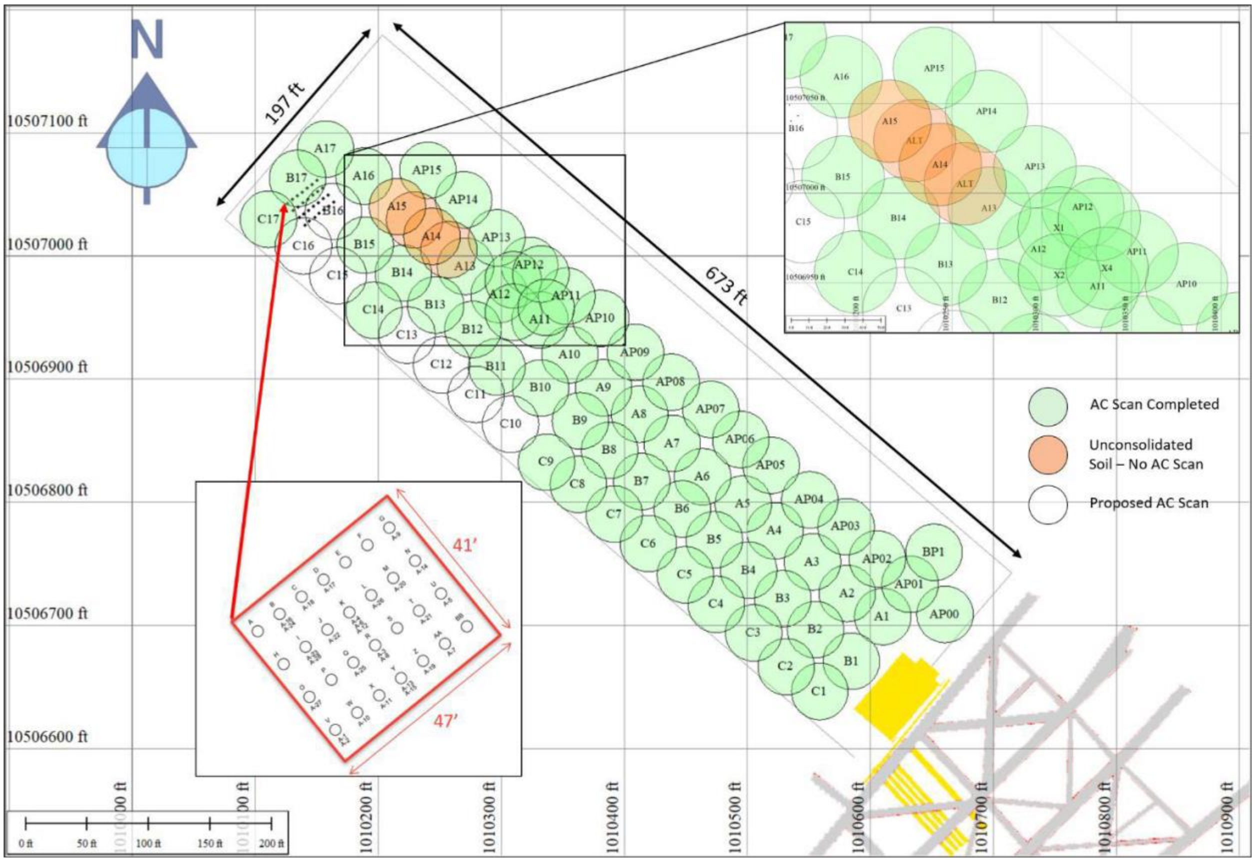

Figure 2: Acoustic Corer Scan Locations extending from the original conductor bay (upper left of the Figure with Conductor Bay inserts shown) to the Subsea Rapid Response Solution (in yellow).

Each of the sixty-three scans was conducted by deploying the Acoustic Core from an OSV (Offshore Support Vessel) onto a prepositioned suction pile on the seabed. Each scan took approximately 14 hours, and results were immediately sent to shore by GDS satellite transmission for further processing and data analysis.

Across the survey site, seven sites were selected for JYG-Cross scans to create the velocity model [5,6]. The first six scans were completed at the beginning of the survey to build a baseline velocity model. These differing scan frequencies create a composite synthetic aperture to be formed with advanced processing algorithms. The data processing results in 3D imagery, which exhibits and helps identify buried objects. Upon completion of each scan offshore, the collected data was transmitted via satellite onshore for additional processing. For each scan location, a preliminary site report based on preliminary data processing helped steer upcoming scan locations based on the information collected from previous scans. The original survey sites were based on three rows of data collection sites (A, B and C locations). As the survey was conducted, it became apparent that an additional row of data sites was required towards the northeast at the AP locations shown in Figure 2.

Further data processing and refinement were performed upon collection of all sixty-three scan locations. A 3-D model was created, allowing for final analysis and interpretation.

Survey Results

Sixty-three focused Acoustic Corer scans were successfully acquired along four survey grid lines: AP, A, B, and C. Additional scans were conducted at BP1 and four X locations surrounding the A12 site (Figure 2). The sites along the lines were combined, resulting in 3D views of the sub-seabed down to a depth of approximately 200 ft and highlighted with clarity the presence of linear conductors in the A and AP scan lines from rows 0 through row 11 (Figure 3 and 4) and minor indications of conductors in the B scan line. Figure 5 is a close-up view of the AP scan line, which shows three distinct locations where vertical features associated with oil/gas emanating from the conductors were observed. These locations were at AP0, AP01 and AP08 scan sites. These three locations suggest that there is minor fracturing of the conductor at these locations (possibly through wall leaks in the conductor). The gas/oil vertical flow found at AP0 is in close proximity to the Rapid Response System and appears to be captured within the curtain region of the containment system.

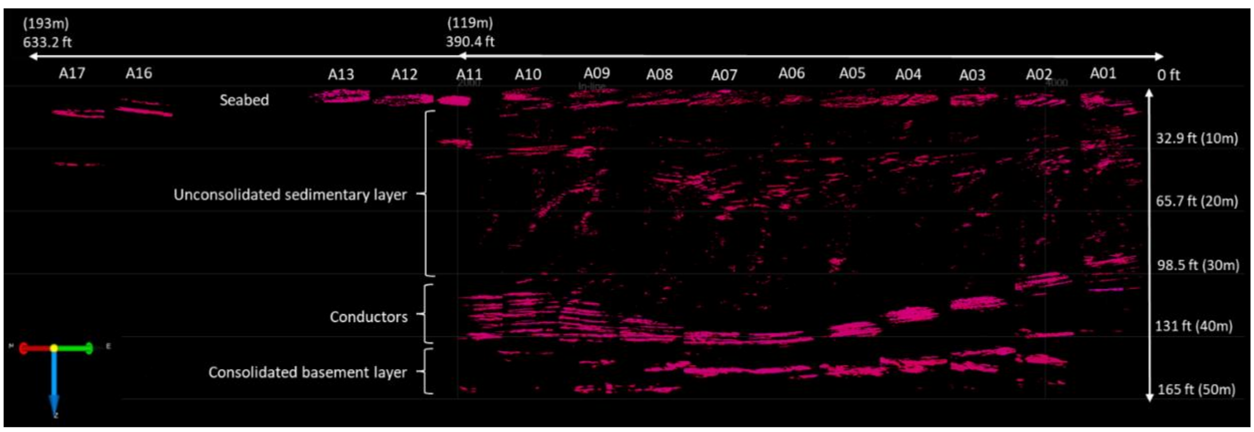

Figure 3: HF volumetric profiles of all sites in the A survey line with annotated interpretations showing conductors extending from row 1 through row 11.

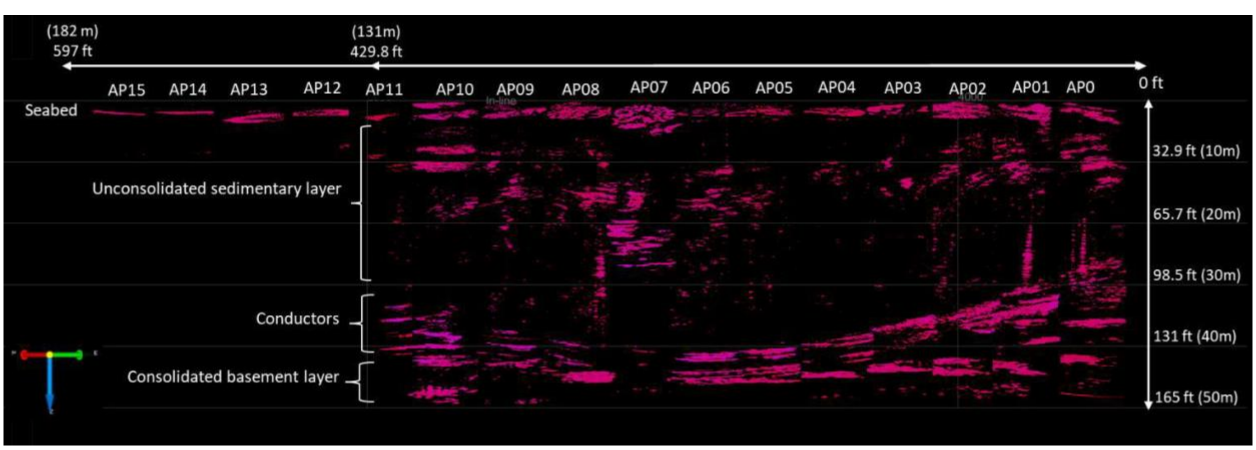

Figure 4: HF volumetric profiles of all sites in the AP survey line with annotated interpretations showing conductors extending from row 0 through row 11.

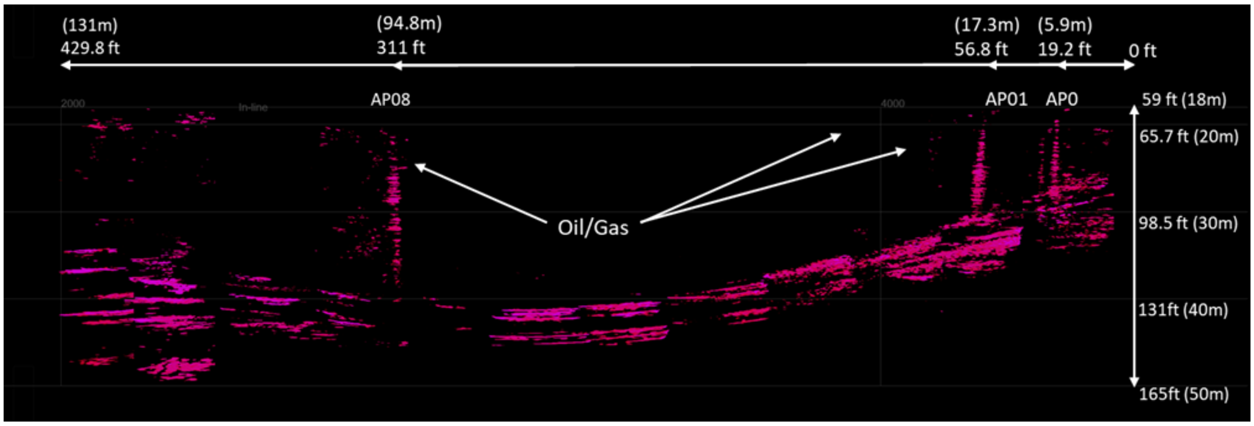

Figure 5: Parametric volumetric profiles of all sites in the AP survey line showing oil and gas vertical features at sites AP0, AP01 and AP08.

Post preliminary scan processing; the sixty-three Acoustic Core data sets were then individually topographically corrected and processed as a singular large area seismic volume encapsulating all regions of the four survey grid lines: grid lines AP, A, B, and C. This combined data set produced a smooth and continuous display of the linear conductors. The conductors appear continuous from the collection dome on row 0 and abruptly end at row 11. At row 11, the conductor ends are individually separated and lifted with a slight downward inclination (Figures 6 and 7). A cross-sectional analysis of the conductor bundle positively identified eighteen of the twenty-eight conductors (Figure 8). The remaining ten conductors may be encased within the conductor bundle but are not detectable due to the shielding effect of the compactness of the conductors blocking the imaging signals.

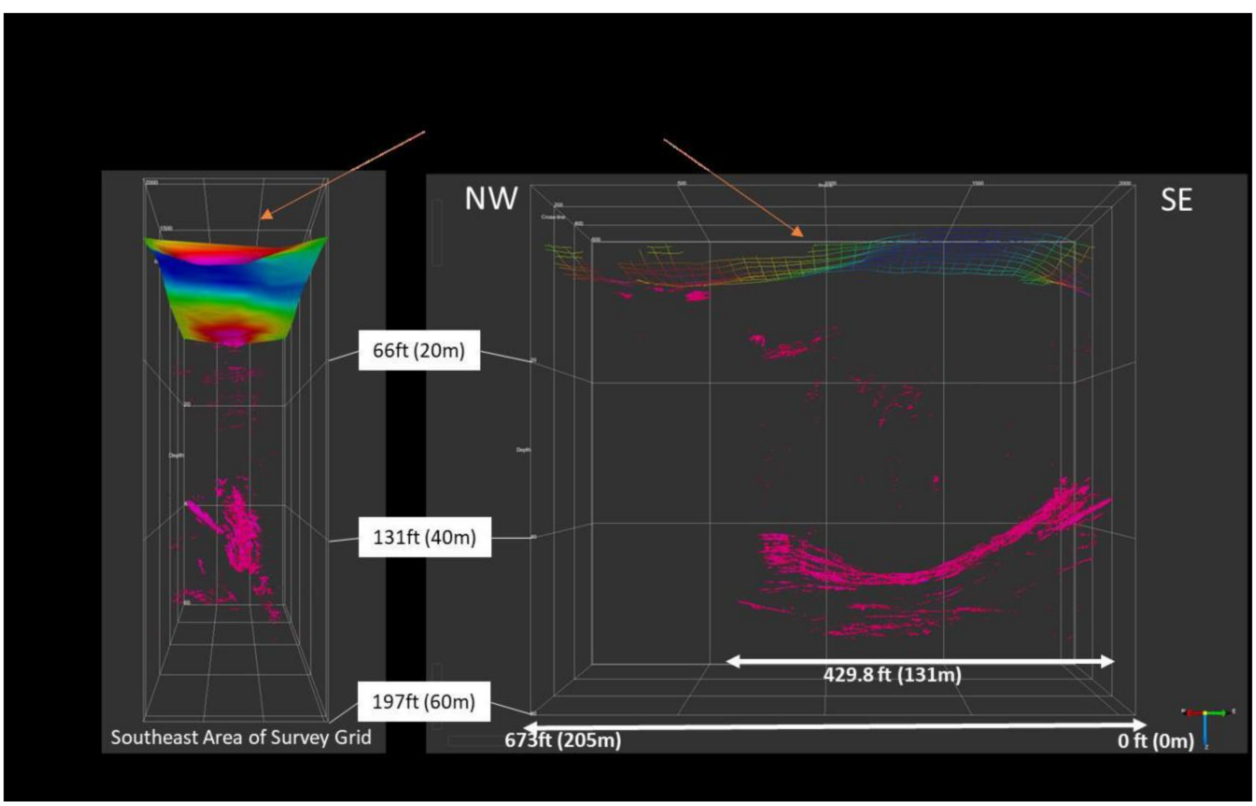

Figure 6 – 3-D volumetric view (Left image looking SE to NW and Right image looking SW to NE)) of the parametric data set with the digitized seabed overlaid.

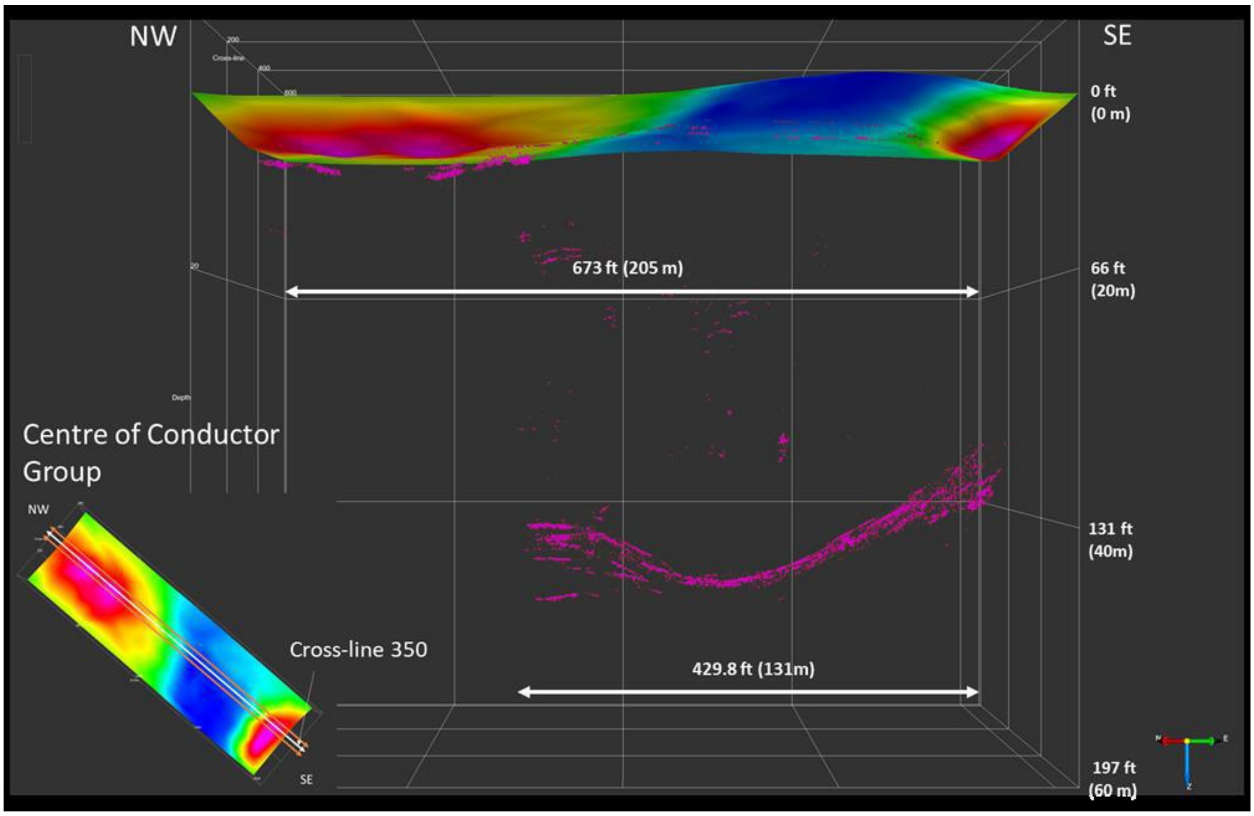

Figure 7: Vertical section (NW to SE) of the parametric data showing the center of the Conductor Group

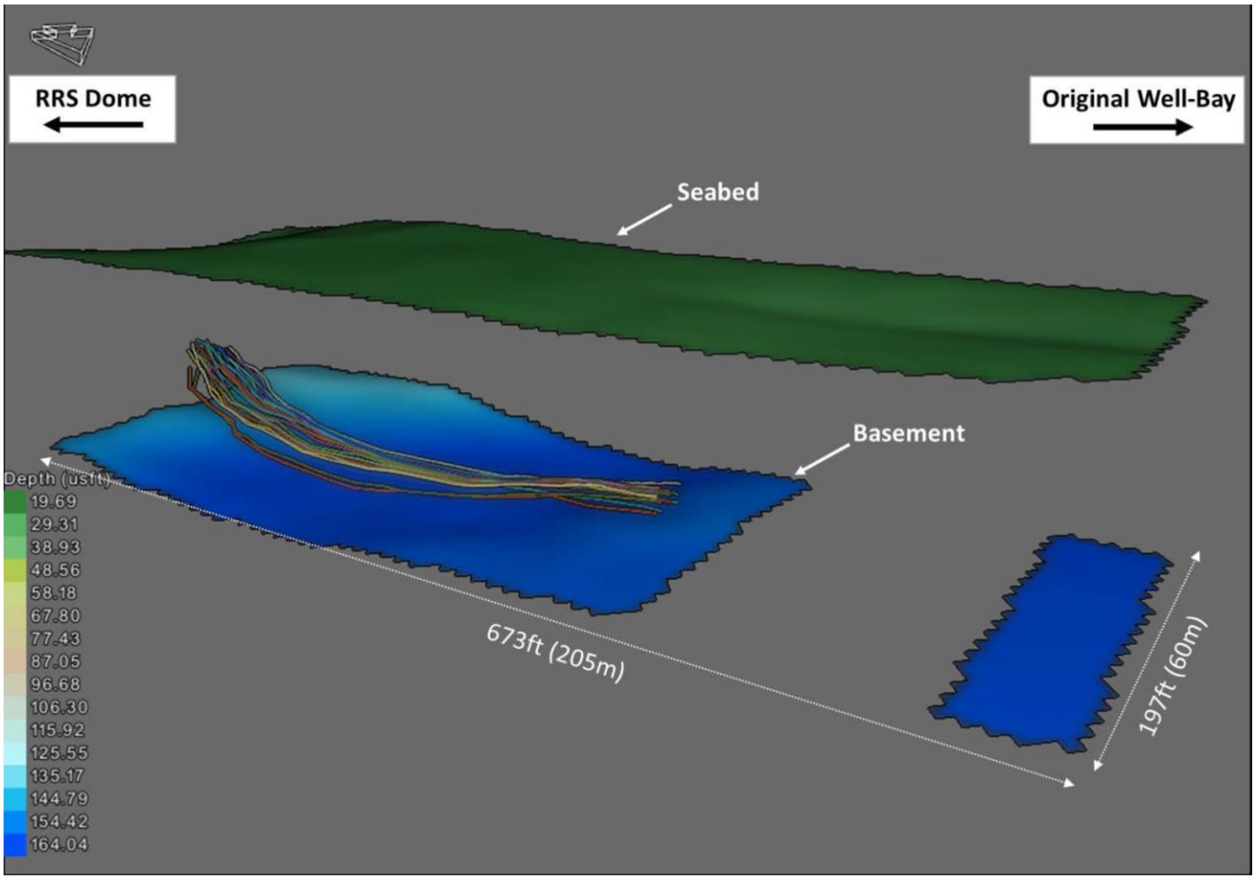

Figure 8: 3D Visualization of the 18 conductors identified during the Full Field Survey

The central area of the linear feature bundle shows that the conductors are grouped in a relatively undisturbed cylindrical package. The outer conductors would mask the inner conductors concealed beneath by their numbers, composition, and sizes. The tightness in this central bundle of conductors and the circular delineation of the form observed suggest that the number and presence of all original conductors are contained in this bundle.

Sloping upwards from the central region to the RRS collection dome, the conductors continue to be present with a continuous smooth upward-sloping trend which follows over the consolidated basement floor. No evidence of gas/oil emerging or percolating from deep in the lower geology underneath the conductors or in their vicinity exists.

In row 11, the form and separation of the conductors suggest that a separation of the conductors from the conductor guide had occurred. The apparent termination of the conductor bundle at Row 11 is due to one of three possible scenarios:

- The conductor bundle has fractured at Row 11, and smaller diameter tubing, or liner, is providing a conduit for the flow of hydrocarbons through the conductors from Row 11 to the RRS dome and cannot be detected by the Acoustic Corer.
- The conductor bundle has been bent downwards at a steep angle and cannot be detected by the Acoustic Corer.
- The gas-entrained soil identified in Rows 11-17 has inhibited the Acoustic Corer from identifying the conductor bundle in these rows.

Additional survey work combined with the Acoustic Corer data is planned to address the issue identified above.

Conclusions

Using the Acoustic Corer technology, the data collected along the survey lines were combined, resulting in 3D views of the sub-seabed down to a depth of approximately 200 ft and highlighted with clarity the conductors' presence, orientation and depth of burial. These conductors were buried in the mud/seabed at approximately 90 to 135 ft depths. There were also three distinct locations where vertical features associated with oil/gas emanating from the conductors were observed.

Concerning well abandonment for this location, there are three options:

1. Permanently plug and abandon these wells to BSEE standards using a top-kill approach. This will require excavation of the seabed down to a depth of up to 135ft beneath the seabed to gain access to the conductors. There are significant technical challenges to be overcome with this option.

2. Drill intersect wells to each of the 28 wellbores and permanently plug and abandon the wells; this option poses significant challenges due to the congested well patterns.

3. Continue to contain and collect the oil emerging from the conductors until reservoir depletion occurs.

References

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