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Review Article

Geophysical methods of investigating the seafloor for the emplacement and monitoring of subsea facilities offshore Niger Delta (Nigeria)

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ABSTRACT:

Different geophysical exploration methods were used to geologically map seafloor sedimentary structures. Recent technological advances brought the objective of complete area mapping to the minds of marine province researchers. The research included several profiles run on parallel and cross tracks with 75–100 m overlap using side scan sonar, a multibeam and single beam echo sounder, a magnetometer, a differential global positioning system, a gyrocompass, a motion reference unit, and a sub-bottom profiler onboard a mobile vessel. The main purpose of this digital image processing was to focus on the specific characteristics in the sonar imagery and identify existing subsea installations and geohazards offshore that could impede sea-going vessels, drilling rigs approaches, and the emplacement of subsea facilities. In a second step, the profiles were used to decipher the sedimentological characteristics of the sea floor of the study area shown in mosaics. The average water depth ranged from 43 m to 42 m, dipping south. Pipelines, jackets, and debris were identified. The seafloor was relatively clear and free from any obstructions or hazards that may hinder any offshore oil and gas field development.

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KEYWORDS: Remote Sensing, Sedimentary processes, Geoacoustic Sensors, Bathymetry

INTRODUCTION:

The geological team carried out a geophysical survey for oil and gas field development within an offshore province in the Niger Delta Basin, Nigeria. The main aim of the seabed survey was to obtain sedimentological and seabed hazard data for sea-going vessels, including rigs and jack-up barges. In doing the stated, the research established the following: a digital seabed survey, a seabed clearance and geohazards record, a report of existing seabed features (especially subsea facilities), bathymetric information within, and an area of 500m by 500m. Relevant high-fidelity underwater sensors such as side scan sonar, multibeam echo sounders, single beam echo sounders, sound velocity profilers, sub-bottom profilers, magnetometers, and surface positioning systems were deployed for this research (Augustine *et al.*, 1996; Chuku and Odigi, 2019; Umoh *et al.*, 2023). All appropriate location data, geodetic parameters, and working drawings of the study area were used. All coordinates quoted in the article and shown on the charts were referenced to Clarke 1880 (Mid Belt). All depth soundings were reduced to the lowest astronomical tide (LAT) (Barnhardt *et al.,* 1998; Jesse and Jennifer, 2012). The survey was executed in accordance with the geologically and oceanographically approved Health, Safety, and Environment (HSE) plan. The study was done from November 17 to December 6, 2018. A mobile vessel SED with sensors' positions (offsets) (table 1 and figure 1) was engaged for the study. The project was carried out adhering to international sedimentological organization standards (Blondel and Murton, 1997; Achanya, 2006). The research will support engineering construction with accurate water depths in the area, explain the implications of the sedimentary processes, possible spud can positions and dimensions, highlight possible debris, determine possible ferrous material, and identify any seabed obstructions.

Table1: MV SED Sensors' Offset

S/N	SENSORS	X	Y
1	DGPS1	-1.60m	1.45m
2	DGPS2	-1.588m	4.444m
3	MBEAM	0.000m	0.000m
4	SBES	0.000m	-10.0m
5	SBP	1.000m	17.3m
6	MAGGY	-9.99m	16.75m
7	SSS	0.000	0.020m

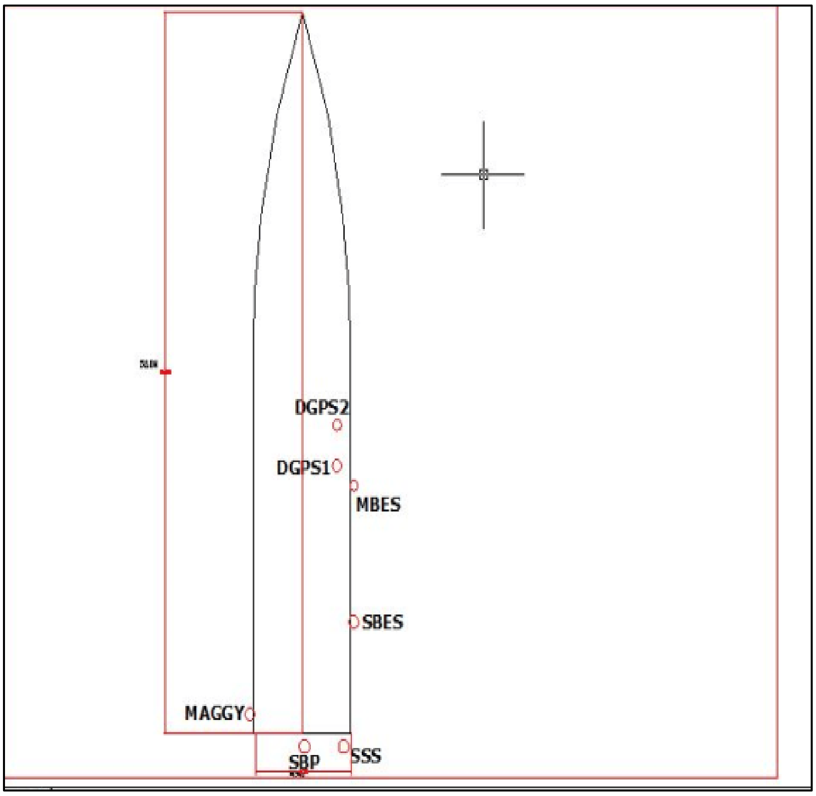

Figure 1: Schematic diagram of MV SED, showing the sensors offsets

Survey Area/Location:

The study area is 500 square meters. It is situated 15.0 kilometers off the coastline from the southwestern end of the Escravos River in the western Niger Delta of Nigeria (Figure 2).

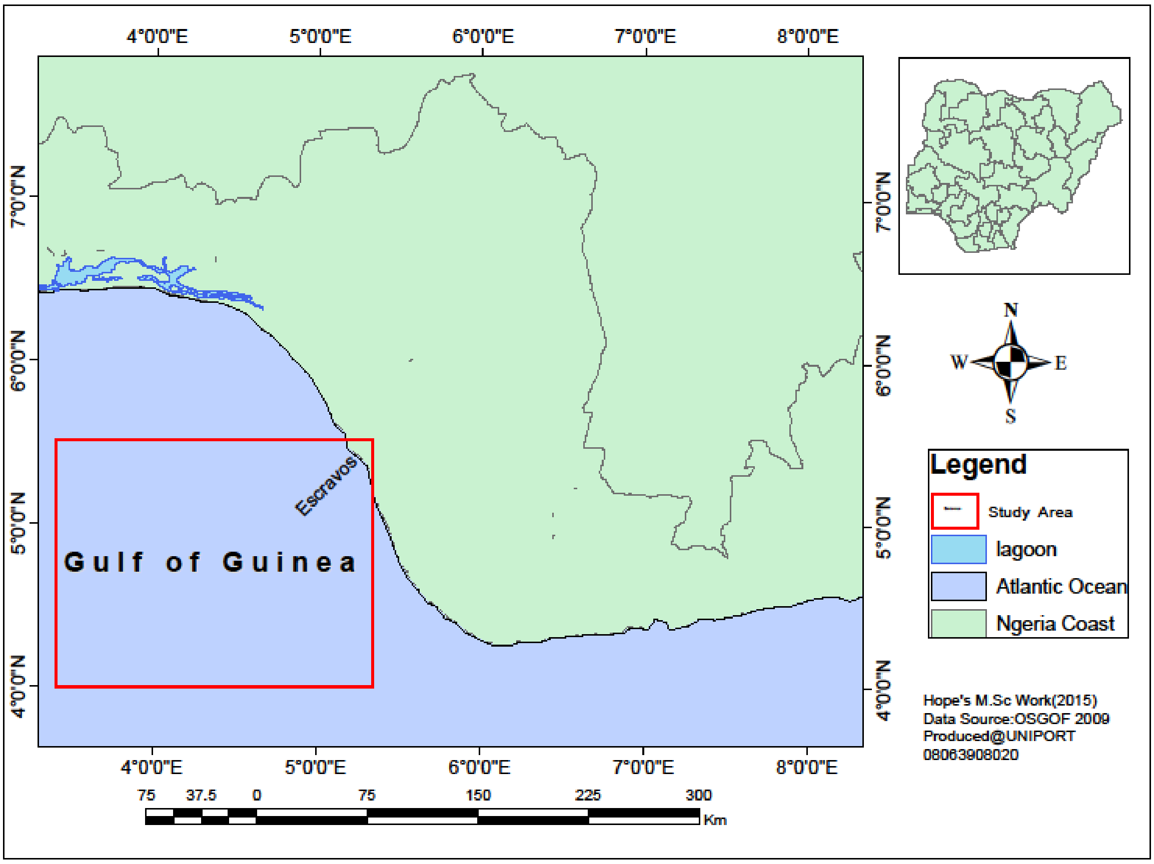

Figure 2: Map of the Study Area, offshore Niger Delta Nigeria (Adapted after Chuku and Ibe 2015, Chuku, et al., 2018, and Chuku, et al., 2023).

The study area is accessible only by helicopter or seagoing vessels. Entry into this offshore environment is generally restricted to authorized persons or groups.

MATERIALS AND METHODS:

1. **Calibration of the Differential Global Positioning System (DGPS)**

The Differential Global Positioning System (DGPS) was powered on and received not less than 10 satellites. HDOP was less than three (3), and the GPS was in stand-alone mode. The Eiva Navipac Navigation System was used to process all computations (WGS 84) and was transformed into the Nigeria Minna West Belt.

Equipment deployed during the survey

- C-Nav Differential Global Positioning System (DGPS)
- Eiva Navipac Navigation System
- SG Brown Meridian Gyro Compass
- Edgetech Sub-Bottom Profiler
- JW Fisher Side Scan Sonar
- Edgetech 4600 Multibeam
- G882 Magnetometer
- Odom Echotrac MVS Dual Frequency ES
- Valeport 600 SVP Probe
- TSS 320B Heave Compensator

Geoacoustic Equipment Setup

The C-Nav was set up in the survey caravan on the deck with its antenna mounted on top of the caravan vessel. This provided an appropriate location with respect to having a clear view of the sky, minimizing electromagnetic interference, physical obstruction, and multi-path. After the unit was powered on, it began to output position data to the Eiva Navipac or Hypack navigation systems. The gyro-compass was positioned headlong at the bow of the vessel, then powered on and allowed to stabilize for forty-five (45) minutes. Calibrations were done to determine the correct positioning of the gyro. Direction data were then outputted into the navigation system (Cochrane and Lafferty, 2002; Chuku *et al*., 2023b).

The echo sounder transducer was installed on a pole and side-mounted on the starboard side of the vessel. It was secured in place with a pre-fabricated beam; it was mounted in a manner that did not pose any safety threat to the vessel or to the personnel onboard. The Heave Compensator was mounted inside a constructed box, placed beside the multibeam echo sounder on deck, and connected to the navigation system. The data obtained was inputted into the sensors to compensate for the pitch and roll errors of the vessel (Chavez and Gardner, 1994; Hughes-Clarke, 2012; Chuku *et al*., 2018). The side-scan sonar was deployed from the starboard side of the vessel. The data and power cables were run from the deck area into the survey room, where the sonar processor unit and the navigation system were located. The side-scan sonar sensor, the processing unit, and the navigation system were all interfaced via cables. The multibeam was installed on a pole and side-mounted on the starboard side of the vessel.

The magnetometer (Figure 3) was deployed from the port stern davit of the vessel via a calculated layback. The data and power cables were run from the deck area into the survey room, where the magnetometer processor unit and the navigation system were located. The magnetometer sensor, the processing unit, and the navigation system were all interfaced via cables.

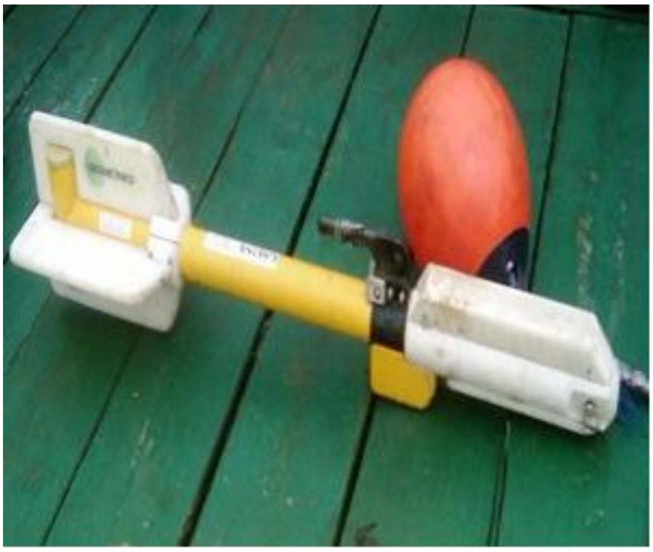

Figure 3: Seaspy Magnetometer and buoy

The Sub Bottom Profiler; (figure 4) was deployed from the starboard stern davit using a block chain. The data/power cable was run from the deck area into the survey room, where the sub-bottom processing unit and the navigation system are located. The sub-bottom profiler, the processing unit and the navigation system were all interfaced via cables.

Figure 4: Sub-bottom Profiler sensor (EdgeTech)

d) Differential Global Positioning System

DGPS was checked to output differential data, which were transformed with the Eiva Navipac navigation software.

e) Single Beam Echo Sounder

The echo sounder was function-tested at the dock prior to the survey. The tests indicated that the transducer was functional (Figure 5). At the site, a bar check was used to calibrate the echo sounder. The velocity of sound in water was read and the value obtained was input into the echo sounder unit. The index error was found to be less than 0.1m. To clear the error, the draft setting on the echo sounder was adjusted to bring the reading to par with that measured in the bar check. The echo sounder was also checked to have unhindered communication with the navigation system (Davis, *et al.* 1996).

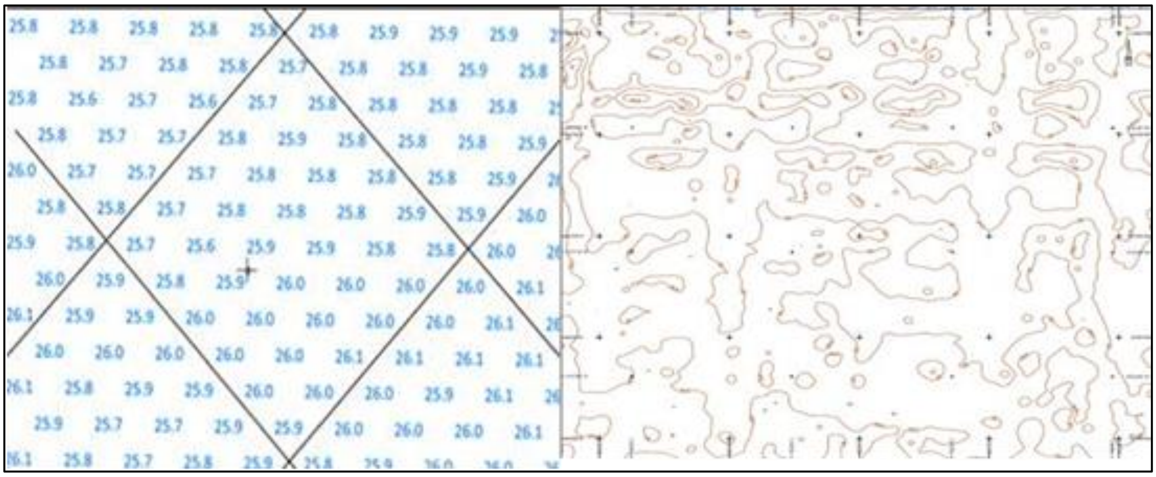

Figure 5: Echo Sounder Cross Line Check and Contouring

f) Multibeam Echo Sounder (MBES)

Edgetech 4600 swath was used for the operation (Figure 6). A patch test was conducted to calibrate the multibeam using created plotted run lines across a pipeline feature. Corrections obtained from the patch test; Pitch: 0.5 Roll: Head 1 = 0.11 Head 2 = -1.29.

Figure 6: Multibeam Echo Sounder (Edge Tech 4600) Transducer

Motion Reference Unit (MRU)

The heave compensator sensor unit placed on the wooden box on deck was shaken. The perturbation-produced output was displayed on the navigation system. These values were applied to the echo sounder readings to adjust for vessel heave, pitch and roll during the survey.

Side Scan Sonar

A rub test (dry test) was carried out on both channels of the Side Scan Sonar, (figure 7). The test was satisfactory. Prior to the survey activity, a wet test calibration test was conducted, (figure 8). This was done to confirm the functionality of the side scan sonar.

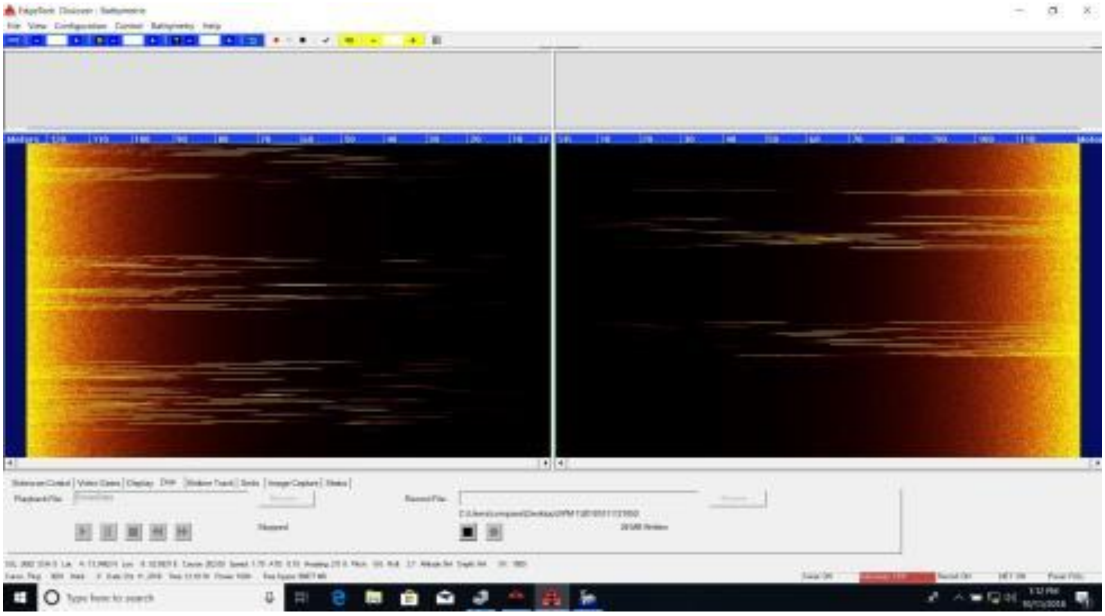

Figure 7: Dry Test Side Scan Sonar (SSS) Screen Dump

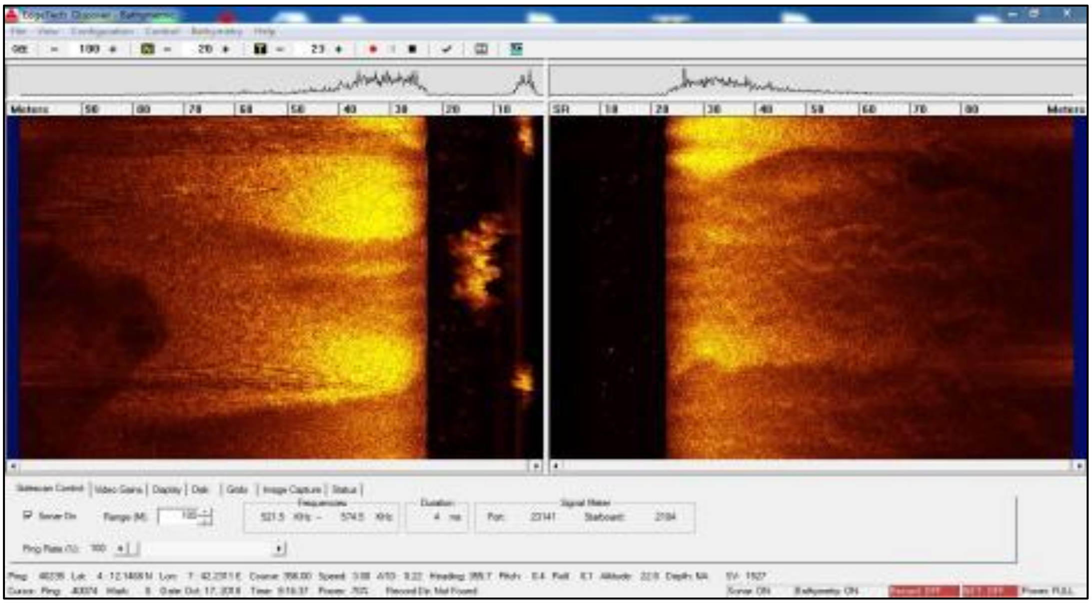

Figure 8: Wet Test Side Scan Sonar (SSS) Screen Dump

The magnetometer is a G-882 Geometrics type capable of detecting magnetic objects on the seabed and below. The dry and wet tests were conducted to ascertain the functionality of the equipment. A dry test was conducted on the deck by placing it close to ferrous materials. Magnetic anomalies were observed on the topside. The equipment was deployed temporally into the water, and the observation seen on the topside as seen on the screen dump indicates that the magnetometer is in good working condition (Figure 9). Also, before deployment, the magnetometer was oriented to eliminate spikes.

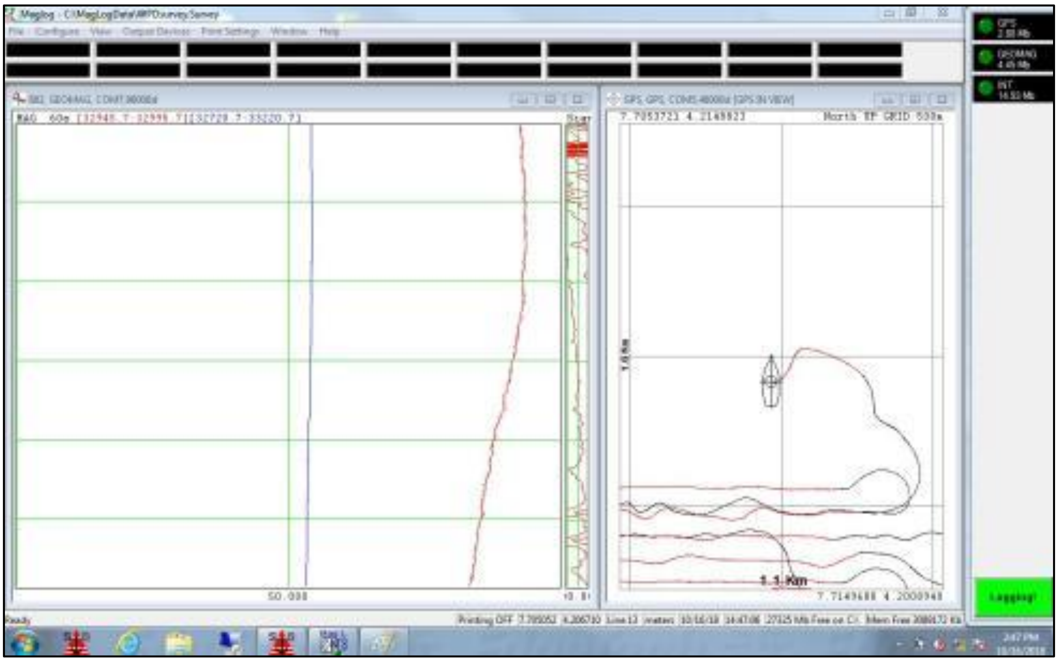

Figure 9: Magnetometer Wet Test Screen Dump

Sub–Bottom Profiler

The Sub-bottom profiler was powered on, and pinging was heard with corresponding display on the topside. A wet test was conducted and data displayed on the topside indicating the system was functioning well (Figure-10)

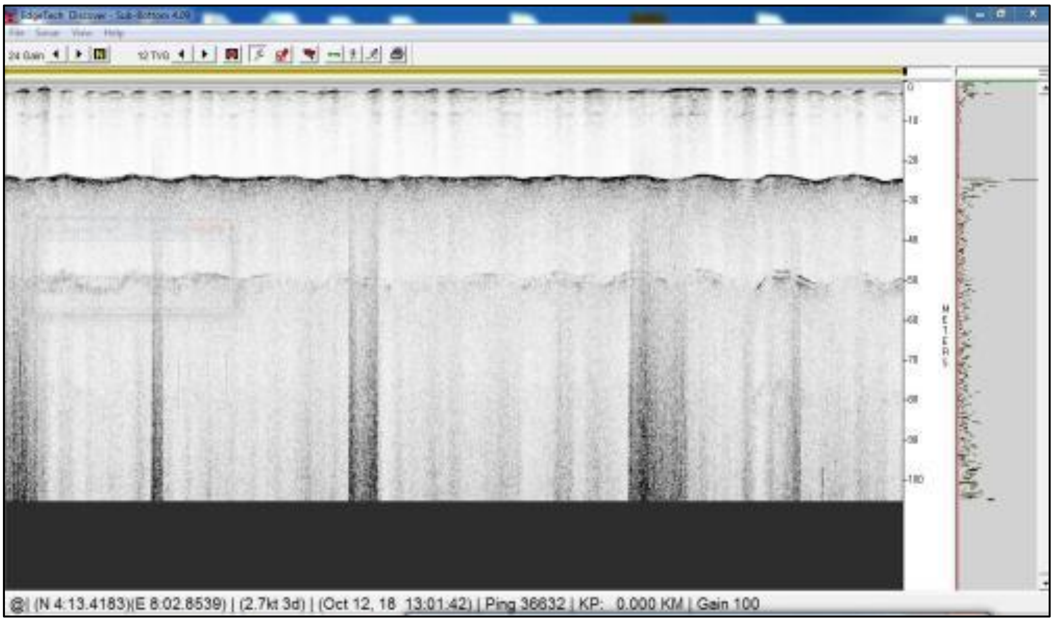

Figure 10: Sub-Bottom Wet Test Screen Dump

Data Acquisition

On 15 November 2018, the survey team with geoacoustic equipment onboard MV SED proceeded to the field Location. Setting up of geoacoustic equipment on MV SED commenced immediately. Dry tests were conducted on the geophysical sensors and were confirmed. Before the commencement of the survey, sound velocity reading was obtained and inputted into Echo Sounder, Side Scan Sonar, Sub-bottom Profiler and Magnetometer, after which they were deployed. Test runs of some lines were done for the purpose of patch test.

Survey Plan and Line Layout

The survey grid was 500m by 500m for the study location (Figure 11). The line survey started, and data were recorded from all deployed sensors. The side scan sonar and magnetometer were towed out from the stern with 45- and 70-meter cables, respectively, while the sub-bottom profiler was towed out on the mid-stern with a 10-meter chain. The DGPS and gyrocompass were interfaced with Eiva navigation software for the acquisition of both position and directional data for the survey (Diaz, 1999).

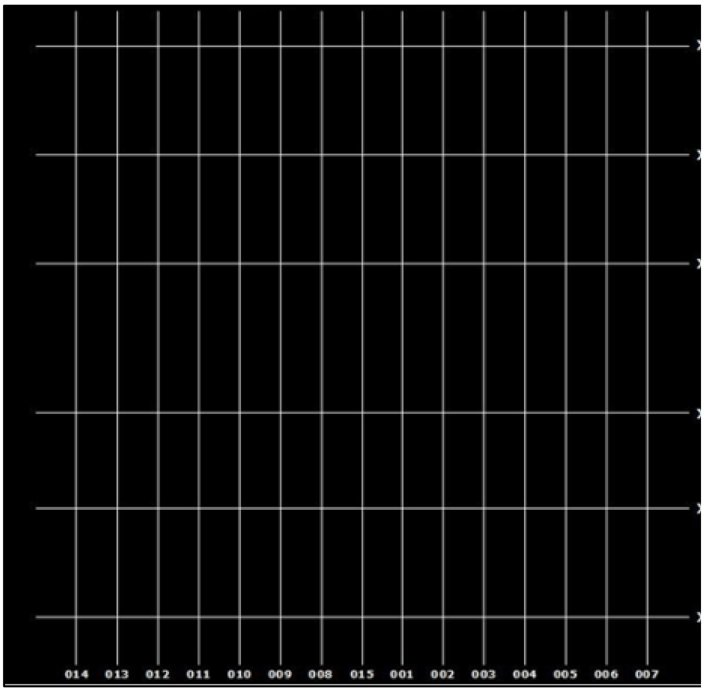

Figure 11: Schematic diagram of survey gridlines of 500m by 500m (After Chuku *et al*., 2023a)

Mainline and cross-line spacing within the surveyed area were run as preplanned (figure 11), scanning of the seabed run throughout the survey, bearing in mind the presence of platforms (figures 18). A total of fourteen (14) main lines and six (6) cross-lines were surveyed (Figure 13) (Chavez and Gardner, 1994, Babangida, 2015, Chuku and Umoh, 2023).

Scan Survey

The side scan sonar survey was carried out using the JW Fisher side scan sonar. The side scan sonar deck unit was interfaced with the navigation system and its tow fish was towed at variable layback distance (figure 12). The side scan sonar was operated at 100 kHz frequency and a range of 50-100m given a swath of 75m on both sides and 100% overlaps. The side scans sonar highly reflective discrete returns were interpreted as linear reflectors to detect debris **(**After Chuku *et at*., 2023**)**.

Single Beam Echo Sounder

The Odom echo sounder transducer and accessories were side-mounted and interfaced with the heave compensator. The heave-corrected depth data was input into the navigation system. The average water depth of the surveyed area is 43.42m. The water depths have been reduced to the Lowest Astronomical Tide (LAT) Opobo River approach from the Nigeria Navy tidal prediction table.

Figure 12: Survey Equipment Setup Room (After Chuku *et at*., 2023a)

SUB-BOTTOM PROFILER

This piece of equipment is designed primarily to operate as a combined transmitter and receiver system. The transducer was mounted 10m away from the stern of the vessel. Through the integrated navigation system, lateral offsets corresponding to the sub-bottom profiler were inputted into the navigation system accurately to calculate the transducer position. This position was then sent to the sub-bottom recorder, allowing for record annotation at a given interval. Any anomalies were noted as events and recorded for further analysis when played back**.**

Magnetometer

The G882 magnetometer system was used to detect ferromagnetic debris. The differential global positioning system was configured into the equipment to receive the real-time position. The magnetometer was towed from the port side at 70m away from the stern of the vessel to avoid magnetic interference from the vessel. When the magnetic field was produced by a ferrous feature sensed by the sensor, a graphic and digital display on the laptop revealed the strength of the field.

Multibeam Echo Sounder

The Edge-Tech echo sounder transducer and accessories were side mounted with all necessary heave corrections inputted. The water depths had been reduced to the Lowest Astronomical Tide (LAT) using Opobo River approach from Nigeria Navy tidal prediction table.

Data Processing

1. Single Bathymetric Data

Acquired data were processed using a combination of Hypack Single Beam Editor, Microstation, and AutoCAD. Navigation data was downloaded from a hard drive created on the online survey computer.

After initial processing and calculation of offset points, the data was examined in the on-screen track editor for quality and time/date matching. The edited data was then exported to track charts with two-point positions (Figure 12).

The bathymetric data were examined and reduced using Hypack's single beam editor and exported to MS Excel. Water depths were reduced to the LAT Opobo River approach from the Nigeria Navy tidal table (Hughes Clarke, 2000a; Chuku and Ibe, 2015).

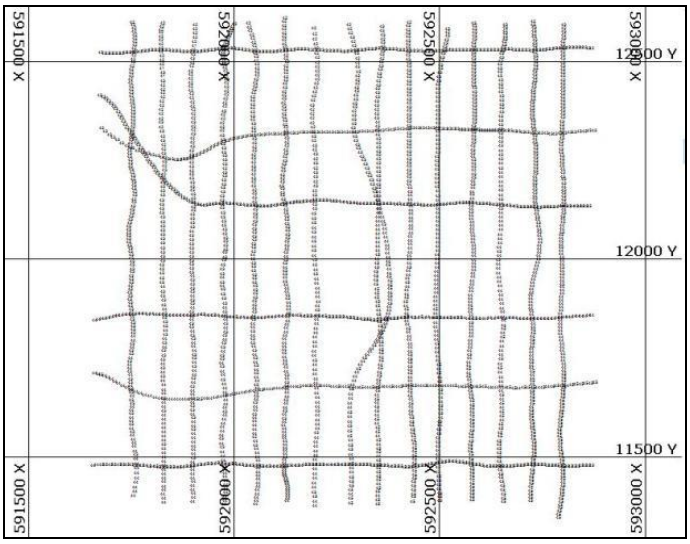

Figure 13: Navigation Track Plot of Ebsom Field Location (Modified after Chuku, *et al*., 2013a)

i. Sub-Bottom Data

Processing of the sub-bottom profiler entails scrutiny of each event recorded using the playback mode available in the software. Strata of the sub-bottom and any anomalies were detected and the position of such features was determined.

ii. Magnetometer Data

The G882 processing software was used for the filtration of flagged features and coordinates converted from WGS84 to the local datum for charting. There are magnetic anomalies in the surveyed area (Figures 13 and 14).

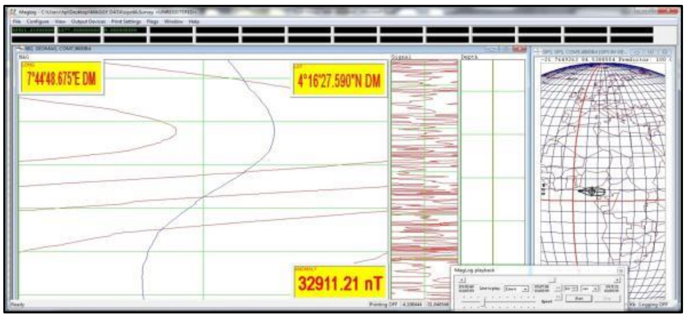

Figure 13: MagLog extract, showing a magnetic anomaly

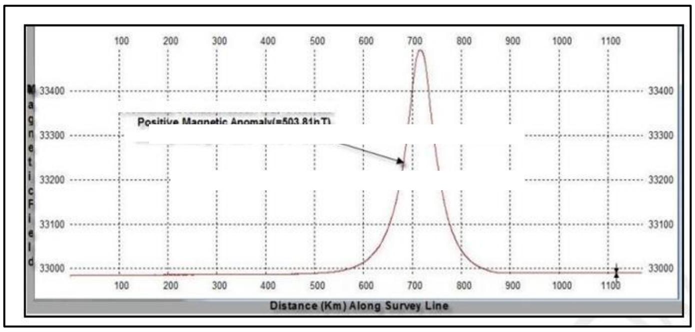

Figure 14: Maggy data extract, showing exposed pipeline detected at the platform area

iv. Side Scan Sonar Data

The side scans sonar data was processed using the playback mode of the software and took appropriate fixes on any feature of interest and these fixes created a data file that depicted the length, width, height, coordinates and description of the target.

v. Multibeam Data

Discovery bathymetric software was used for processing the multibeam data. The software offered filtering and pinning to reduce the density and noisiness of processed sounding prior to gridding. The field is predominantly low reflective sediments(silt and clay)with pockets of high reflective sediments(pebble and sand) (Figure 15).

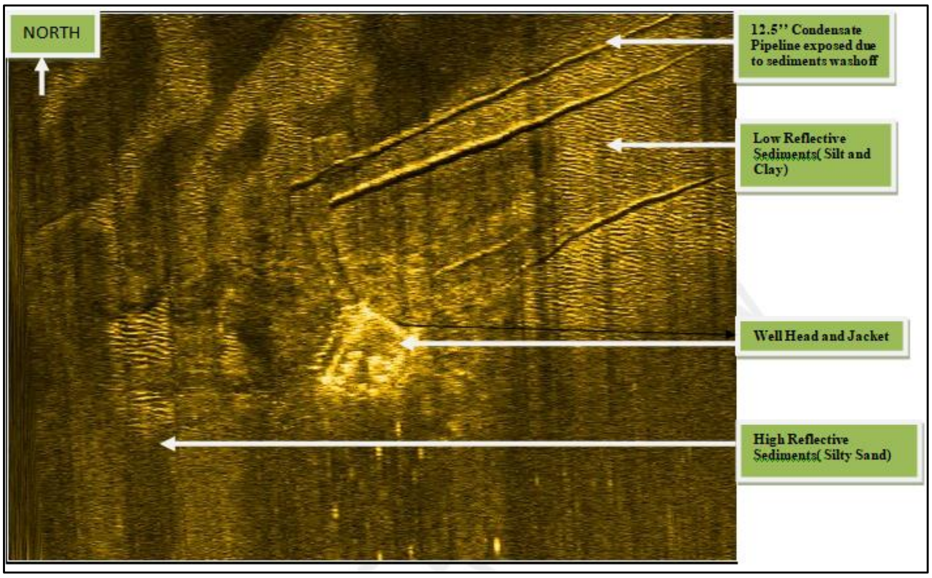

Figure 15: Ebsom field seabed mosaic

RESULTS AND DISCUSSION:

SIDE SCAN SONAR

The sides scan sonar data of the 500m radius surveyed area around the field was consistent (Figure 16). The data showed high reflective discrete returns on subsea installations. It also showed all the pipelines entering the jackets. There was a conductor lying on the seabed about 370m southeast of the field location and debris at about 350m northeast (Figure 17) with an observation of a spud can.

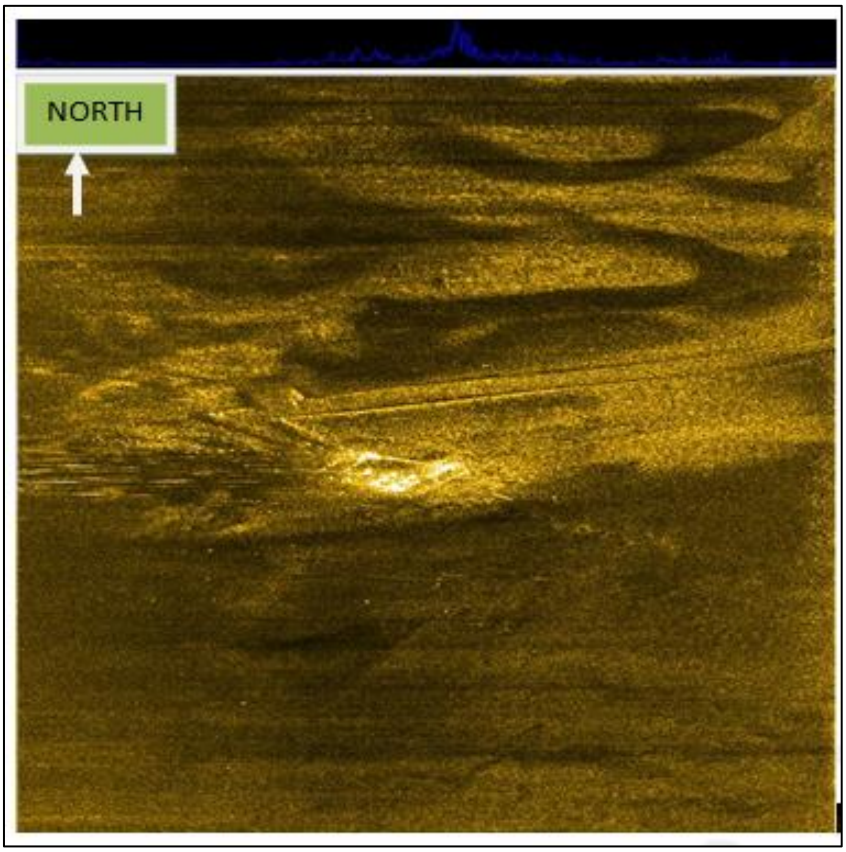

Figure 16: Side Scan Sonar (SSS) extract, showing partially buried seabed features in Ebsom Field

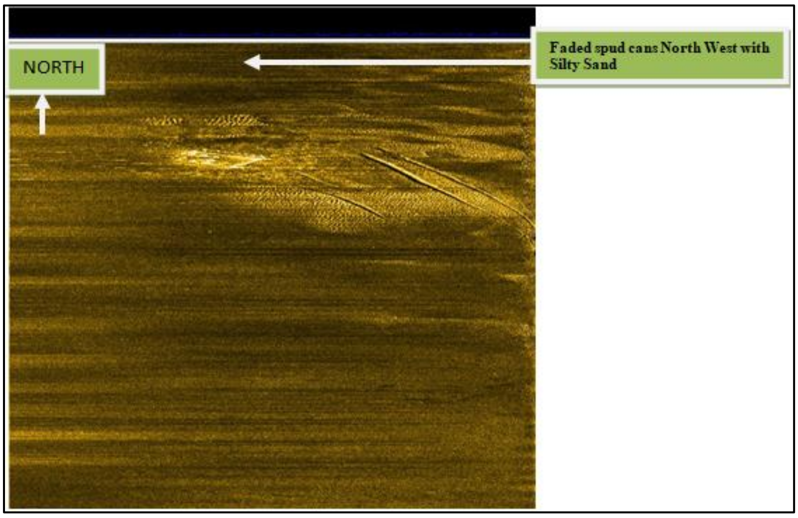

Figure 17: Side Scan Sonar (SSS) extract, showing pipelines and jacket with surrounding pockets of silt and clay

Figure18: Production platforms situated within the survey area

BATHYMETRY

Single Beam Echo Sounder

The water depth within the survey area ranged from 41.27m to 45.75m.

Multibeam Echo Sounder

The water depth within the survey area ranges from 41.48m to 45.16m.

1. **Shallow Geology**

   The Sub Bottom Profiler data showed the seabed is found between 23m to 24m. The data was limited to not more than 15m (12m, ASV 1600m/s) of interpretable data due to limited penetration and the random burst of noise within the data (Figure 19). More regular noise was removed with a frequency filter.

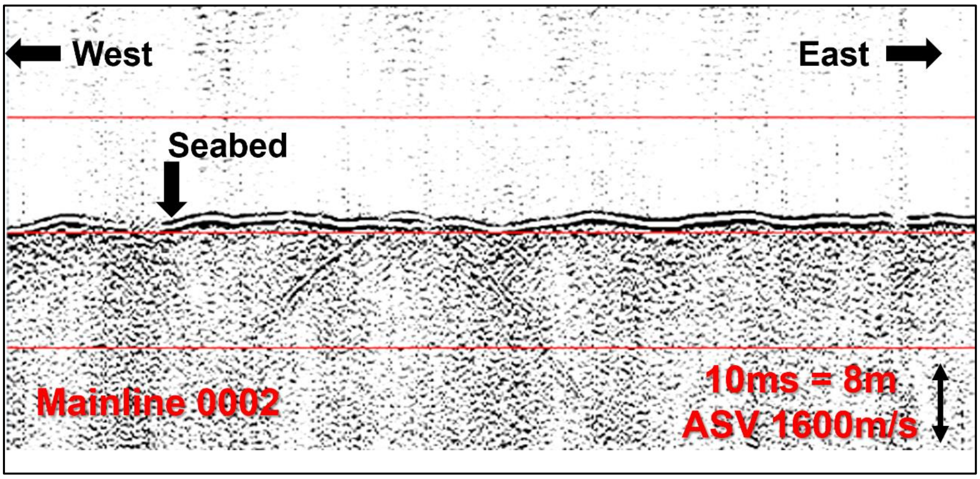

Figure 19: SBP data extract of survey mainlines, showing exposed pipeline

CONCLUSION:

The area of a 500m-by-500m radius of the Ebsom field location was surveyed on 17 November and 6 December 2018. The water depth ranged between 41.88m to 45.46m within the study area corridor. The sonar records of the Ebsom field inferred the dominant presence of low reflective sediments interpreted to be composed of silty clayey sand all over the area. The magnetic anomalies observed were due to existing pipeline and platform structures. The seismic profile suggested a variation in sediment thickness between 1.22m and 1.52m. No other significant structures were seen within the data set underlying the reflector underneath the seabed apart from the trails of diffractions from the existing pipelines running in and out of the field, conductor and debris. There were observations of existing and faded spud can footprints of previous work rigs. However, sand waves were the major seabed features characterizing the field. Debris measuring about 9.5m and about 350m northeast of field was also seen. From the observed sonar record of the survey corridor, there were no significant seabed features or obstructions that posed constraints or hazards to the jack-up barge.

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CONFLICT OF INTEREST:

There is no conflict of interest.

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