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Article

Recent sedimentary processes of the seabed in the Gulf of Guinea, SW Niger Delta: evidence from multibeam bathymetry and facies prediction

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Abstract

High-resolution seafloor imageries, bathymetry and shallow profile data reveal a range of geomorphic expressions in the Gulf of Guinea, SW Niger Delta, which can be tied to processes of sediment transport and deposition. A complete suite of acoustic data was acquired during the survey from the 10th and 20th April, 2014.The data provided a detailed image of the present seafloor and subsurface. Sand, silt and clay facies were identified using onboard instrumentation of side scan sonar, sub bottom profiler, multi/single beam echo sounder, differential global positioning system and gyro compass in the study area. The integration of the seafloor and shallow subsurface data assisted in defining the processes responsible for each of the acoustic facies. Morphologically, the northern and southern parts are very different and the average water dept is 25m. The northern part has amphitheater-shaped slump scars by recent sediment accumulation, and it shows relatively low backscatter (clay). Outcrops and positive relief features were relatively captured in sub bottom profiles. The southern wall was characterized mostly by depository processes and relatively high backscatter. Interpretation shows the presence of a wide range of processes (sediments weathering, erosion, transportation, deposition, etc) shaping the present-day seafloor. The depositional processes are mostly located in the shallow area with a sandier seabed on the south and silty sediment near the north, indicating a field of wavy seafloor. Hyperbolic echoes cover the seafloor indicating also how widespread the erosive processes are in the study location. Factors like erosion, transport medium and environment of deposition of the area affected the sediment types, topography and water depth.

Keywords: Multibeam, seabed imageries, sedimentary processes, seabed profile, Gulf of Guinea.

1. Introduction

The application of high-resolution seafloor surveying and sounding equipment over the past decades have contributed to the detailed profiling of continental margins and revealed images of spectacular sea scapes [1]. Submarine depressions were amongst the most outstanding geomorphic features observed, especially because they share strong physical characteristics with onshore river valleys although caused by rig spudding. Studies revealed that submarine depression are common features along east-west margins of the study area and that they play a major role in accumulation of sediments from shallow-marine to deep marine environments because they are preferential pathways for shelf sediments exchange [2][3]. As part of a sediment transport study program to understand the origin of stratal formation on continental margins, we participated in multiple cruises to sample and analyze the south western Niger Delta, in particular, the outer continental shelf. Our goal is to improve our understanding of how sediments move across the sea bed and how they combine to form characteristic stratigraphic sequences, such as drapes and other well recognized geometrical patterns. The geometry of stratification, as represented by acoustic reflectors of sub bottom profile is critical to interpreting the evolution of sedimentary strata and sequences and shedding insight on the mechanisms of sediment transport and deposition. Recent publications using high-resolution geophysical data and data obtained from moorings show the SW Niger Delta to be active today, with a range of processes interacting to create the present day morphology [4][5]. There is still little knowledge about the recent sedimentary processes in the study area within the continental shelf. This manuscript discusses and integrates the direct geophysical datasets to better understand the present-day seafloor and the recent geological processes that have shaped it.

1.1 Study Area and Location

Table 1: Study Area line defining coordinates (Projection: Nigeria West Belt C.M. 004°30' East)

S/N	Easting(m)	Northing(m)
1	295436	171836
2	294567	169350
3	273866	196831
4	274777	194365
5	280746	164977
6	295638	173024

Over the years, many oil companies' projects have been conducted within the Niger Delta making it an increasingly well-documented study location (Fig. 1). Though the studies ranged from sedimentology to stratigraphy, many also looked at the physical and geologic properties of the Basin.

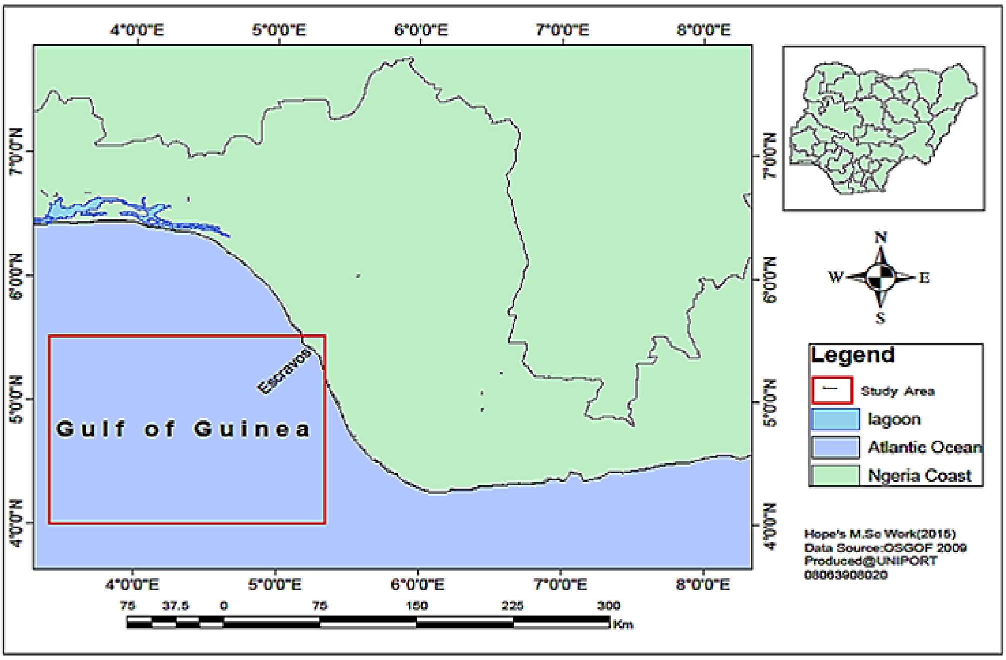

Figure 1: Map of the Study Location and coordinates, 25.82km offshore Western Niger Delta Nigeria (Modified after [6][1].

2. Methods

During April 2014, G-log Survey Ltd. and Mgog Geophysics Inc. mapped the SW Niger Delta to provide a baseline data set for ongoing offshore province development study supported by the IOC Community and the department of petroleum resources. Data were acquired with a side-mounted

Simrad 30kHz geoacoustic system (degree configuration) aboard MV Geo Prospector. Northwest-southeast lines were run approximately parallel to the location axis at speeds from 2.5 to 3 knots. The multibeam data were acquired using a fixed swath-width and an equidistant beam-spacing to ensure regularly spaced beam center points in all water depths and in highly irregular terrain [7][8]. The data were corrected for transducer depth and vessel motion and converted into depth using water sound velocity data obtained from casts with a C-tron Conductivity- Temperature-Depth (CTD) probe, acquired during the mapping program. The resultant bathymetric data were gridded at a maximum cell size of 10metres with no interpolation or smoothing applied. The multibeam bathymetry data were processed using Geokit software, and binned at a cell size slightly larger than the beam-to-beam spacing for each area.

Coda Octopus Geokit was used for quantitative geomorphic analysis, whereas EivaNavipac software was used for navigation. The final bathymetry grids include a 100m cell size for the acquisition where the shallower water required a narrower line spacing, which in turn resulted in a closer beam-to-beam centre point spacing and a higher ping repetition rate. Deeper in the location, the final bathymetry grid utilizes a 50m cell size, which allows for at least one ping per cell sounding density (note that this sounding density is not appropriate for hydrographic surveying, but in this case, allows us to grid the data at a small cell size to image the finest scale geomorphic features). Sub-sampled backscatter mosaics of the field area have a pixel size of one metre for all water depths. The multibeam was run simultaneously with a side-mounted Geo-acoustics-transducer-array for the sub-bottom profiler pinger data (Fig. 1). The transducer array for the sub-bottom profiler data operated at 3.5 kHz. The data were acquired along the center of each survey line and recorded with Fugro'sGlog acquisition software. Record length was kept constant at 100ms for every file. The data were output in standard SEGY-format (after gain was applied(after [9][10]).

Data were digitally recorded by an on-board PC-based Del Seismic recording system. Differential GPS position fixes were written into theseismic data trace headers and also as ASCII textfiles. The seismic profiles were converted from DelSeimic proprietary format to standard SEG-Yformat and to AutoCAD plot files using Navigation Data software. The NPD files were converted toJPEG image file using Coda to Image software. Both sub-bottom profiler datasets were interpreted with Coda software packages. Cores A suite of cores (piston, kasten and box cores; a total of 227) was acquired throughout the survey.

3. Results and Discussion

3.1 Seafloor morphology

The acquired geophysical datasets provide detailed information about the morphology of the study area and the surveyed part of the subsea facilities. The average water depth in the surveyed area is 25m; the depth of penetration of the acoustics of the acquisition, based on the achievable time varying gain is about 25m below the sea bed. Weak seismostratigraphic layer was observed below the seabed.

Table 2: The subsea facility observed in the profile is 42″ oil pipeline.

S/NO	FEATURES	COORDINATES	
		EASTING	NORTHING
1	Chain 6	619827	34318
2	42″oil pipeline	620151	34141
3	Chain 1	620162	34516
4	Chain 6	619986	34371
5	Chain 5	620023	34048
6	42″ oil pipeline	619947	34795
7	Chain 5	619940	34095
8	Chain 6	620176	34216
9	42″ oil pipeline	620099	34390
10	42″ oil pipeline	619996	34674

The acoustic backscatter properties of this layer indicate that the layer is composed of water-sediments interphase of arenite origin which is 25m thick. The acoustic penetration was found to be limited to this layer(according to [11][12]). No occurrence of shallow gas was observed within the seismic profiles of the surveyed area, till the extent of the acoustic penetration.

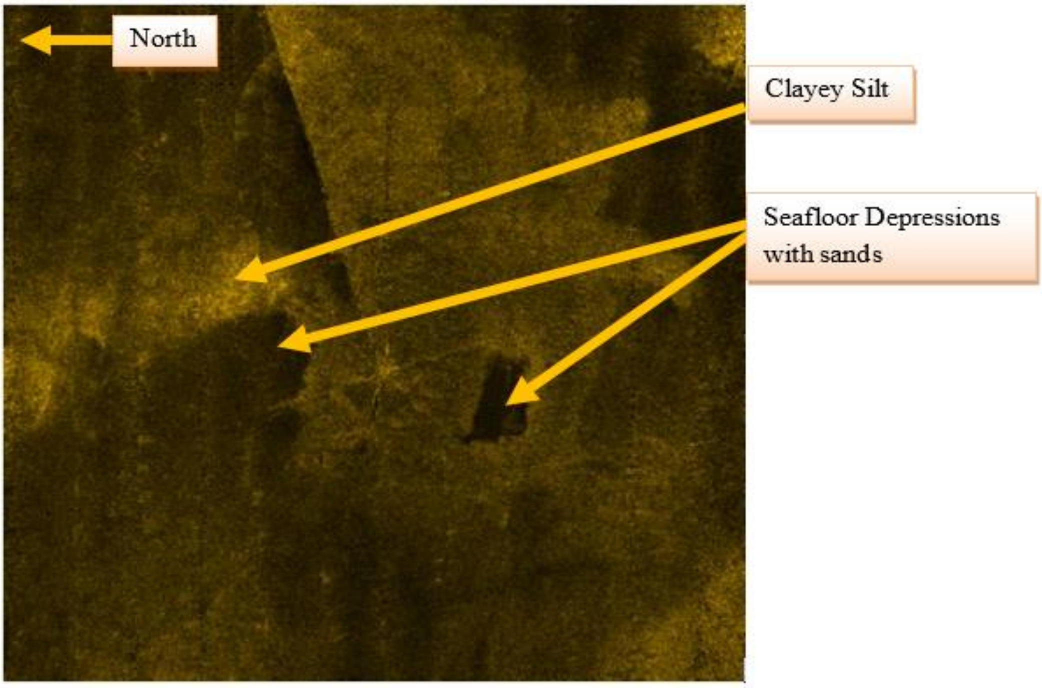

Figure 2: Multibeam imagery of seafloor depressions caused by rig movements

Average depression diameter of 10m and are located in the interfluve at 26m water depth (interpreted rigs spuds). The majority of the spud wall is characterized by anomalously low backscatter (Fig.2). The south wall of the chain (Fig. 3) is characterized by relatively high backscatter seafloor(after [13][14]). On the south flank of the buoy, between the base of the steep walls, the seafloor slopes more gently toward the depression axis, and shows a distinct furrowed morphology in the multibeam bathymetry. These furrows are parallel in some places and in others, they occur in an oblique angle. These furrows are long, linear features that do not appear to branch. Individual furrows are tens of centimeters to a meter deep, typically 10m apart, and are continuous for meters. In Fig. 3 these features can be identified in the southern cross-sections 4to 5 as a very irregular seafloor southwest of the bouy axis.

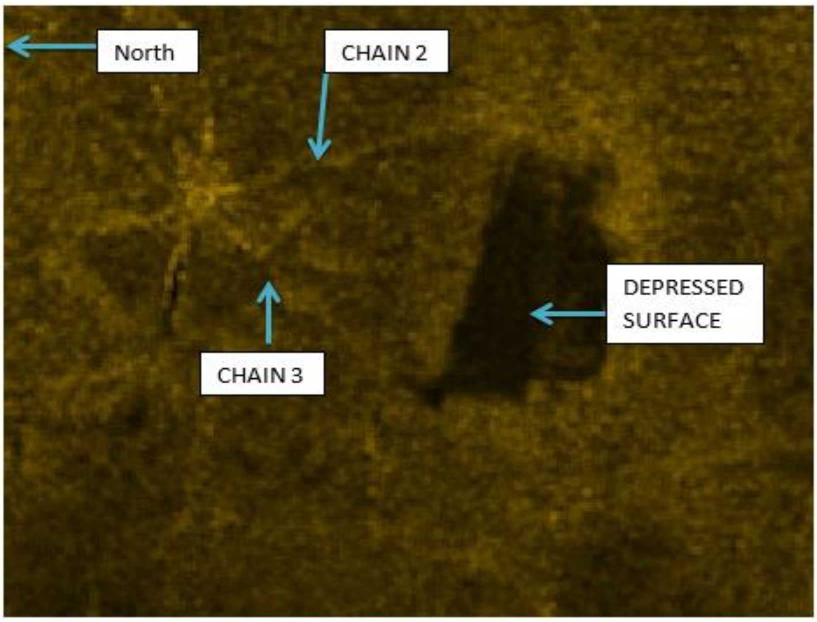

Figure 3: Side Scan sonar showing chains and depressed Surfaces.

Table 3: Side Scan Sonar Contact Listing

SSS Contact Listing				
Feature	Acquired code	Code	Easting	Northing
SPM1 Bouy	SPM1	SPM1	620142	24132.01
Anchor Pile	anchor pile	anc	620192	24402.2
Chain 1	nc1	c1	620136.4	24131
	nc2	c2	620138.8	24144
	nc3	c3	620142.2	24158.5
	nc4	c4	620147.5	24179.9
	nc5	c5	620153.2	24201.7
	b4	c6	620161.4	24241.1
	b3	c7	620168.3	24274.9
	b2	c8	620174.1	24300.3
42" Oil Pipeline	pnc1	p1	620132.1	24127.9
	pnc2	p2	620129.3	24134.2
	pnc3	p3	620125.7	24146.1
	pl2	p4	620117.2	24171.5
	pl3	p5	620107.6	24200.8
	q6	p6	620098.7	24239.4
	q5	p7	620084.1	24286.3
	q4	p8	620074.7	24318.2

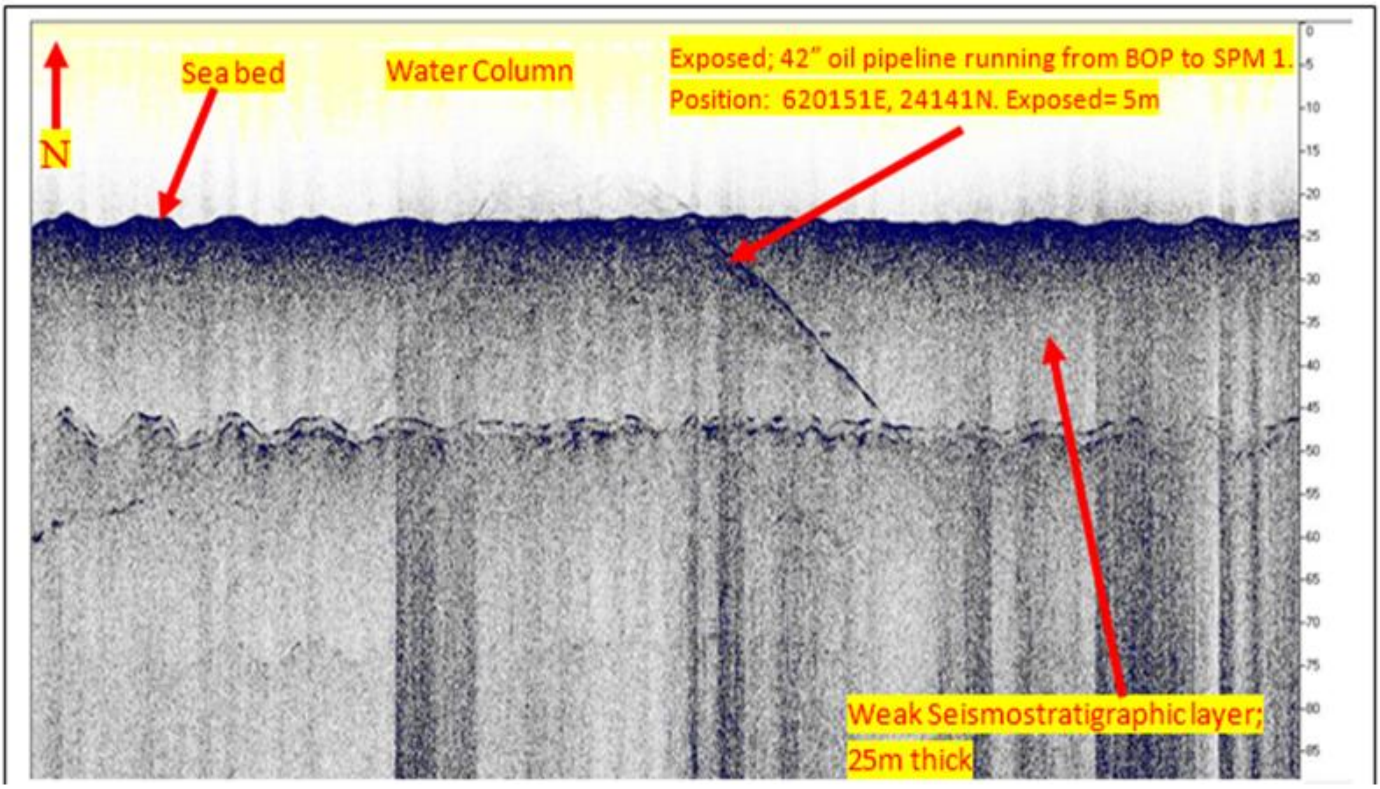

Figure 4: Sub bottom Profile Data Extract Showing the Strata below the Seafloor.

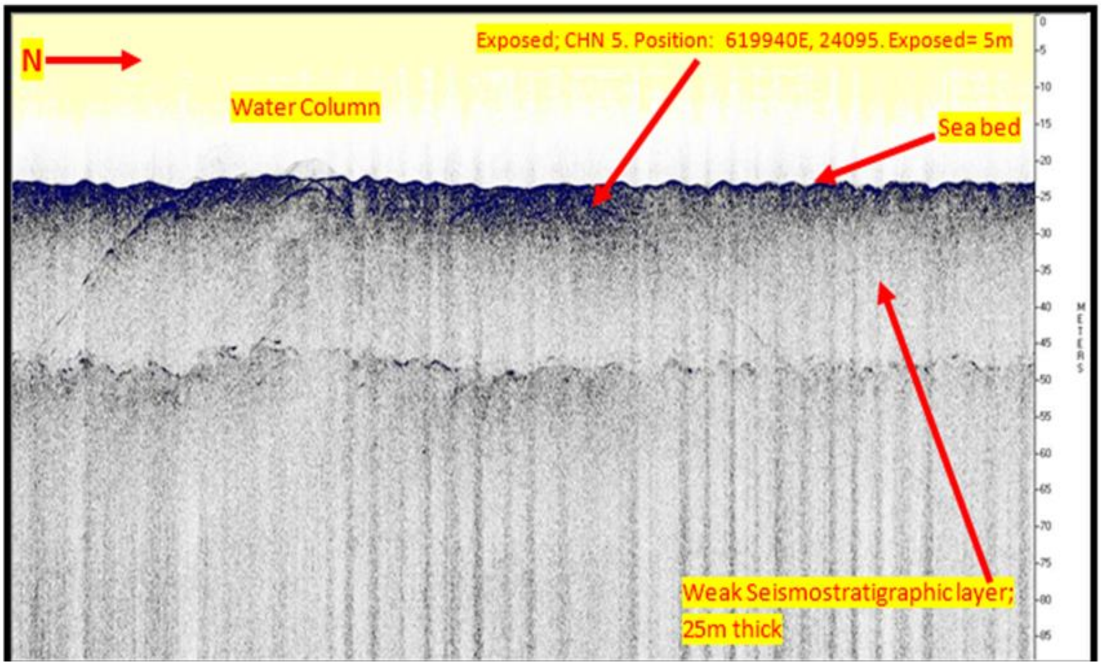

Figure 5: Sub bottom Profile Data Extract Showing the chains below the Seafloor

The extracts below from magnetometer provided the details of the magnetic anomalies observed within the surveyed area, which are associated with the SPM1 and Chains (Table 4) and Figure 6.The planned survey lines that are running north/south and east/west determined these anomalies.

Table 4: Details of the magnetic anomalies observed within the surveyed area

		COORDINATES	
	FEATURES	EASTING	NORTHING
1	SPM1 chain 4	620122.98	34016.77
2	SPM1 chain 3	620483.75	33904.02
3	SPM1 chain 1	619916.11	33906.07
4	SPMI and chain 2	620225.49	24151.45
5	SPMI chain 5	620182.93	34309.32

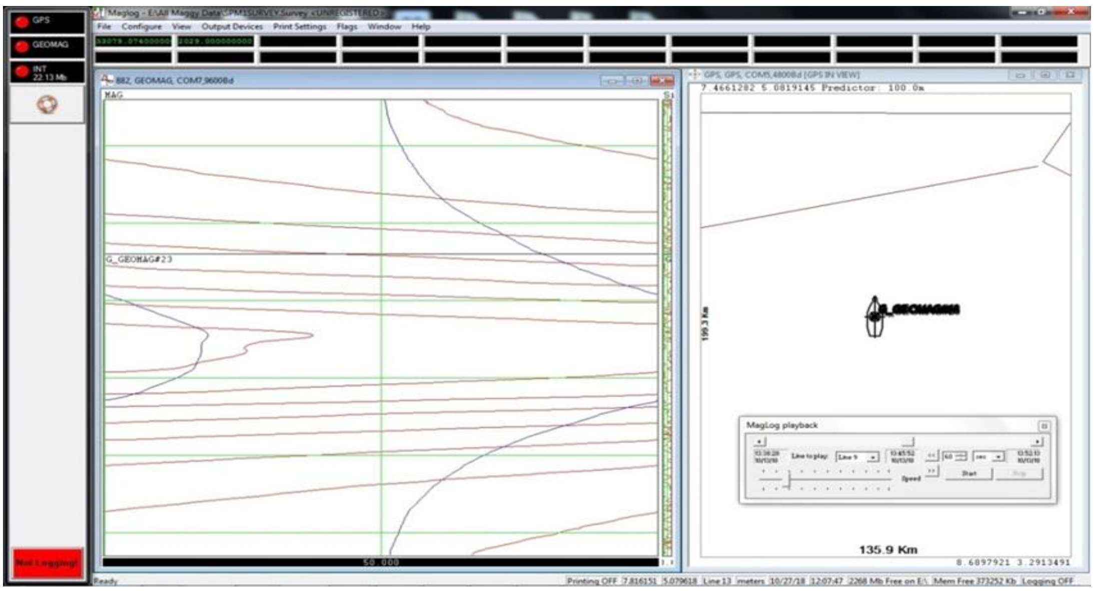

Figure 6: MagLog Extract showing magnetic anomaly corresponding to Chain 4.

The side scan sonar has a highly reflective discrete returns interpreted as SPM1 buoy, part of 42'' oil pipeline Fig. 9) from BOP to SPM1, chains (1 to 6) (Fig. 10) attached to SPM1 and suspected anchor Piles(fig 8) towards the end of chain 1(table 5). The sea floor in between and towards the end of chain 2 and 3 shows slight depression but not significant due to the measured water depth in that area (Fig. 7).

Table 5: Depression between chain 2 and 3 coordinate

Feature	code	Easting	Northing	Length (m)	Width (m)
Depressed surface	DS	620331.93	24081.3	150	80

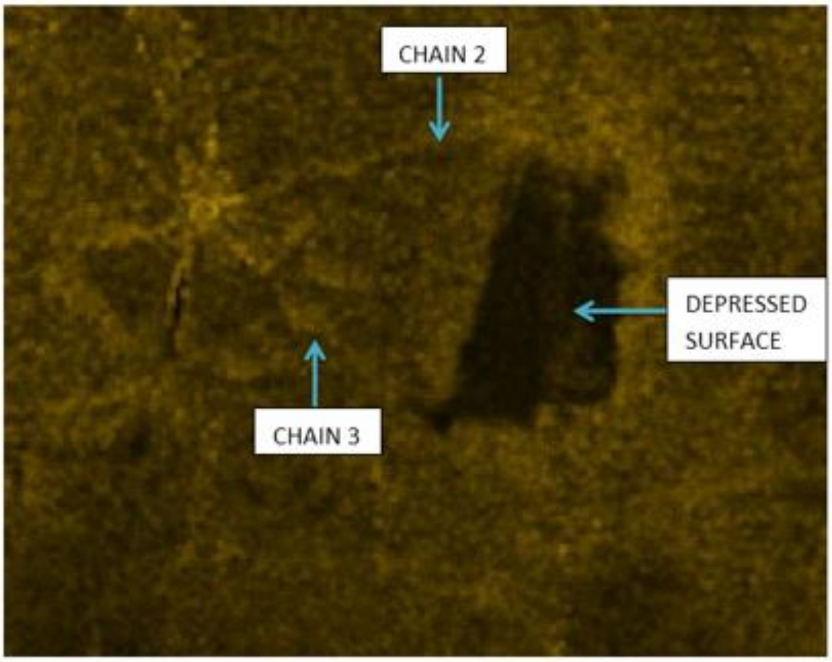

Figure 7: Side Scan sonar showing chains and depressed Surface

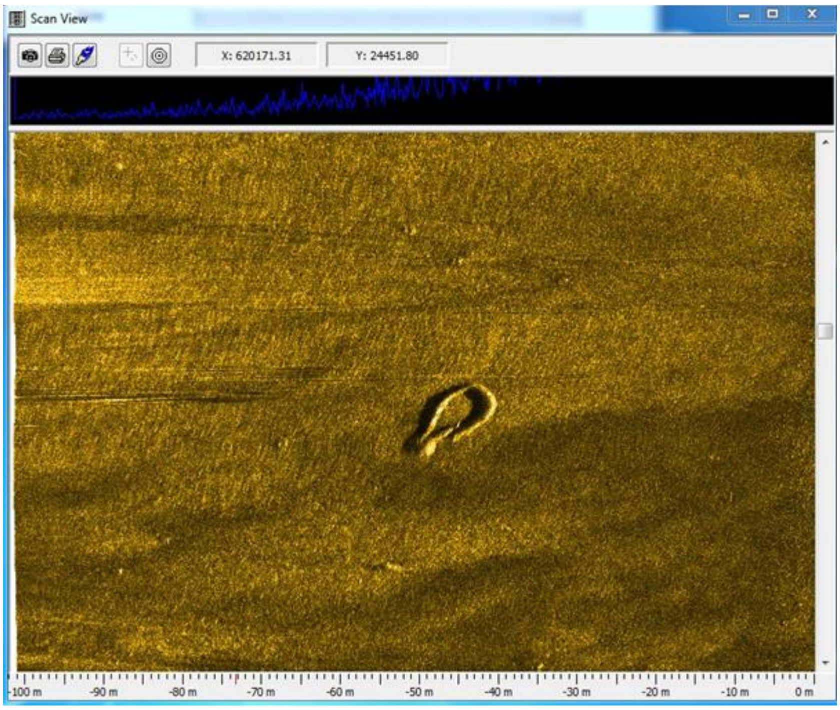

Figure 8: Side Scan Sonar Showing Anchor Pile

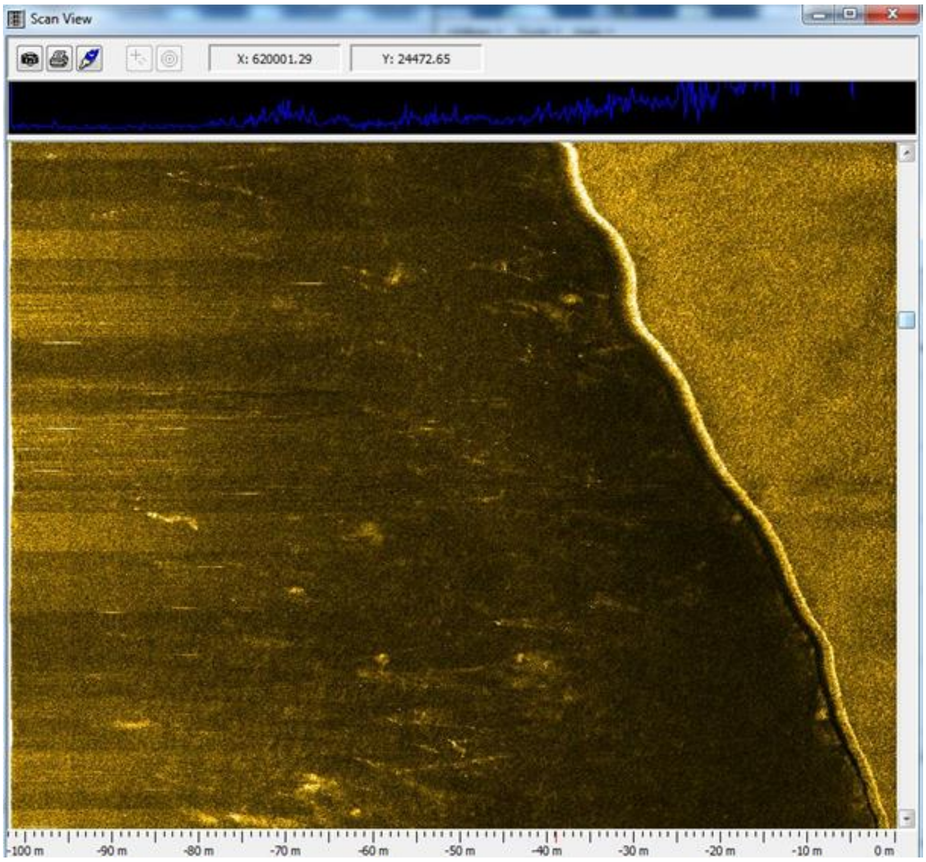

Figure 9: Side Scan Sonar Showing Exposed 42''pipeline

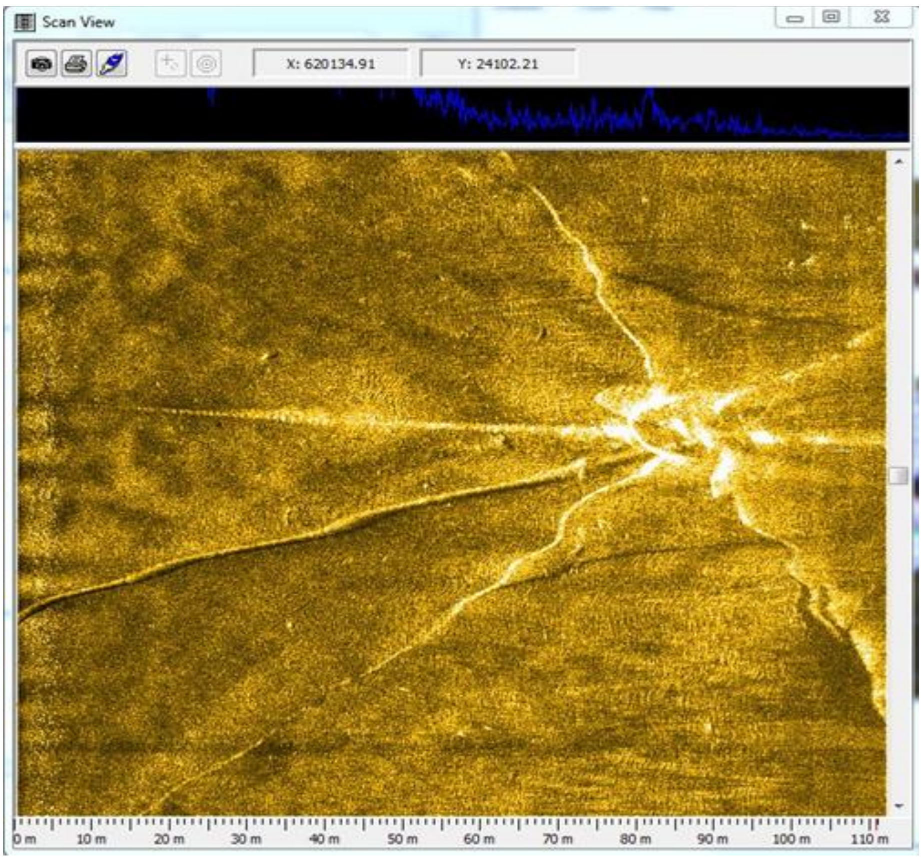

Figure 10: Side Scan Sonar Showing SBM1 with Chain Spread

3.2 Bathymetry

Single Beam Echo Sounder

The single beam bathymetric values were reduced to the lowest astronomical tide, LAT of Opobo river entrance. The average water depth within the survey area 26.13m.

Multibeam Echo Sounder

The multibeam bathymetric values were reduced to the lowest astronomical tide, LAT of Opobo river entrance. The average water depth within the survey area is 26.26m

Charting

Micro Station and AutoCAD were used for charting. Micro Station and AutoCAD are Windows based post-processing, and charting software. The graphics display has advanced interactive plotting and editing functions specifically tailored to meet the needs of survey charting. Track plots were compiled by importing the processed datum tack lines into the processed charts (after [15][16]). Bathymetry charts were compiled by importing the processed sounding data into the charts. Seabed features chart are constructed from the interpretations of the side scan sonar imagery response acquire for each survey line. Charts are produced at a scale of 1: 5000 in AUTOCAD DWG format and are based on Minna west Belt projection.

4. Conclusion

The area of 500mby 500m radius face-out from the SBM1 center coordinates 620142.00mE 24132.01mN as indicated in the chart, was surveyed from the 10th-20thApril, 2014. Side-scan sonar records were consistent with the provided chart. Within the survey area sonar records reveals both exposed and buried chains attached to the Buoy. Also, there is an exposed 42′′ pipeline running within the survey area.

All observed seabed features, were fully digitized to their lateral extents and displayed in the accompanying AutoCAD chart. Bathymetric data showed that seabed topography was relatively flat with a dipping slope to the south of the survey area. Average water depth within the area was 26.26m. Magnetometer anomalies were recorded within the survey area correlating to features captured both by side scan sonar and the sub-bottom profiler.

In conclusion, the results of the pre-JUB seabed survey are largely consistent with supplied chart. The seafloor is clearly shows exposed pipeline, exposed and buries anchor chains and piles within the survey area. JUB approach and final position must be designed putting these existing features in consideration. The survey was carried out in accordance to international hydrographic organization standard, with high level professionalism required for this type of project. Results show no danger or threat to the proposed Jack up rig move.

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Informed Consent Statement: Not applicable.

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Conflicts of Interest: The authors declare no conflict of interest

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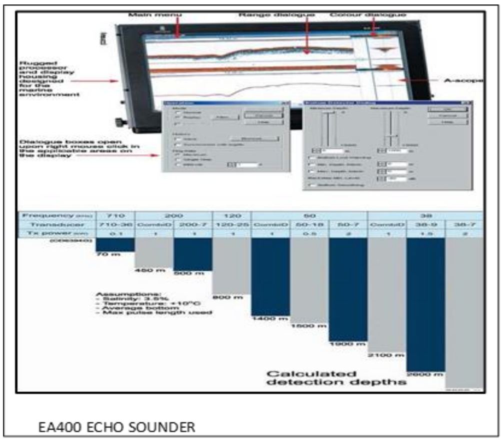
APPENDIX

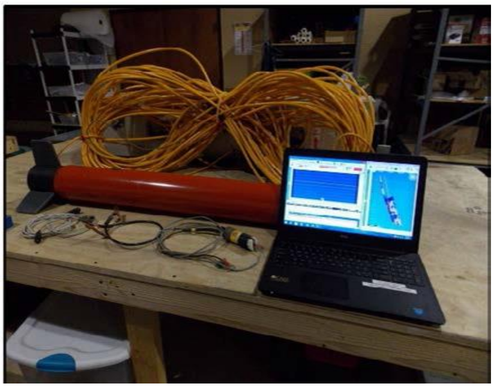


EA400 Echo Sounder

MultibeamEchoSounder (MBES) SetupSystem

Coda Geophysical Acquisition System

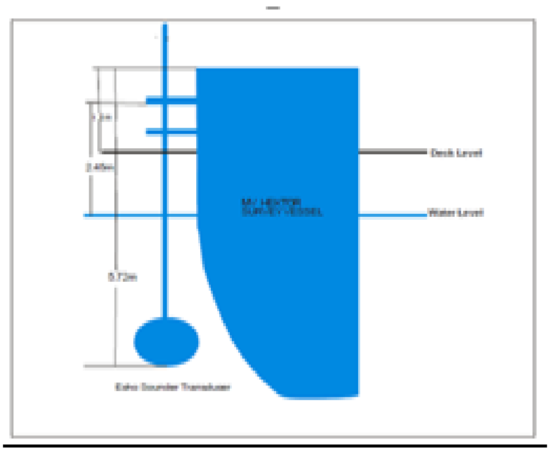
Sub BottomProfiler (SBP)System



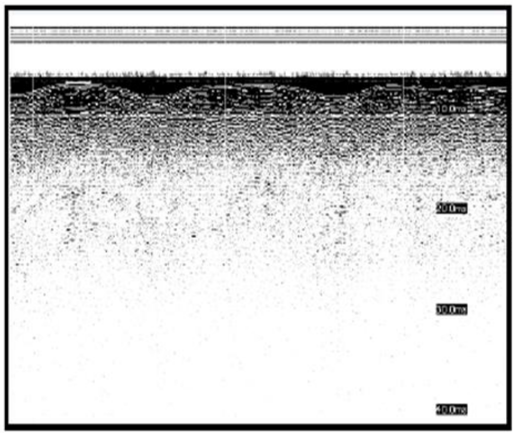
SeaspyMagnetometer(Maggy)System

Side Scan Sonar System

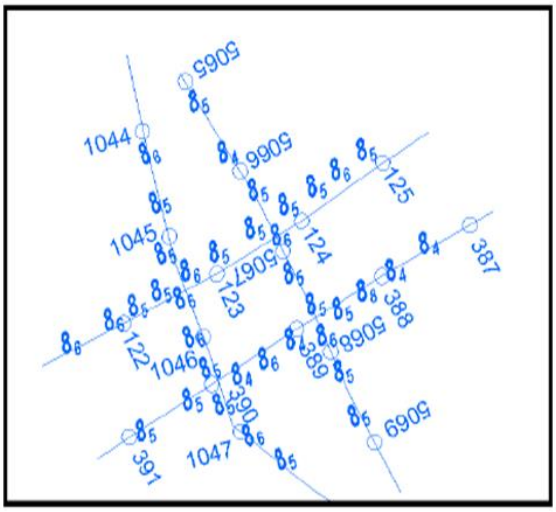
GeoSurvey Mobile Vessel



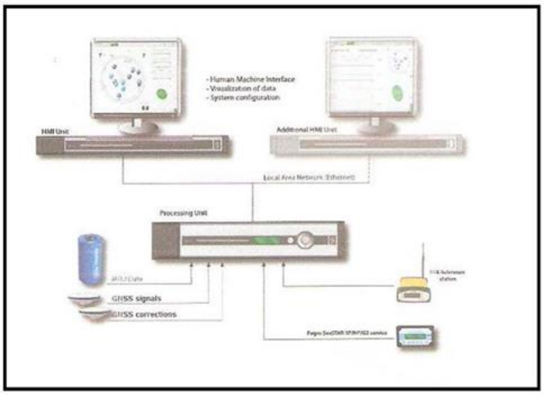
Echosounder DraftMeasurements



Sub BottomProfiler Wet Test

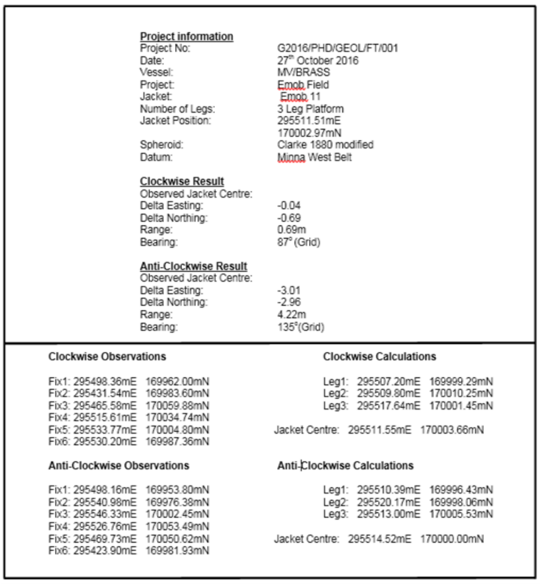


Cross Line Check



Differential Global Positioning System(DGPS)

Vale Port ConductivityTemperature DepthProbe(CTD)



Project information
Project No: G2016/PHD/GEOL/FT/001
Date: 27th October 2016
Vessel: MV/BRASS
Project: Emob Field
Jacket: Emob 11
Number of Legs: 3 Leg Platform
Jacket Position: 295511.51mE 170002.97mN
Spheroid: Clarke 1880 modified
Datum: Minna West Belt

Clockwise Result
Observed Jacket Centre:
Delta Easting: -0.04
Delta Northing: -0.69
Range: 0.69m
Bearing: 87° (Grid)

Anti-Clockwise Result
Observed Jacket Centre:
Delta Easting: -3.01
Delta Northing: -2.96
Range: 4.22m
Bearing: 135°(Grid)

Clockwise Observations

Fix1: 295498.36mE 169962.00mN
Fix2: 295431.54mE 169983.60mN
Fix3: 295465.58mE 170059.88mN
Fix4: 295515.61mE 170034.74mN
Fix5: 295533.77mE 170004.80mN
Fix6: 295530.20mE 169987.36mN

Clockwise Calculations

Leg1: 295507.20mE 169999.29mN
Leg2: 295509.80mE 170010.25mN
Leg3: 295517.64mE 170001.45mN

Jacket Centre: 295511.55mE 170003.66mN

Anti-Clockwise Observations

Fix1: 295498.16mE 169953.80mN
Fix2: 295540.98mE 169976.38mN
Fix3: 295546.33mE 170002.45mN
Fix4: 295526.76mE 170053.49mN
Fix5: 295469.73mE 170050.62mN
Fix6: 295423.90mE 169981.93mN

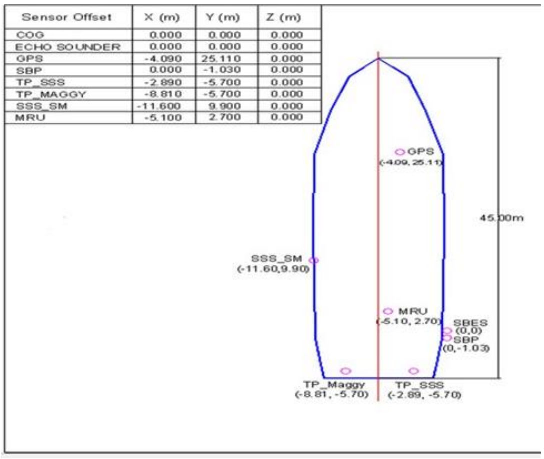
Anti-Clockwise Calculations

Leg1: 295510.39mE 169996.43mN
Leg2: 295520.17mE 169998.06mN
Leg3: 295513.00mE 170005.53mN

Jacket Centre: 295514.52mE 170000.00mN

Sea Verification KongsbergSeapath 330GNSSReceiver

TSSTeledyne Motion Sensor



Sensor Offset	X (m)	Y (m)	Z (m)
COG	0.000	0.000	0.000
ECHO SOUNDER	0.000	0.000	0.000
GPS	-4.090	25.110	0.000
SBP	0.000	-1.030	0.000
TP_SSS	-2.890	-5.700	0.000
TP_MAGGY	-8.810	-5.700	0.000
SSS_SM	-11.600	9.900	0.000
MRU	-5.100	2.700	0.000

Vessel Offset Measurements

Trimble DGPS

SG Brown Gyro MeridianCompass