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Research Article

TOPOGRAPHY AND LITHOFACIES OF THE SEA FLOOR IN MEREN FIELD, OFFSHORE WESTERN NIGER DELTA

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ABSTRACT

Knowledge of the geological state of the sea floor is critical to oil field development in the offshore province to obviate problems related to instability and drifting of drilling rigs, collapse of offshore structures including production platforms, grounding of operations vessels, pipeline ruptures (with concomitant spillages), etc. This study of the Meren Field in the inner shelf environment offshore western Niger-Delta combined results from measurements using high fidelity onboard instrumentation with data from existing well cuttings for the characterization and sediment mapping, surface and sub-surface, of the seafloor. Bathymetry ranges between 15m-18.3m with a deepening trend from the northeast to southwest caused by ripples currents and storm processes affecting the shore face zone. The lithofacies of the sea bed scan varies from sand, through silt to clay. The lithified sediments (competent bed) were found 20m-25m below the seabed as corroborated by the lithofacies analysis of the well cuttings which show the presence of sandstone at 25m, and two paleo-channels separated from each other by flood plain deposits, marked by a fining upward facies sequence. Gas charged sediments about 20m thick occur between the sea bed and lithified layer. The sea floor scan also shows existence of genetically related depressions and rings of sand around them called pock marks which vary between 3m-10m in diameter. Based on findings, a number of recommendations have been formulated for the safe and cost effective development of this Oil Field.

Keywords: Sea floor, Bathymetry, Lithofacies, Competent bed, Pock marks.

INTRODUCTION

The seafloor topography and lithofacies mapping and characterization are a high-fidelity information tool use to identify the geological state of the seabed offshore. This study is a geological investigation of the inner shelf environment of Western Niger Delta offshore(Gulf of Guinea) using side Sean Sonar, well cutting, sub-bottom profiler and Echo sounder technique. This technique according to is useful in determining the nature of surface sediments, subsurface lithofacies, environment of deposition of the sediments, bed forms and other geomorphologic features of the sea floor. Whether the study area as suitable and safe for the emplacement of offshore structures or has the potential to develop further into a situation leading to damage or uncontrollable risks. The exploitation and transportation of crude oil require adequate knowledge of the sediments distribution pattern on the seabed for sitting of subsea facilities. For example: drilling rigs, pipelines, platforms jack-up barges as well as the navigation of sea going vessels. Sea floor sediments studies require the understanding of differences in acoustics reflectivity and reverberation of sound over rock bottoms of the seafloor Emery, (1976). This understanding is very vital for accurate measurement of distances, depth and determinations of the nature of the seafloor for its potentials and use by various interested workers. In the search for hydrocarbon, the knowledge of sand blanket and gas vent (pockmarks) at the continental shelf can aid in the recognition and prediction of petroleum occurrence where it is established that thick sedimentary fill exist in the basin. Sediments of economic value abound and can be mind from the ocean floor. For example, placer deposits like sand and gravel, and heavy minerals. This research believed will support other related research works.

The aim of this study is to describe the seafloor sediment distribution for field development operations like oil well drilling and pipelaying operations in the study area.

The objectives include: To determine the type of sediments on the sea bed, sea bed topography, identify other sea bed features, determine shallow subsurface lithofacies and identify the various sedimentary structures. The study area is 3.08km^2. It is situated 15 kilometers off the coast line from the south western end of Escravos River in western Niger Delta of Nigeria.

(Projection: Nigeria West Belt C.M. 004°30' East)

S/N	Easting(m)	Northing(m)
1	271655.2599	197303.5180
2	272154.4069	196148.4093
3	271833.8046	197390.0864
4	272324.6466	196163.3347
5	272920.2356	196298.1488
6	272997.7203	196302.5806
7	273511.5893	197965.5162
8	273776.445	196677.1498
9	274056.2398	196779.12
10	271928.3425	196091.709

Table 1: Study area line defining coordinates

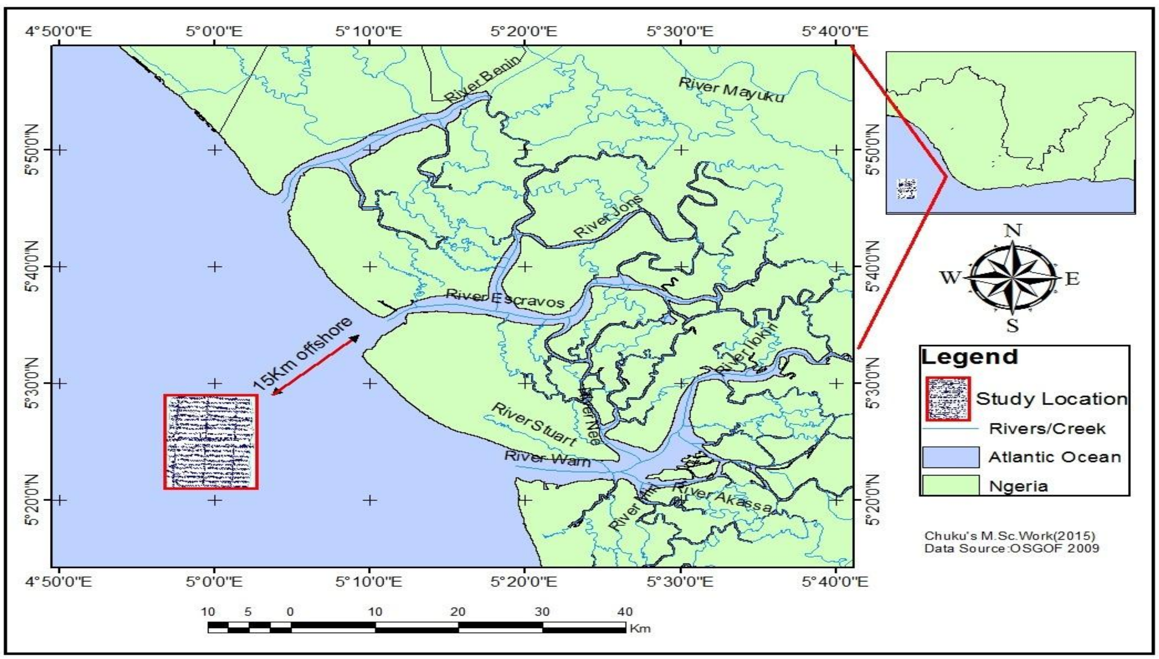


Figure 1: Location Map of the Study Location 15km offshore Western Niger Delta Nigeria.

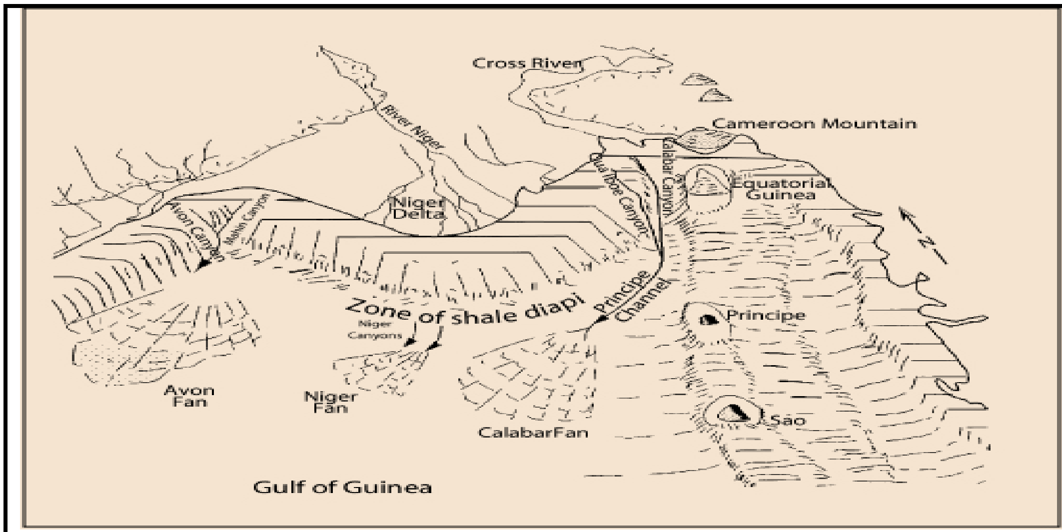


Figure 2: Niger Delta Physiographic Sketch of the Marine Sediments (Modified from Burke (1972) and Reijers, et al. 1997.

SUBSURFACE		**SURFACE OUTCROPS**		
Youngest known Age	**Oldest known Age**	**Youngest known Age**		**Oldest known Age**
Recent Benin Formation (Afam clay member)	Oligocene	Pleistocene	Benin Formation	Miocene
Recent Agbada Formation	Eocene	Miocene Eocene	Ogwashi-Asaba Amaeki Formation	Oligocene Eocene
Recent Akata Formation	Eocene	L. Eocene Paleocene Maastrichtian	Imo shale Nsukka Formation Ajali Formation	Paleocene Maastrichtian Maastrichtian
Equivalent not known	Cretaceous	Campanian	Mamu Formation	Campanian
		Campanian/ Maastrichian	Nkporo shale	Santonian
		Coniacian/ Santonian	Awgu shale	Turonian
		Turonian	Eze-aku shale	Turonian
		Albian	Asu River Group	Albian

Table 2: Correlation of Subsurface and Surface Formations of the Niger Delta Area (Short and Stauble, 1967).

METHODOLOGY

The study seeks to integrate four sets of data in studying the nature of surface and subsurface sediments derived from geoacoustic survey (Bathymetry, side-scan sonar and sub bottom profiler), and well cutting data to bring about the understanding of the geological state of the study area in relation to the regional geology (Niger Delta) and bring into focus the contributions of geoscientists to offshore engineering activities in relation to oil and gas prospecting. Approximately 27 linear kilometers of sub bottom profiler, side scan sonar and echo sunder data were surveyed using Geo acoustics SSS 941 Tow fish with Geo acoustics

15GD acoustics SSS Tow fish with fish with Geo Acoustics 15GD Transducers, Geo pulse SBP 5430A Transmitter and EA 400 single beam hydrographic echo sounder. The accurate positioning of the side-scan sonar, sub bottom profile and echo sounder track line was accomplished by means of a kongsberg sea path 330 receiver(DGPS), the backscatter of the surface sediments (side- scan sonar), couple with sea bed sample has enable the distinction of the sea floor lithofacies. Water depths measured form echo sounder was used to determine the bathymetric classification and location of the study area within the inner shelf environment of the Niger Delta. The final bathymetric chart was plotted form echo sounder readings for which cross actions were taken to determine the sea bed topography. Bed forms captured from the sea bed scan were matched with the topographical features to deduce the processes shaping the sea floor environment of the study area.

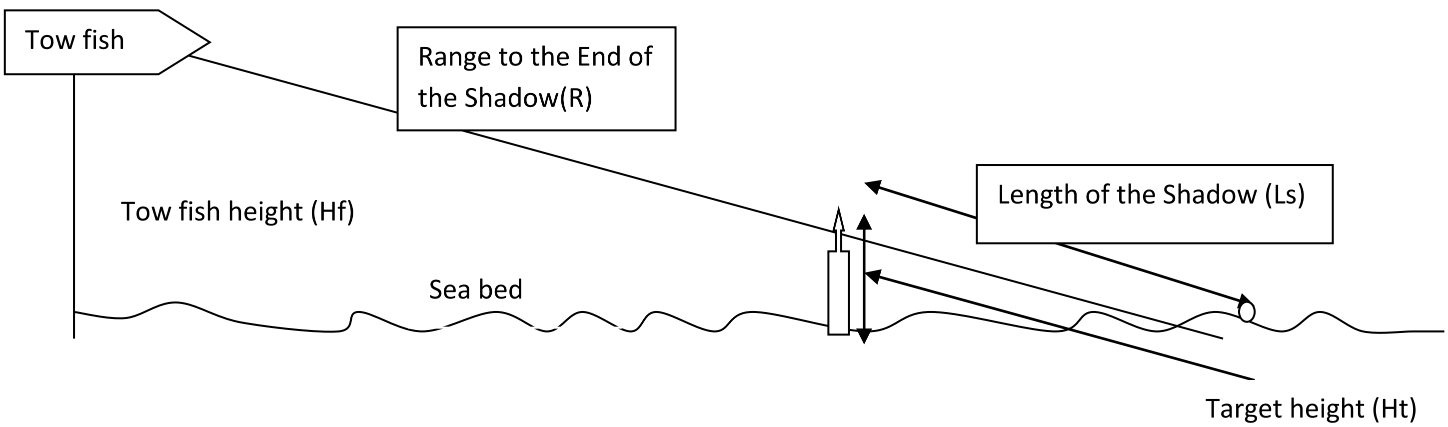


Figure 3: Target height measurements above sea bed (Fisher, 1996).

RESULTS AND INTERPRETATION

These consist basically of three sets of data: bathymetric data, sub bottom data and side scan data with respect to lithology, sea floor topography, subsurface stratigraphy, observed features, environment of deposition and sedimentary structures.

(A) BATHYMETRIC SOUNDING DATA:

1. Water Depth:

The water depth measured over the study area ranges between 15.7 to 18.3m. The shallowest water depth (15.7m) occurred in south western portion. This bathymetric range indicates that the study area is located within the middle to upper shore face setting of the inner shelf. The result obtained from the water depth measurement was used to plot a bathymetric map for the study area using Naviedit software at a scale of 1:0000. On this map the various sedimentary features observed were also plotted.

Rom Kp to Kp	Water depth range (m)
Kp0.00 to 0.10Kp	18.3
Kp0.10 to 0.20Kp	17.5
Kp020 to 0.30Kp	16.9
Kp0.30 to 0.40Kp	16.8
Kp0.40 to 0.50Kp	16.8
Kp0.50 to 0.60Kp	16.8
Kp0.60 to 0.70Kp	16.8
Kp0.70 to 0.80Kp	16.7
Kp0.80 t0 0.90Kp	15.7
Kp0.90 to 1.00Kp	15.7
Kp1.00 to 1.10Kp	15.7
Kp1.10 to 1.112Kp	15.7

Table 3: Water depths within the study area

2. Sea Bed Topography:

The sea bed slopes with very gentle gradient from the North eastern part of the study area towards the southwest. The sea bed topography observed from several cross sections taken reveals undulating topographies in the north eastern and south western parts of the study area.

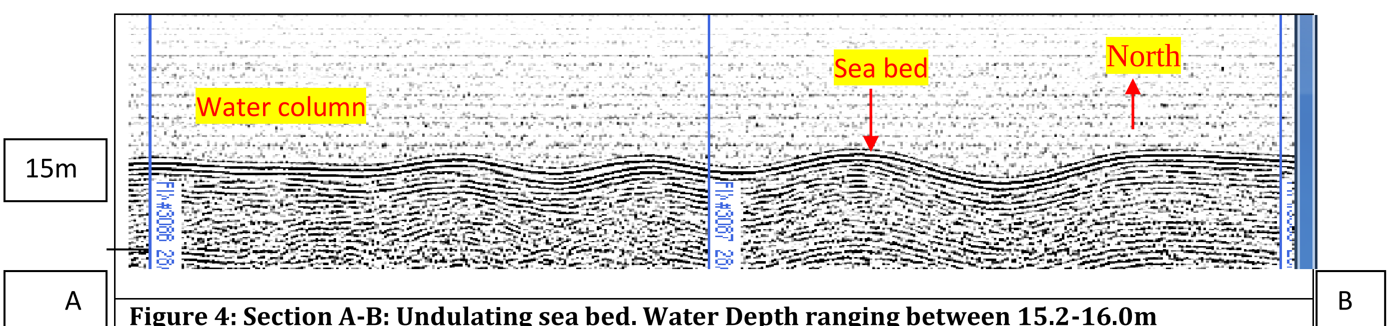


Figure 4: Section A-B: Undulating sea bed. Water Depth ranging between 15.2-16.0m Drawing Scale 1:1000

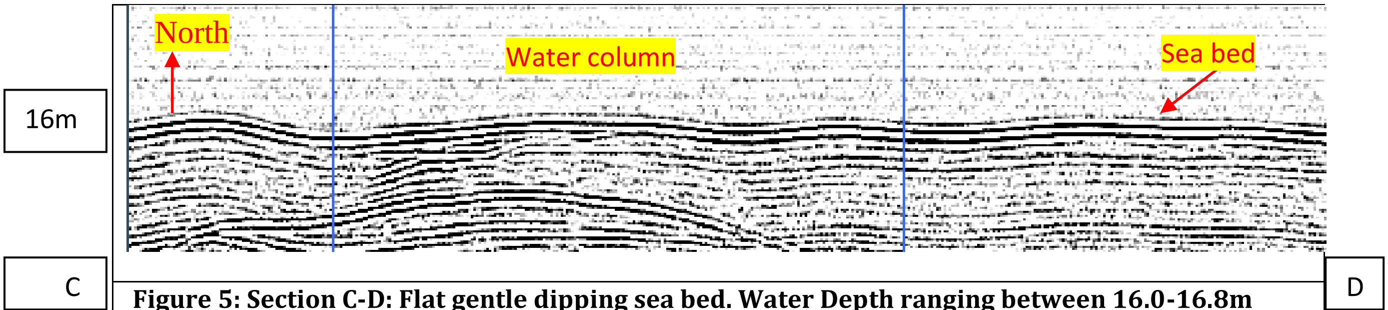


Figure 5: Section C-D: Flat gentle dipping sea bed. Water Depth ranging between 16.0-16.8m Drawing Scale 1:1000

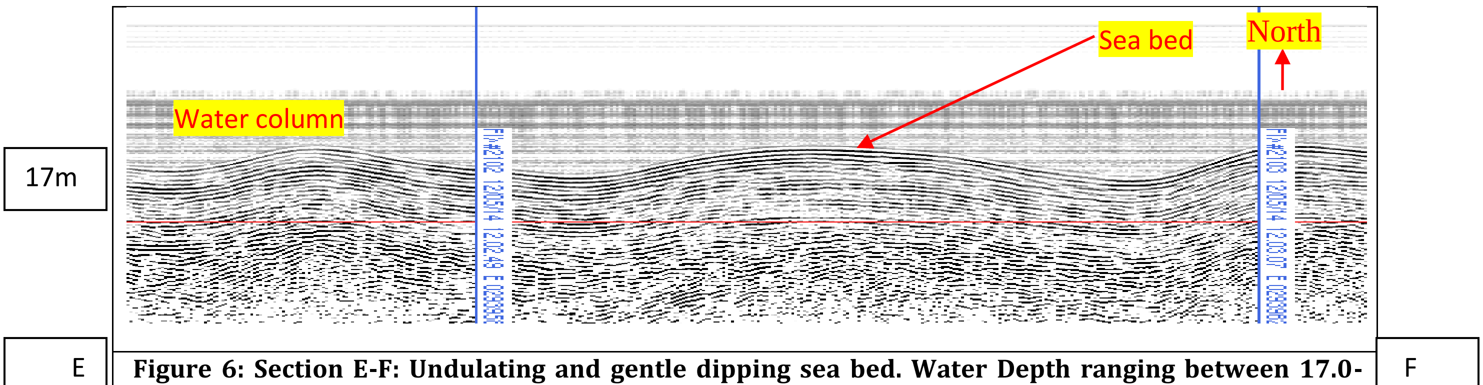


Figure 6: Section E-F: Undulating and gentle dipping sea bed. Water Depth ranging between 17.0-17.5m Drawing Scale 1:1000

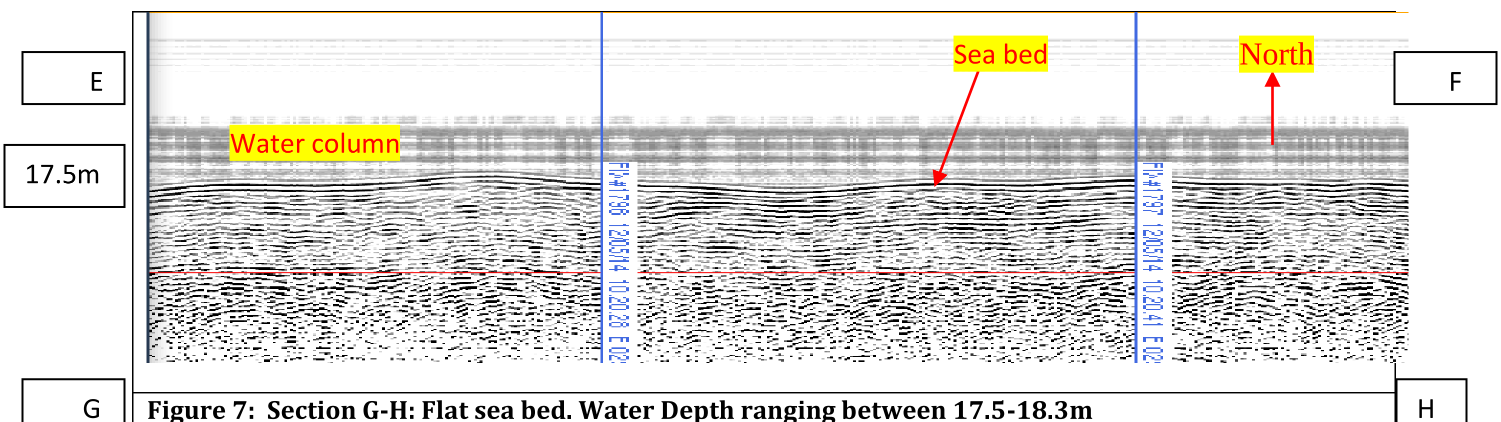
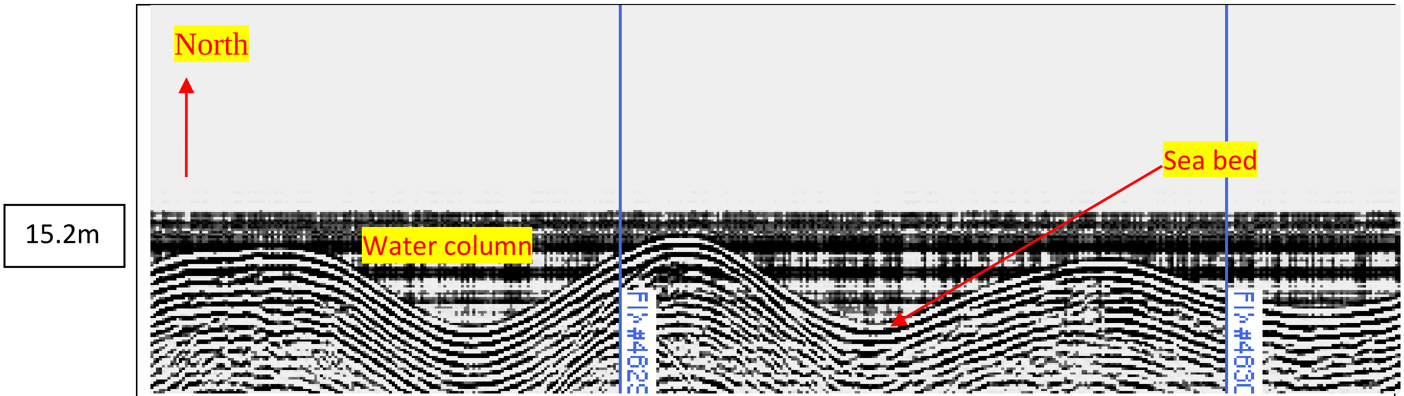


Figure 7: Section G-H: Flat sea bed. Water Depth ranging between 17.5-18.3m Drawing Scale 1:1000

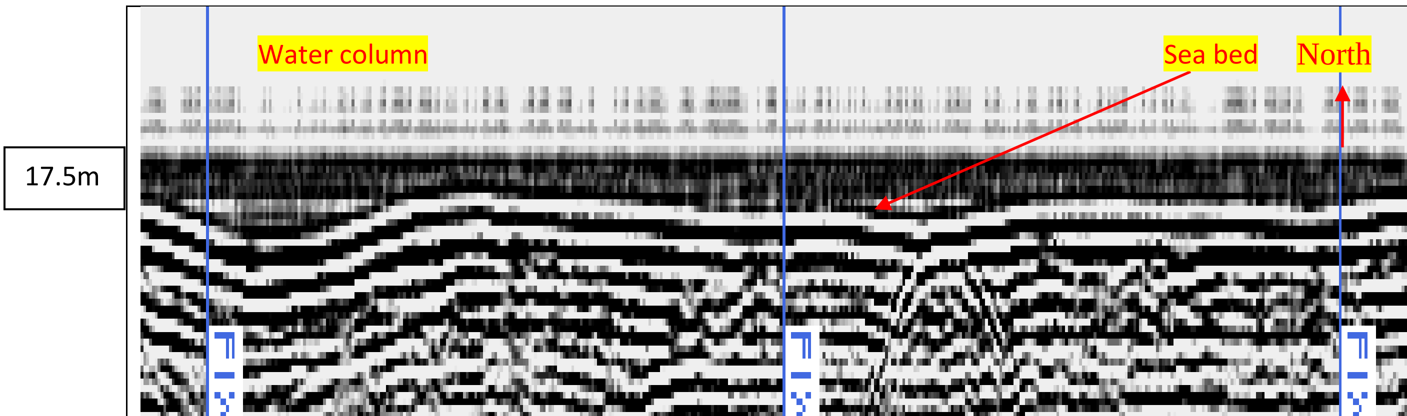


I

Figure 8: Section I-J: Very Undulating sea bed. Water Depth ranging between 15.2-17.0m

Drawing Scale 1:1000

J



K

Figure 9: Section K-L: Very Flat sea bed. Water Depth ranging between 17.5-18.0m

Drawing Scale 1:1000

L

Generally the sea bed profile within the study area slopes gently from north towards the south.

(B) SIDE SCAN SONAR IMAGERY (LITHOLOGY):

The side-scan imagery revealed the textual characteristics and varying reflective strengths of the sea bed within the study area. Low intensity back scatter dominate the entire study area. This is interpreted as clay and silt with pockets of sand.

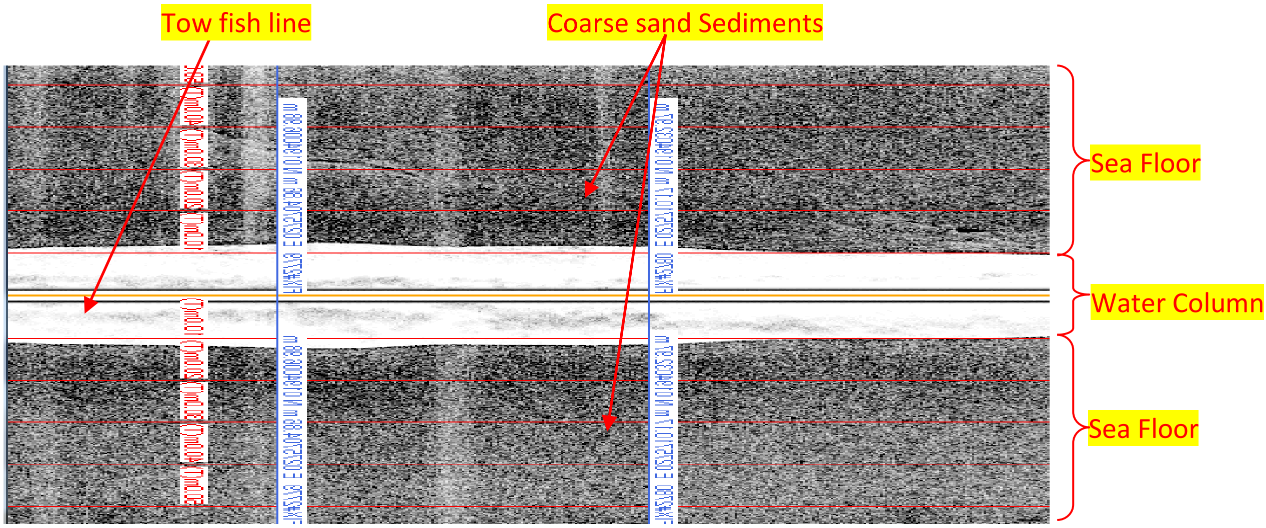


Figure 10: Sea bed lithologic interpretations from side-scan sonar

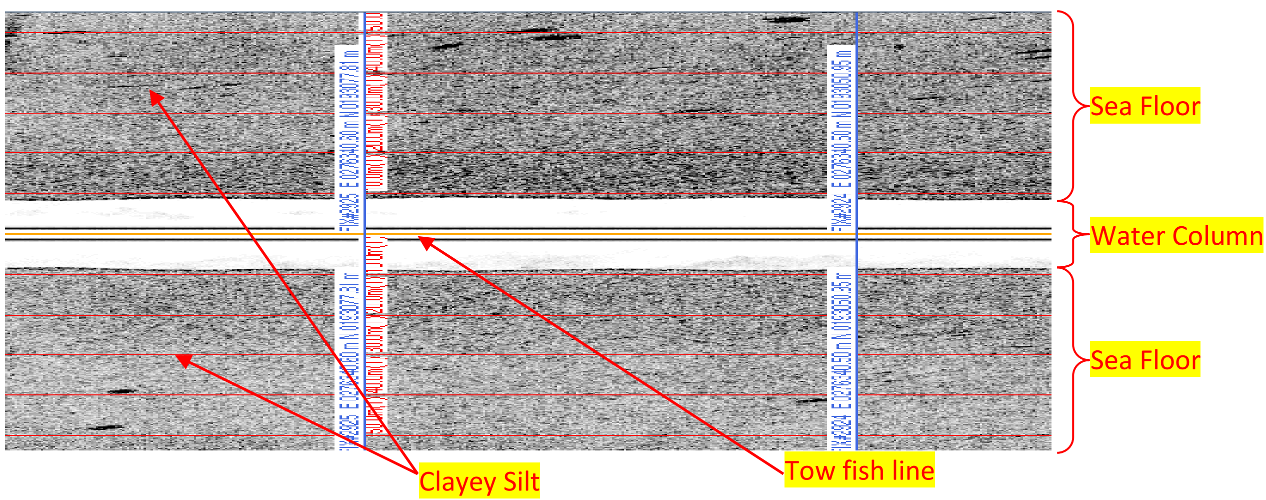


Figure 11: Sea bed lithologic interpretations from side-scan sonar.

1. Sea Bed Sediments:

The sonar records of the survey area infer the dominant presence of low and high reflective sediments, interpreted to be composed of silty clayey SAND. The high reflective sediments, interpreted to be composed of clayey, silty SAND was observed as pockets in its south west. The high reflective sediments were also observed as rims within the study area.

From		**To**		
Easting (m)	**Northing (m)**	**Easting (m)**	**Northing (m)**	**Sediment types**
272997	196488	172988	196499	High reflective sediments
272988	196499	272609	197505	Low reflection sediments
272609	197505	272601	197509	High reflective sediment
272980	196389	273872	196812	Low reflection sediments
272952	196403	273462	196846	Low reflection sediments
272659	196414	273556	196903	Low reflection sediments
272922	196417	273270	196913	High reflective sediments
272885	196433	273644	196975	High reflective sediments
273083	196448	273735	197041	High reflective sediments
273077	196464	273090	197072	High reflective sediments
272754	196509	273808	197093	High reflective sediments
273046	196519	273701	197203	High reflective sediments
272536	196522	272294	197211	High reflective sediments
273656	196543	273739	197212	High reflective sediments
273129	196604	272941	197212	High reflective sediments
272599	196648	273784	197248	High reflective sediments
273532	196674	272205	197255	High reflective sediments
273231	196680	273812	197288	Low reflection sediments
273928	196719	272275	197302	Low reflection sediments
273318	196748	272707	197401	Low reflection sediments
273421	196763	273692	197431	Low reflection sediments
274027	196768	272648	197462	Low reflection sediments
272390	196781	272615	197489	Low reflection sediments
272469	196782	272561	197557	Low reflection sediments

273404	196804	273666	197560	Low reflection sediments
272831	196294	272556	197580	Low reflection sediments
272723	196360	273541	197658	Low reflection sediments
273011	196374	273872	196812	Low reflection sediments
272980	196389	273462	196846	Low reflection sediments

Table 4: Sea bed sediment distribution with the area

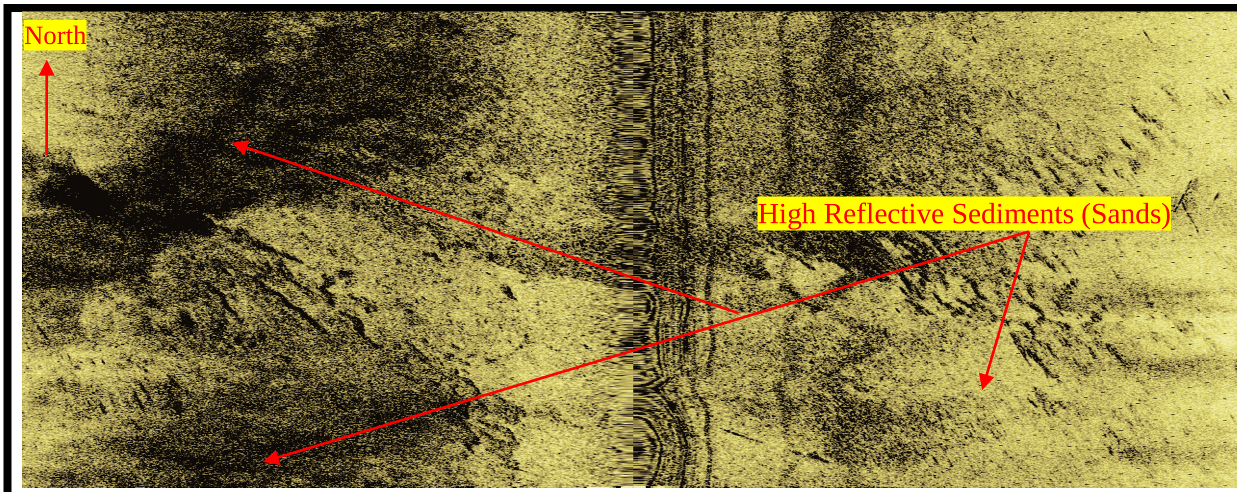


Figure 12: SSS Data extract showing High reflective sediment accumulations.

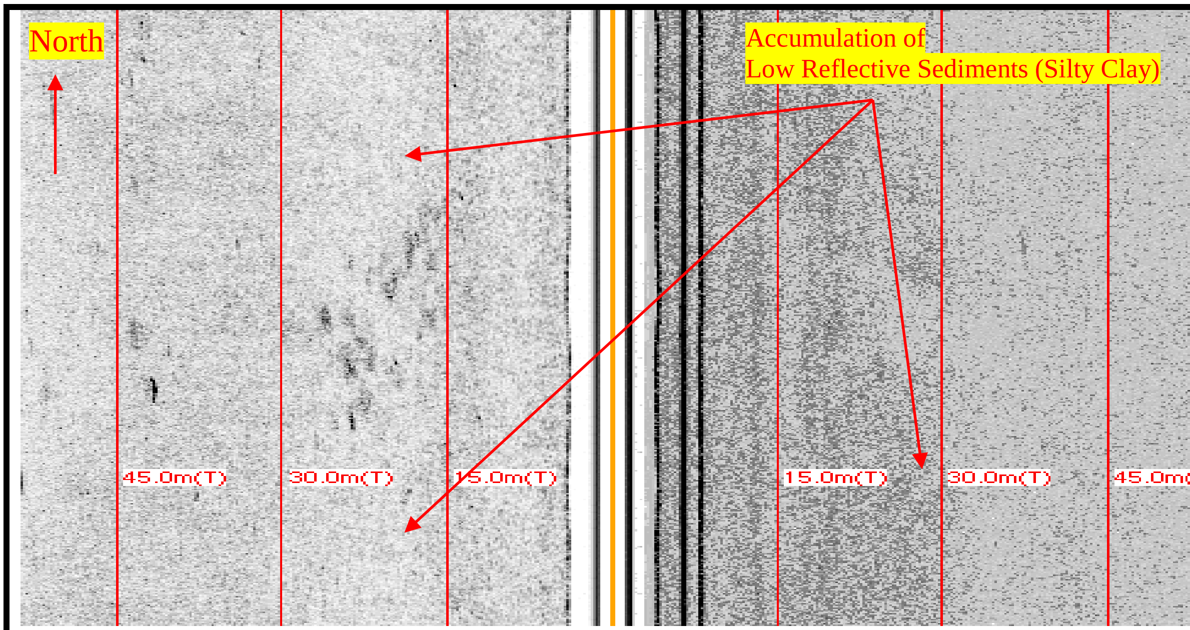


Figure 13: SSS Data extract showing Low Reflective Sediments.

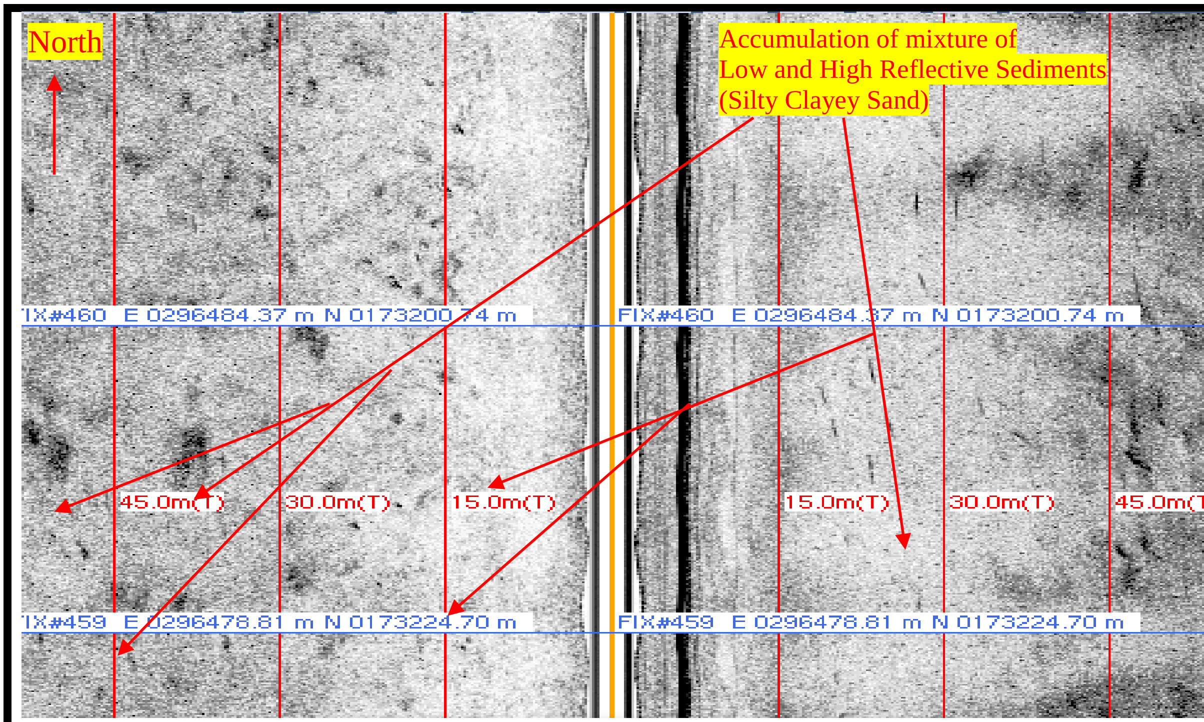


Figure 14: SSS Data extract showing Accumulation of mixture of Low and High Reflective Sediments.

The sea bed within the study area exhibits smooth texture. No aberrations on the sea bed, the one normally associated with rugged texture, were observed over the area.

2. Sea Bed Feature Observed (Pockmark):

Fluid escape features such as pockmarks which are often associated with gas hydrate and biogenic gas bearing sediments in continental margin settings were observed in the study area. Pockmarks are seabed culminations of fluid/gas escape chimneys which appear as cone-shaped circular or elliptical depressions. Form sometimes through the eruption of methane gas trapped in the sediments of the sea floor. They were first discovered off Nova Scotia, Canada and classified as seabed gas and pore water escape features (Tesmi, 2008). They vary in sizes ranging from a few meters to 300 m or more in diameter. They appear as isolated patches, underlain by wipe-outs or pipes, which are narrow vertical zones of low reflectivity.

Table 5: Pock marks in the study area

S/N	From To		
	Easting (m)	Northing (m)	Diameter (m)
1	272118	196292	7.4
2	272152	196282	3.2
3	273606	196759	8.0
4	273596	196774	10.0
5	273705	196873	8.3
6	273707	196904	3.6
7	273124	197048	4.5
8	272601	197510	3.0
9	273083	196448	3.0
10	273077	196464	2.0

S/N	From	To	
	Easting (m)	Northing (m)	Diameter (m)
11	272754	196509	1.7
12	273046	196519	3.8
13	272536	196522	2.8
14	273656	196543	1.9
15	273129	196604	1.4
16	272599	196648	2.6
17	273532	196674	1.5
18	273231	196680	2.1
19	273928	196719	2.5
20	273318	196748	2.0
21	273421	196763	2.2
22	274027	196768	2.5
23	272390	196781	2.1
24	272469	196782	2.3
25	273404	196804	2.2
26	272831	196294	2.5
27	272723	196360	1.9
28	273011	196374	1.8
29	272980	196389	1.8

S/N	From To		
	Easting (m)	Northing (m)	Diameter (m)
30	272952	196403	2.5
31	272659	196414	2.2
32	272922	196417	1.5
33	272885	196433	1.0
34	273083	196448	1.5
35	273077	196464	1.6
36	272754	196509	4.0

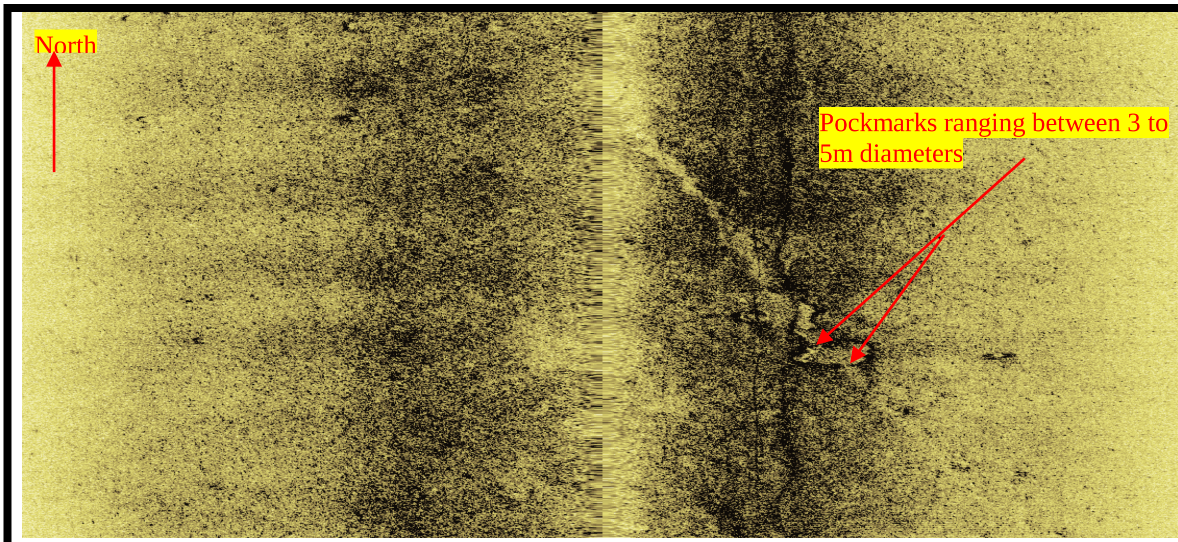


Figure 15: SSS Data extract showing Pockmarks associated with Scar Feature 153m Northwest.

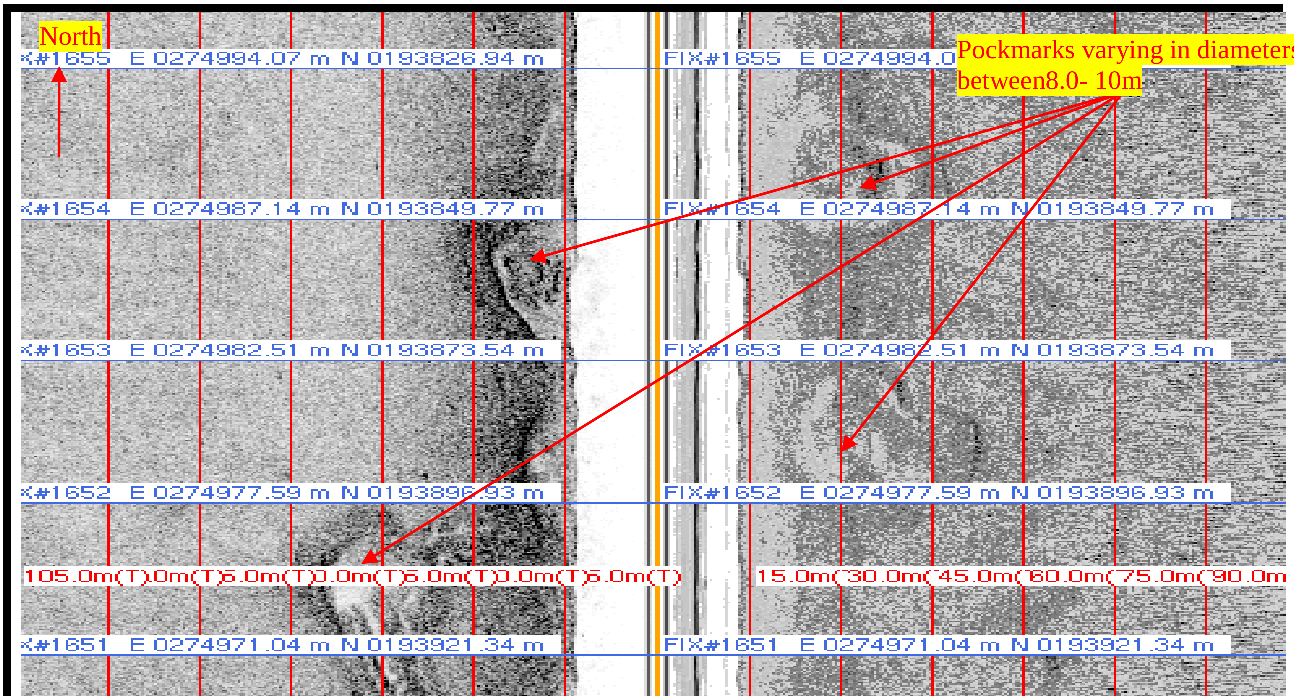


Figure 16……..SSS Data extract showing Pockmarks on seafloor of study area ….

(C) SUB BOTTOM PROFILE DATA:

The seismic record of the survey area suggests the presence of the lithified sediments at approximately 20.0m to 25.0m below the sea bed. The prominent seismic stratigraphic interface that separates the lithified sediments from the overlying sea bed sediments was found to shoal towards north east of the survey corridor. Accordingly the sediment thickness between the lithified sediments and the sea bed was found to vary between 20.0m observed at north east to 25.0m observed at South West.

From		**To**			**Depth (m)**
Easting (m)	**Northing (m)**	**Easting (m)**	**Northing (m)**	**Sediment types**	
272848	196292	273566	196894	Lithified Sediments	20
272703	196350	273270	196915	Friable Sediments	18
272954	196408	273553	196948	Lithified Sediments	22
273011	196451	273634	196998	Lithified Sediments	24

272939	196456	273156`	197036	Lithified Sediments	20
273069	196478	273088	197071	Lithified Sediments	20
272872	196484	272940	197186	Lithified Sediments	25
272760	196513	272294	197223	Friable Sediments	17
273649	196555	272193	197244	Gas charged Sediment	18
273032	196569	273795	197269	Lithified Sediments	24
273130	196611	272270	197276	Friable Sediments	16
273562	196620	273638	197284	Friable Sediments	18
273534	196654	272784	197311	Friable Sediments	16
273452	196687	272758	197381	Lithified Sediments	25
273413	196783	272577	197499	Friable Sediments	16
272468	196790	273669	197536	Lithified Sediments	20
272402	196792	273549	197568	Lithified Sediments	20
273401	196815	273550	197659	Friable Sediments	17
273866	196831	273566	196894	Gas charged Sediment	17
272848	196292	273270	196915	Lithified Sediments	22
272703	196350	273553	196948	Lithified Sediments	20
272954	196408	273634	196998	Lithified Sediments	25
273011	196451	273156	197036	Friable Sediments	18
272939	196456	273088	197071	Friable Sediments	18
273069	196478	272940	197186	Gas charged Sediment	18

272872	196484	272294	197223	Lithified Sediments	21
272760	196513	272193	197244	Friable Sediments	19
273649	196555	273795	197269	Friable Sediments	19
273032	196569	272270	197276	Lithified Sediments	20
273130	196611	273638	197284	Friable Sediments	16
273562	196620	272784	197311	Lithified Sediments	20
273534	196654	272758	197381	Lithified Sediments	23
273452	196687	272577	197499	Lit-hified Sediments	23
273413	196783	273669	197536	Friable Sediments	20
272468	196790	273549	197568	Gas charged Sediment	19
272402	196792	273550	197659	Friable Sediments	19

Table 6: Subsurface Sediments

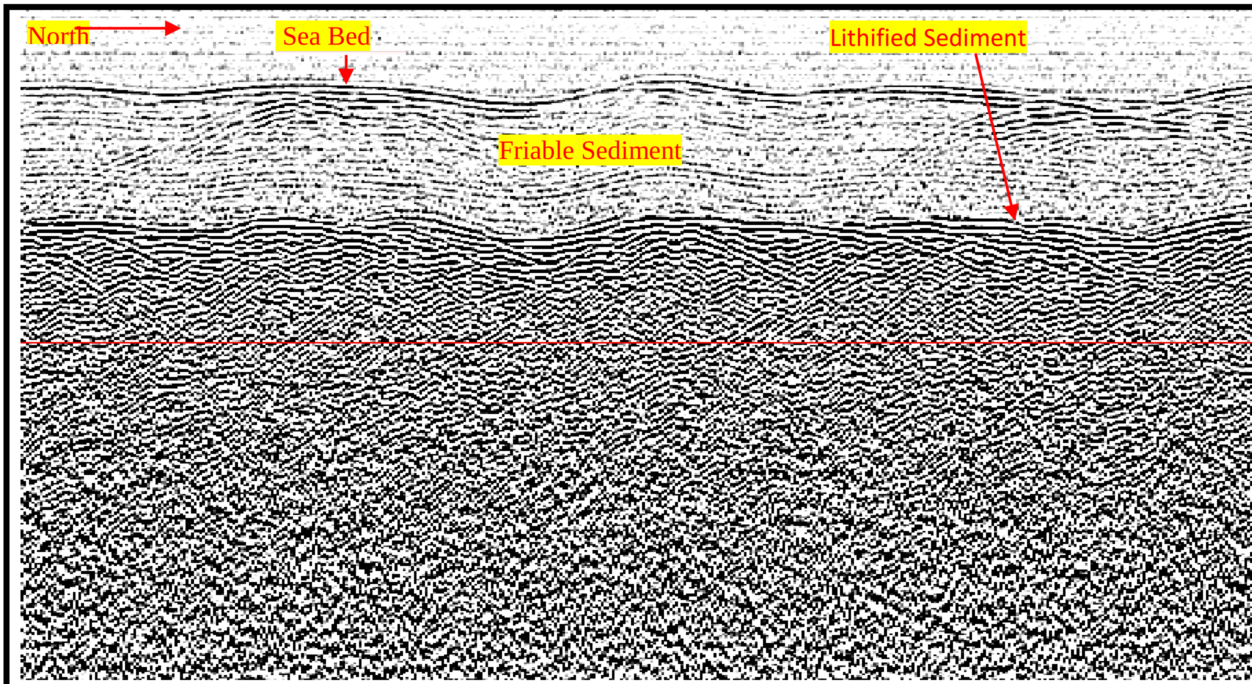


Figure 17: SBP Data extract indicating well Lithified Sediments at 20m below the sea bed.

The seismic profile of the area suggests the variation in sediment thickness of 3.3m was observed at km 0.00 while the maximum sediment thickness of 4.5m was observed at Km 0.200. The gas charged sediments were observed along the route between KP 0.004 and KP 0.045.As shown below;

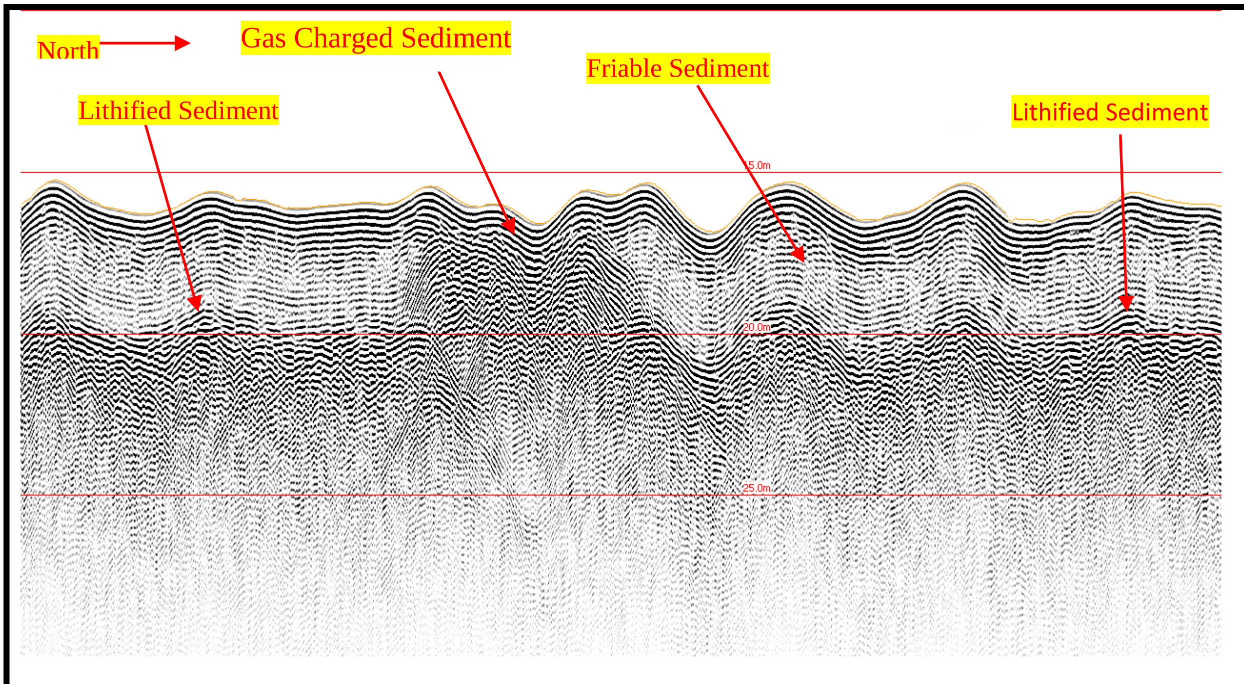


Figure 18: SBP Data extract indicating Gas charged sediments.

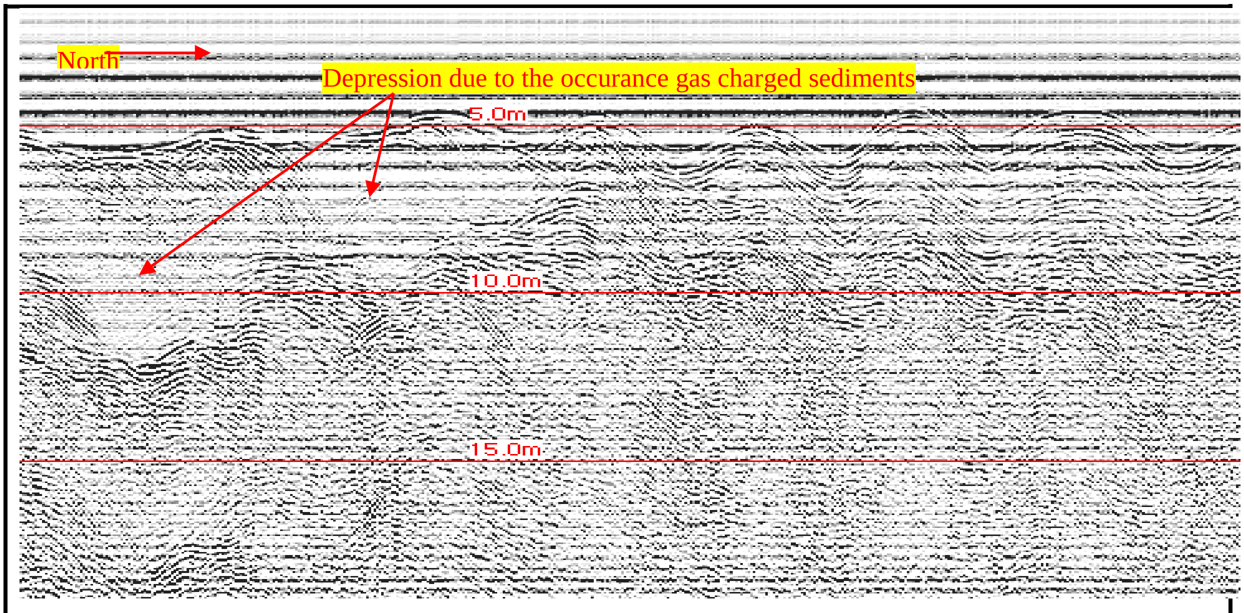


Figure 19: SBP Data extract indicating sea floor depression.

- **Sedimentary Structures**

Basically two bed forms types were observed. These include ripples and wave ripples. These sedimentary features confirm the undulating topographic elements of the sea bed in cross sections within the study area.

Types	Height (m)	Wave length (c)	Remark
Ripples	0.06	0.04-0.6	Straight sinuous or isolate
Mega ripple	1.34	2.35	Very shape crest

Table 7: Showing sedimentary structure types

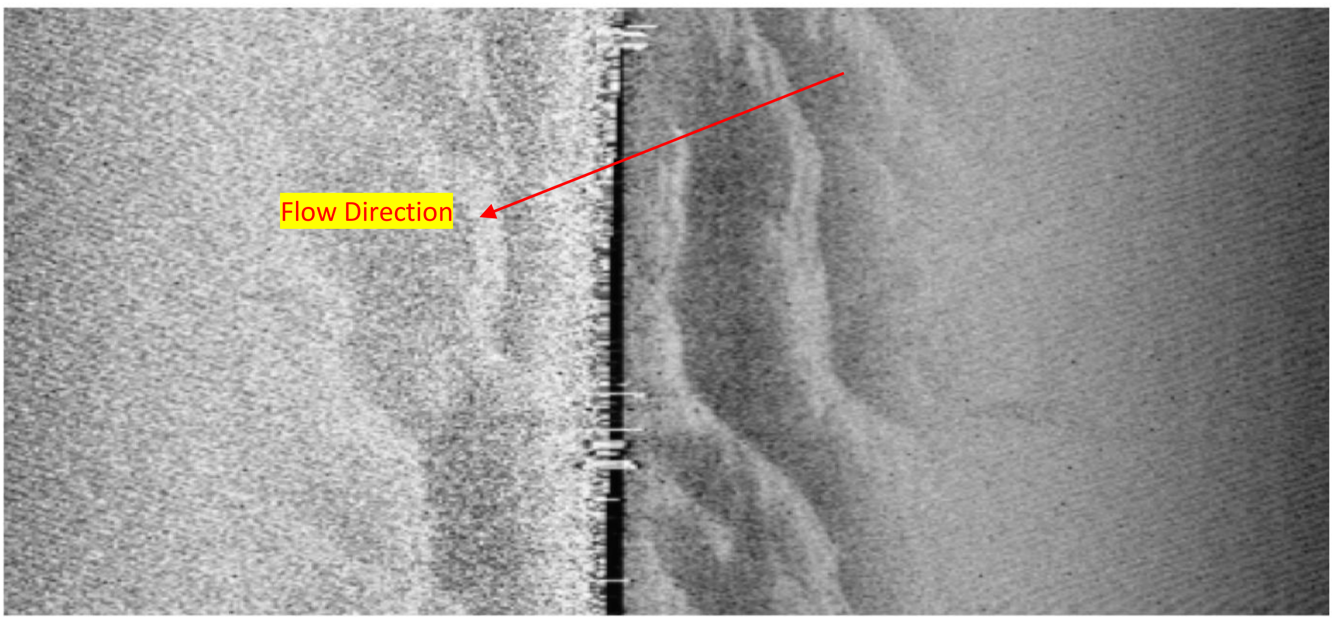


Figure 20: Depositional bed forms (sand ripples)

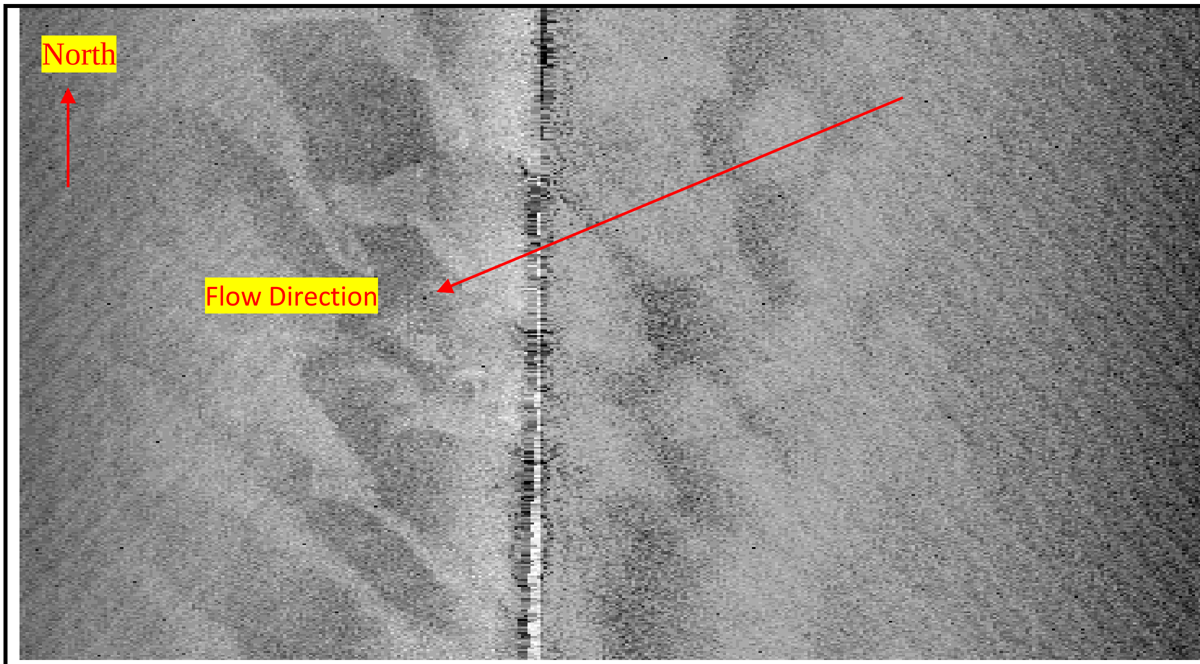


Figure 21: Depositional bed forms(sand patches)

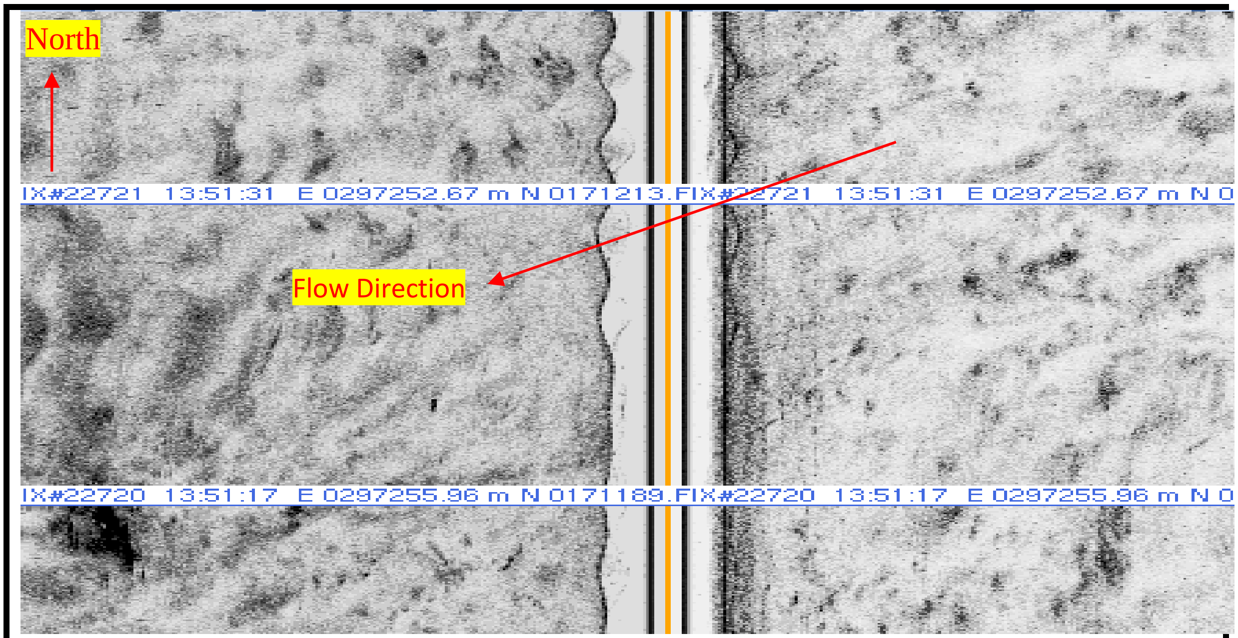


Figure 22: Depositional bed forms (sand waves)

Straight Sinuous Isolated (Linguoid)

Curr ʌ with straight, s solated crest

(Height: 0-0.06; wavelength: 0.04-0.06)

DISCUSSION

The sea bed sediments from the scan in the study area support a composition consistent with sand, silt and clay deposits on the inner shelf. There are indications that sediments have moved across the sea bed of the surveyed area. The bed form structures in the scanned sea bed data gives credence to this assertion and at the same time brings into focus the kind of processes occurring in the shelf area.

The current ripples are located in the north western part while the wave ripples occur in the south western part. The structure and texture of these bed forms clearly divides the shore face profile of the area surveyed into two distinctive grain size provinces: - An upper shore face consisting of fine, sea ward fining sand occurring in water depths of between 15-18m with current ripple structures. And lower shore face of coarse sand in water depths of above 15m within the limits of study having wavy bed forms that is suggestive of sand waves.

Swift, (1971) and Van Straaten, (1965) in their study of the storm dominated coast of Virginia to North Carolina and the Dutch coast respectively. They critically analyzed the distribution of grain sizes on the two retrograding coasts. On these coasts the upper shore face sand tends to be fine grained to very fine grained, and become finer in a sea ward direction. According to Swift, (1971) and Van Straaten, (1965), the grain size gradient is perhaps the result of progressive sorting operating on the suspended sand load of rip currents. While the coarse texture of the shore face may be the effect of coastal boundary currents associated with peak flow events. The coarse sand was basically residue materials mantling the eroding surface of the underlying older deposits where its final resting place appears to be the adjacent sea floor.

Howard and Rein (1972) in their study of depositional structure along the coast of Georgia having a milder wave climate than that of Swift, (1971) and Van Straaten, (1965), also discovered fine sand of the upper shore face and the coarse sand of the lower shore face occurred at about 20km from the beach. At a water depth of 5-10m the upper shore face consist of laminae and thin beds with sharp, erosional lower contacts, grading upward into bioturbated structure. Howard and Reineck (1972) suggest deposition during storm intervals, alternating with periods of fair weather and bioturbation. Seaward of 10m, the muddy gently dipping shore face becomes markedly coarser, than gives way to a flatter sea floor of medium to coarse sand, characterized by heart urchin bioturbation and trough cross-stratification.

Bernard and Leblanc, (1969), observed western Gulf of Mexico- a prograding coast remarkably different. No grain size gradient was observed between the upper shore face and the lower shore face. In his view the absence of the coarse lower shore face, can be attributed to the massive import of sand delivered by littoral drift during fair weather than can be removed by storms. On this coast, the fine seaward fining sand of the upper shore face extends down to the break in slope where it may become as fine as mud, and continues across the Shelf floor. Thus, it can be established that the shore face texture and bed forms of the study area fits into that of a retrograding coast. Two basic processes cooperate to maintain the shore face profile: wave under fair weather and storm events that may have occurred in the past. During fair weather two mechanisms: bottom wave surge and littoral circulation pattern cooperate to store sand in the beach prism. The wave regime divides the available sand into s fraction undergoing bed load transport and a fraction undergoing mainly suspension sand coarser than the critical size threshold will be driven landward as bedload by the land ward stroke of the bottom wave surge, towards the breaker point (Longuet-Higgins, 1953 and Russell and Osorio, 1958). At the breaker point, much of the energy available to drive sand land ward over the bottom is lost to turbulence and tends to accumulate as a break point bar. Waves of oscillation turn into waves of translation forming a two layer flow system. An upper layer of flow drifting landward and a basal compensated return flow (Schiffman, 1965). The bar builds upward until the rate of deposition of sand at the conclusion of wave breaking is equaled resuspension during wave breaking. Sand throw into suspension at the break point and fine enough to stay in suspension in the trubulent surf zone will tend to be fluxed along shore by long shore flow in the surf zone, and out through a rip channel to rain out on the shore face (Cook, 1969). This way the upper shore face profile of the study area maintains its fine texture.

The upper shore face system of wave driven long shore sand flux interacts with coastal boundary of the storm flow field (Moody, 1964). Sand eroded from the beach and bar by storm passes seaward in intensified rip currents to the zone of friction dominated flow which during storm may take the form of down welling coastal jet. The wave ripples of the study location must have formed on the transit sand from the beach/ bar erosion unto the shore face where the low wave energy is only able to resuspend them.

Water depth measurements of between 15-18m offshore indicated perhaps that the bathymetric classification of the study area is within the upper shoreface setting (transitional environment).

CONCLUSION

The side scan sonar records of the study area infer the dominant presence of low reflective sediments, interpreted to be composed of silty clayey SAND, all over the study area. The high reflective sediments interpreted to be composed of clayey, silty SAND was observed as pockets all around. The area is a shoreface setting based on its bathymetric classification. Water depth ranges between 15-18m with the shallowest bathymetry in the northeastern part of the study area while the deepest portion is at the south western part. The prominent seismic stratigraphic interface (Lithified layer) revealed on sub bottom record occurred at varied depth below the sea bed. It was observed around 20-25m below the sea bed. Based on its acoustic back scatter properties manifested on seismic records, it is concluded that the prominent seismo-stratigraphic interface refers to the lithified sedimentary sequence within the study location. The well cutting data analyzed show that the sand stone was found within 20-25m which confirms the position of the lithified sediments from the sub bottom profiler. The other obvious sea bed features of the study area are culminations of gas escape chimneys which appear as cone-shaped circular or elliptical depressions (pock marks), appeared as isolated patches; significant areas of gas charged sediments were also observed between the sea bed and lithified sediments in the study area. The sea floor sediments are constituted of clay to silt formation as well as residual sand sheets whose textures separates the shore face profile into an upper shore face consisting of fine sand. And lower shore face of coarse sand. The bed form types are suggestive of a low energy environment where current wave and storm processes combine to shape the sea bed.

This study has shown that substantial information can be derived from seafloor sediments distribution study offshore using geo acoustic equipments. The Knowledge of the nature of the seabed imagery, bathymetry of the seabed, the prominent seismo-stratigraphy and the depositional environment immensely guide in oil field development in terms of oil well drilling and pipe laying operations offshore.

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