COMPREHENSIVE 3-D SEISMIC DATA ACQUISITION IN OML Q FIELD OF NIGER DELTA: TECHNIQUES AND OPERATIONAL STRATEGIES

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Abstract

This study presents the methodology and results of a 3-D seismic data acquisition conducted in OML Q Field of Niger Delta using dynamite as an energy source, an array of geophones and shot points, and recording instruments. The acquisition involved four major operational sections: surveying, drilling, recording, and seismology, with other auxiliary units. The surveying section produced finished seismic lines, while the drilling section drilled the seismic holes according to pre-defined pattern hole geometry. The recording section charged and detonated sources in the seismic holes to generate seismic wave energy and map the subsurface. The seismology section carried out base station data reduction computation, ensuring data quality control, pre-survey design and parameter definitions, and noise test experimentation and analyses using the fixed shot, split spread array technique. This section also performed LVL/weathering analysis to determine the velocities, "Vw" and "Vc" distribution in the surface, intermediate, and consolidated layers and to determine the weathering depth, "Dw" in the area. The results of the LVL/weathering analysis were used to achieve cophasal alignment of seismic reflection events and ensure optimal signal resolution through static correction. Finally, the records were both vertically and CDP stacked, with the vertical stacking achieved by using multiple source-geophone arrays and the CDP stacking achieved by using CDP Roll along Cables and stacking box migratory switch. The findings of this study provide valuable insights into the subsurface geology of OML Q Field, which can be useful in oil and gas exploration and production.

Keywords: 3-D seismic data acquisition, Niger Delta, Dynamite, Seismology, Signal resolution

Introduction

The Niger Delta region of Nigeria is known to be one of the most productive petroleum provinces in the world (Ekweozor *et al*., 2018). It is also known for its complex subsurface geology which makes it difficult to accurately locate and produce hydrocarbon reserves (Adegoke *et al.*, 2020). To overcome this challenge, the acquisition of high-quality 3-D seismic data has become crucial in the exploration and production of hydrocarbons in the Niger Delta region (Mehrotra *et al*., 2019).

The 3-D seismic data acquisition process is a comprehensive and multi-step process that involves the use of dynamite as an energy source, an array of geophones and shot points, and recording instruments to map the subsurface geology. The acquisition process involves surveying, drilling, recording, and seismology, with other auxiliary units. The surveying section produces finished seismic lines, while the drilling section drills the seismic holes according to pre-defined pattern hole geometry. The recording section charges and detonates sources in the seismic holes to generate seismic wave energy and map the subsurface. The seismology section is responsible for carrying out base station data reduction computation, ensuring data quality control, pre-survey design and parameter definitions, and noise test experimentation and analyses using the fixed shot, split spread array technique. This section also performs LVL/weathering analysis to determine the velocities and weathering depth in the area. This information is applied in the static correction to achieve cophasal alignment of seismic reflection events and ensure optimal signal resolution. Finally, the records are both vertically and CDP stacked.

In recent years, 3-D seismic data acquisition has become an important tool for improving the success rate of exploration and production activities in the Niger Delta region (Rehak *et al*., 2015). The Niger Delta is known to be one of the most prolific hydrocarbon-bearing regions in the world, and the acquisition of high-quality seismic data is critical for effective reservoir characterization and development planning (Omatsola and Adegoke, 1981).

Seismic data acquisition is a crucial step in the exploration and production of hydrocarbons in the oil and gas industry. The acquisition of three-dimensional (3-D) seismic data is an important tool used to map the subsurface geology and locate hydrocarbon reserves with greater accuracy and efficiency (Sheriff and Geldart, 2013). The 3-D seismic data acquisition in OML Q Field of Niger Delta was a comprehensive and multi-step process that utilized dynamite as an energy source, an array of geophones and shot points, and recording instruments to map the subsurface geology.

Despite the importance of 3-D seismic data acquisition in hydrocarbon exploration and production, there are still some challenges associated with the process. For instance, the use of dynamite as an energy source poses a risk to the environment and may result in negative effects such as soil erosion, water pollution, and noise pollution (Olayinka *et al.*, 2020). Furthermore, the complex subsurface geology of the Niger Delta region makes it difficult to accurately interpret the 3-D seismic data acquired, and this may result in inaccurate estimation of hydrocarbon reserves and production.

To address these challenges, various studies have been conducted to improve the 3-D seismic data acquisition process in the Niger Delta region. For instance, Olayinka et al. (2020) suggested the use of alternative energy sources such as air guns and vibroseis trucks in place of dynamite. Additionally, Adegoke et al. (2020) proposed the use of machine learning algorithms in the interpretation of 3-D seismic data acquired in the Niger Delta region.

Seismic data acquisition is an important step in the exploration and production of hydrocarbon reserves. It involves the use of various techniques to map the subsurface geology, including the use of seismic waves generated by explosions or vibrations. The 3-D seismic data acquisition in OML Q Field of Niger Delta was carried out using dynamite as an energy source, an array of geophones and shot points, and recording instruments. The aim of this study is to describe the comprehensive and multi-step process involved in the 3-D seismic data acquisition in OML Q Field. We will also evaluate the accuracy of the acquired data and provide recommendations for the improvement of the process. By doing this, we hope to contribute to the advancement of hydrocarbon exploration and production in the Niger Delta region and other similar regions around the world.

Materials and Methods

The 3-D seismic data acquisition in OML Q Field involved four major operational sections: surveying, drilling, recording, and seismology, with other auxiliary units. The surveying section produced finished seismic lines that defined the coordinates, elevations/depressions, and positions of the shot points and geophone stations. The drilling section drilled the seismic holes according to pre-defined pattern hole geometry, and the recording section charged and detonated sources in the seismic holes to generate seismic wave energy and map the subsurface. The seismology section performed noise test experimentation and analyses using the fixed shot, split spread array technique to study the velocity, frequency ranges, and wavelength of the most disturbing ground rolls to be attenuated in the area. This enabled effective noise attenuation design, including optimal definition of array patterns, trace numbers/center, and spread length. The LVL/weathering analysis carried out by the seismology section determined the velocities, “Vw” and “Vc” distribution in the surface, intermediate, and consolidated layers, as well as the weathering depth, “Dw” in the area. This information was applied in the static correction to achieve cophasal alignment of seismic reflection events and ensure optimal signal resolution.

Study Area

The study was conducted in the OML Q Field of the Niger Delta region, which is located in the Southern part of Nigeria. The study area covers an approximate area of 200 km^2, and it lies within the latitudes of 4°30′ and 5°00′ N and the longitudes of 6°30′ and 7°00′ E.

The Niger Delta basin is a significant geological feature located in the Gulf of Guinea, situated offshore Nigeria's Southern region (Fig.1). Encompassing an extensive area of approximately 140,000 km, the basin is distinguished by a 12 km thick sedimentary pile. Upon closer inspection of Table 1 and Fig. 2, it becomes evident that the stratigraphy of the Niger Delta is comprised of formations spanning from the Cretaceous to Tertiary periods.

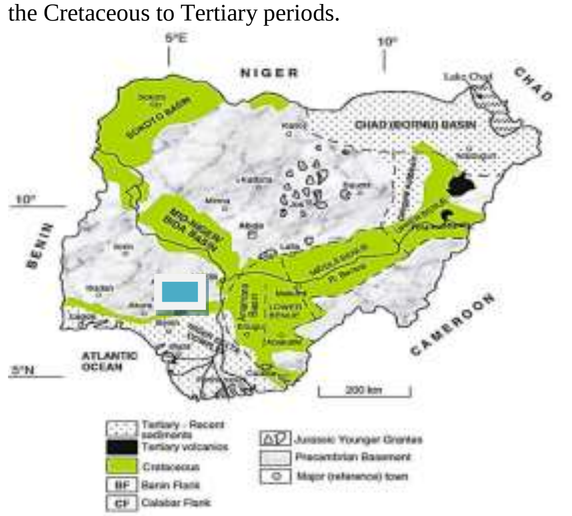
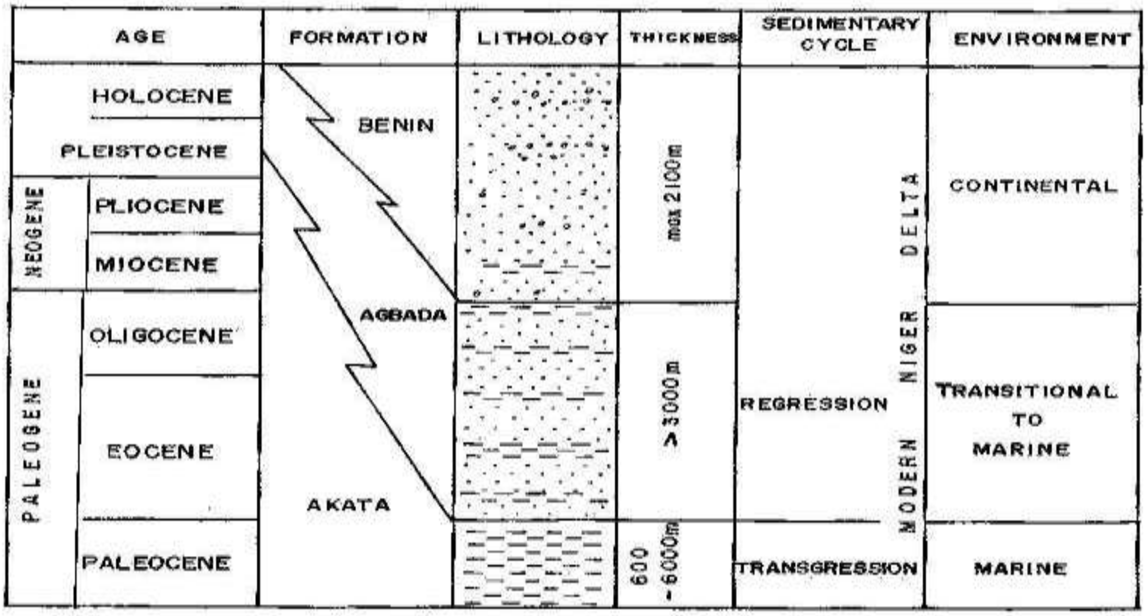


Figure 1 Geological map of Nigeria showing the major geological components; Basement, Younger Granites, and Sedimentary Basins and the Study Area in blue box (After Obaje, 2009)

Nwangwu (1990) provided a generalized lithostratigraphy of the Niger Delta region (Table 1). The sequence consists of four main sedimentary units, namely the Akata Formation, Agbada Formation, Benin Formation, and the Older Coastal Plain Sands. The Akata Formation is composed of shales, silty shales, and mudstones with occasional thin sandstones, while the Agbada Formation consists mainly of sandstones and coarse-grained sediments with interbedded shales and siltstones. The Benin Formation is made up of alternations of sandstones, shales, and limestones. The Older Coastal Plain Sands consist of fine to coarse-grained sandstones with occasional shales and lignite seams. These formations were deposited during the Paleogene and Neogene periods, and they are important hydrocarbon reservoirs in the Niger Delta region (Nwajide, 2013).

Table 1 Generalized lithostratigraphy of Niger Delta (from Nwangwu, 1990).



Stratigraphy of Niger Delta

The Niger Delta constitutes an advance of terrestrial deposits into a high energy marine environment. At present, deposition occurs simultaneously under fully terrestrial (fluviatile) conditions, under conditions where there is interplay between terrestrial and marine influences (paralic) and under fully marine conditions (Frankl and Cordry, 1967). Short and Stauble (1967) recommended and identified three major Stratigraphic units in the subsurface of Niger Delta (Fig. 2). They are the Benin Formation (youngest) the Agbada Formation and the Akata Formation (oldest). Benin formation is the youngest formation of the tertiary Niger Delta. It is made up of massive, highly porous, fresh water bearing sandstone with local thin shale interbeds which are thought to be of braided stream origin. The shale interbeds where present usually contain some plant remains and dispersed lignite. It is thicker in the central onshore part where it is about 1970m (1.97km) and thin towards the delta margins. The transitional Agbada Formation is a paralic sequence of sandstone and shale representing deposit of delta front, distributary channel and deltaic plain origin. The sandstone is medium to fine grained, locally calcareous, fairly clean, glauconitic and shelly. They are made up of essentially of quartz, potash feldspar, kaolinite, illite and plagioclase. The shales of this formation contain microfauna, which is best developed at the base of individual shale units. The known age of the formation ranges from Eocene in the North to Pliocene/Pleistocene in the South and Recent in the delta surface. Akata Formation is believed to be the lowermost unit and the oldest formation of the tertiary Niger Delta sequence. The marine Akata formation is a continuous shale unit and these shales are medium to dark grey in color. The shales are under compacted and may contain lenses of abnormal high pressures siltstone or fine grained sandstone. The formation ranges in thickness from 600 to 6000m. The Akata Formation contains rich foraminifera fauna. Planktonic foraminifera may constitute more than fifty percent of the microfauna

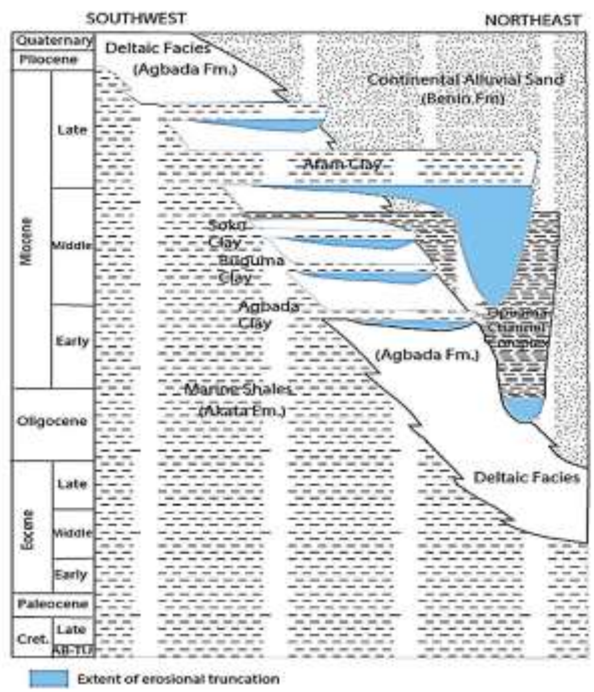


Figure 2 Stratigraphic column showing the three formations of the Niger Delta. Modified from Shannon and Naylor (1989) and Doust and Omatsola (1990).

Furthermore, Fig. 3 depicts an onshore-offshore NNE-SSW cross-section, which elucidates the regional structural framework of the Delta. The geological composition and framework of this region hold immense significance from an exploratory perspective, and the insights gleaned from studying it could have substantial implications for energy exploration and development. As such, the Niger Delta remains a compelling area of study for professionals in the geological and energy sectors.

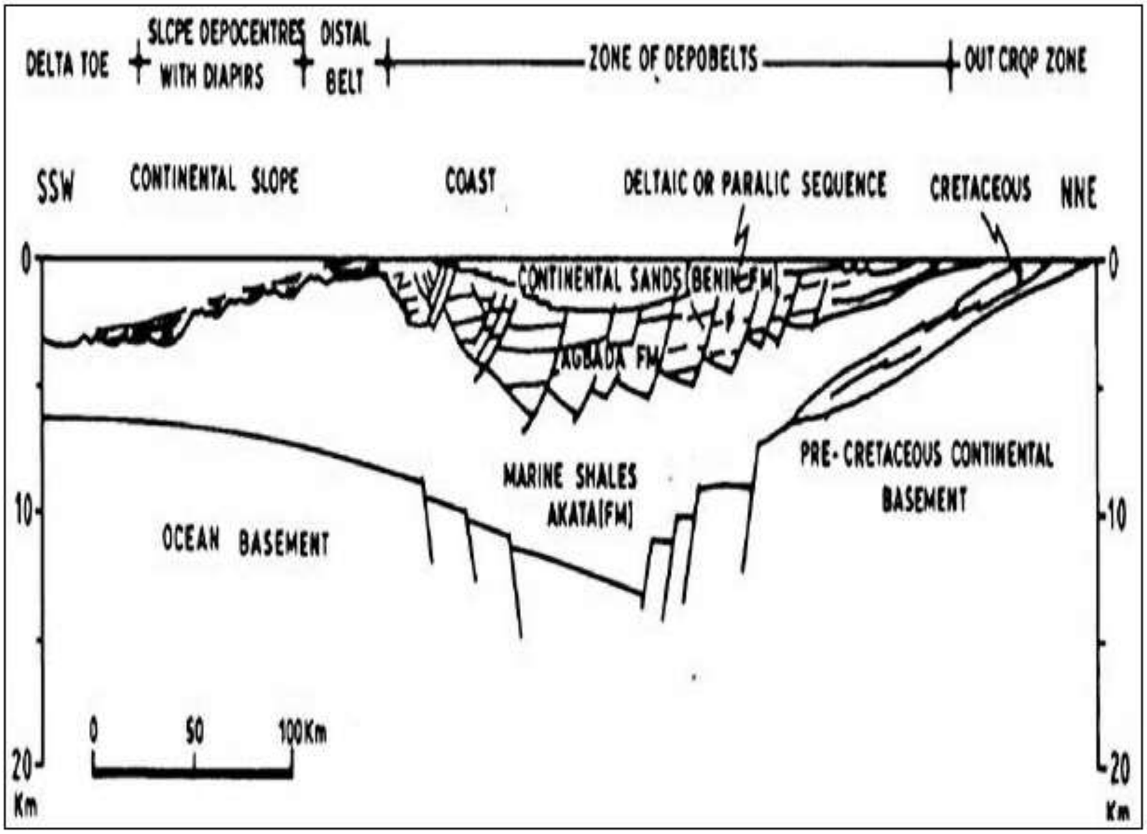


Figure 3 schematic sections through the axial potion of the Niger Delta, showing the relationships of the tripartite division of the tertiary sequence to basement (Doust and Omatsola, 1990).

Aim and Objectives of study

Aim:

The aim of this study is to provide a comprehensive analysis of the 3-D seismic data acquisition process in the OML Q Field of Niger Delta and evaluate the accuracy of the acquired data. The comprehensive and multi-step process involved in the 3-D seismic data acquisition in OML Q Field is described in this study.

Objectives:

1. To conduct a survey of the 3-D seismic data acquisition process in the OML Q Field of Niger Delta.
2. To evaluate the quality and accuracy of the 3-D seismic data acquired.
3. To identify any challenges and limitations associated with the 3-D seismic data acquisition process in the OML Q Field of Niger Delta.
4. To provide recommendations for the improvement of the 3-D seismic data acquisition process in the OML Q Field of Niger Delta and other similar regions around the world.

Data Acquisition

The data were acquired with seismic party OML Q which is Petroleum Prospecting Company. The primary objective of seismic field crews is to measure accurately the travel times from energy sources to receivers. It the travel times are measured accurately and the velocity assumptions are reasonable, and then geologic structures can be mapped. Under certain geologic conditions, the seismic method can be used to predict weather subsurface reservoir rocks contain oil, gas or water. However, the main use of seismic field data for this study is for the location and mapping of subsurface structures that may or may not contain hydrocarbons. The 3-D seismic data acquisition was carried out using the dynamite as the energy source. The surveying section produced finished seismic lines, and the drilling section drilled the seismic holes according to pre-defined pattern hole geometry. The recording section charged and detonated sources in the seismic holes to generate seismic wave energy and map the subsurface. The seismology section carried out base station data reduction computation, ensured data quality control, pre-survey design, and parameter definitions, and noise test experimentation and analyses using the fixed shot, split spread array technique. This section also performed LVL/weathering analysis to determine the velocities and weathering depth in the area. The records were both vertically and CDP stacked.

Organizational setup
The party consists of four (4) major sections namely: Surveying section headed by the chief surveyor, the drilling section headed by the drilling master, the recording section headed by the chief observer and Seismology section headed by the chief seismologist (Fig.4). In addition to the above nuclear section, there are other units whose functions are auxiliary but very fundamental in the production of the seismic crew operations. These include; the administrative unit, Permit unit, the safety/security unit, The maintenance and transport unit and catering services.

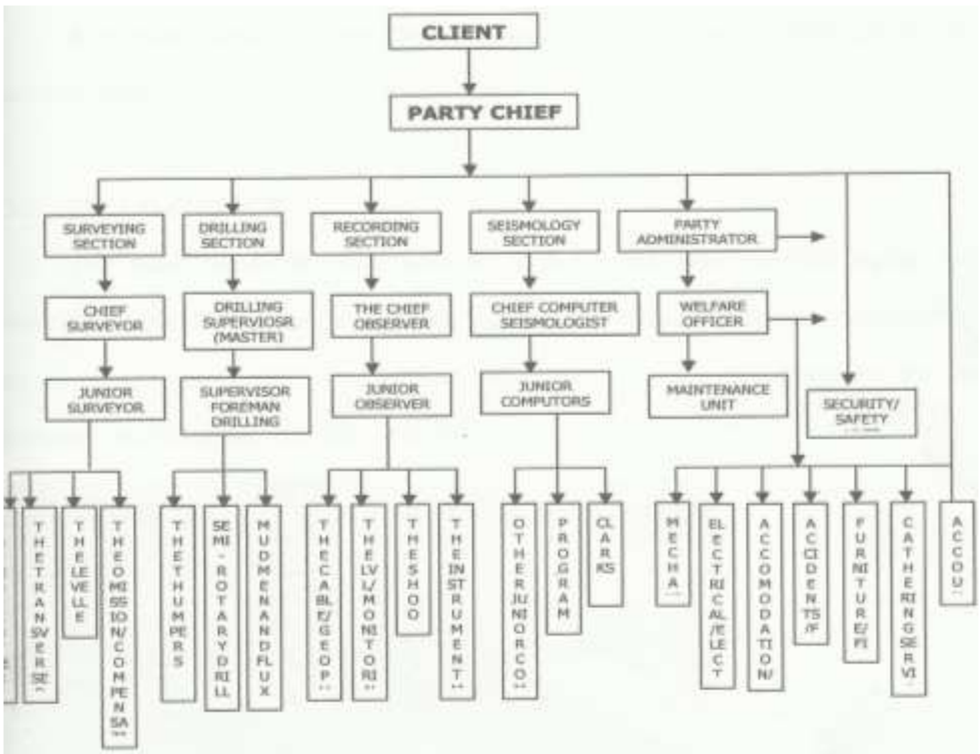


Figure 4 Organizational set up.

Production line and unit functions
A seismic field crew may be thought of as two offices which coordinate their effort to obtain the best possible data.

Central Office
A typical central office staff is composed of a party chief geophysicist, an assistant party chief, and two or more technicians.

Field Office
The land field office consist of a party manager, permit agent, surveyor, drillers, seismic instrument operators, maintenance man, shooter, seismometer crew and wireman.

Party Chief
The party chief is the coordinator between the exploration office and the field crew and is responsible for the entire operation of the seismic field crew. The party chief; Assigns area of prospects to be worked, Assigns seismic traverses and Select field methods, energy sources and data processing parameters.

Additional responsibilities include personnel evaluation, public relations, liaison between the company and its client and government agencies and perhaps the initial interpretation of the seismic data.

Party Manager
The party manager is in charge of field office, operating problems, costs, field personnel, maintenance, safety and crew moves are among the diverse area under his direction. He reports to and works closely with the geophysicist party chief.

Permit Agent
The permit agents arrange for all permit required for the safe and legal operation of the field crew. They obtain permission from land owners, surface lessees, mineral owners, oil and gas lease holders etc. Furthermore, they may work closely with country, state and federal agencies in securing the necessary permits for the field crew operation. The permit agent, who is usually the initial contact between the crew and surface land owners, should adapt to public relation

The Seismologist
Often, the party chief may not be a seismologist and the actual job of geophysical "Data Quality Control" may be the responsibility of the chief seismologist (a geologist/geophysicist) and his assistant. He works under the control of and report to the party chief. He assist the party chief at the office, supervises the base station pre – processing, data reduction and interpretation operation. He also advises the surveyors, drillers and observers on the geophysical field parameter requirement, monitor the

accuracy of all field operation and supervises the up-hole surveys.

The Surveyor

Surveyors are the first set of people to go to the field. They create both the source and receiver lines. Source lines are 600meters apart and are parallel to each other but perpendicular to the receiver lines, while the receiver lines are 500m away from each other. Along the receiver lines, pegs flagged with green/blue bands are stationed every 50m while on the source lines, the pegs are flagged with red bands and are stationed at 50m interval also. The flagging is to differentiate the source lines and the receiver lines. The main instrument used in surveying is the Theodolite (Fig. 5). The theodolite gives accurate distance of its focus and has the ability of maintaining a straight line with precision. For a theodolite to work properly, it has to be centralized with a bob. A pole is staged and used as the point of focus. The designer of the 3D seismic programme and the surveyor must maintain close communication in order to locate the programme correctly and to execute it properly.

Figure 5 A surveyor using Theodolite.

The Observer

The observers are in charge of seismic field crew during all field operations (Fig. 6). Their main area of responsibility is operating the recording instruments. All phases of field operation, energy sources, cables, geophones/hydrophones are under his supervision.

Figure 6 An observer in the instrument room

The Driller

In a seismic field crew using dynamite as energy source, shot holes must be drilled for charge placement. The individual in charge of this activity are called drillers. The shot holes are drilled according to specified geometric pattern. The instrument used in the drilling operation is the hand auger. The drillers are only interested in the source line which is the line with red pegs. On each peg, the driller drills 5 – hole pattern of 4m deep at 10m interval along the source line. The drill makes up their tools in a clock wise direction and drills only in the same manner. This is to avoid losing their drilling tools in hole since the tools are made up in a clockwise manner, drilling in the opposite direction will result to losing your tools in hole.

Quality Control To ensure the quality of the data, a quality control procedure was put in place. This involved regular monitoring of the acquisition process, data processing, and interpretation. Any errors or inconsistencies were immediately corrected.

Modifications to Published Procedures The 3-D seismic data acquisition and processing procedures used in this study were based on previously published procedures (Mehrotra et al., 2019). However, some modifications were made to suit the specific conditions of the study area. For instance, the LVL/weathering analysis was done using the fixed shot, split spread array technique, which was not explicitly mentioned in the published procedures.

Results and Discussion

The three main results of the acquisition are presented. These are: The observing and computing results, the noise test experiment results and The LVL monitoring/weathering analysis.

Observing and Recording Results

The result of the observing was acoustic source generation, subsurface sampling and imaging. The operation was purely quality controlled subsurface sampling and imaging. The productions were signal enhanced analog and digital magnetic tape records. The source generation involved laying of cables, (signals transporters), along seismic lines. The planting of geophones, (acoustic wave detectors along receiver lines), according to pre-determined geophone arrays. The loading and charging of seismic holes with specified charge size, the positioning, earthling and connecting of the field instruments, testing, shooting, detonation of the charge, modification of the signals, and recording of the geophone response outputs in analog/digital magnetic tape. The observer also undertook field pre-processing operation by use of certain instrument devices and platform control systems. These include the CDP and vertical stacking of events for noise attenuation as well as the use of recording system amplifiers to modify, (amplify or suppress signal amplitude). The use of filters to discriminate against the choice of seismic signals frequency recorded and improvement in signal to noise ratio (S/N).

Computing Results

The result of the computing section was field quality controlled and sub-surface overage sheet. The sheet among other things shows reports of the quality control parameters, pre-survey design parameters and definitions, omission and compensation, reports, LVL and weathering analysis reports and base station data reduction computation report. The specific objectives of these analyses were to enable effective survey planning for seismic data acquisition, processing and interpretation.

Frequency Analysis

Although frequency could be computed from the relationship $V = \lambda f$, where V = velocity of propagation of noise, λ and f are the wavelength and frequency respectively, the present study based the frequency computation on the fact that frequency is the inverse of time. Where the time is the period "T", of repetition of the periodic seismic wave, using the relationship:

F = 1/T. Since the field parameters were to be designed based on the minimum and maximum frequencies, wavelength or velocities of the ground rolls, these factors were considered in the computations (Table 2). The record time was in milliseconds so the time is scaled by 1000 to convert to seconds. Minimum and maximum frequencies were statistically calculated from SP 5046 through SP 5206. For example, using SP 5046, we have

ti_1 = 18 milliseconds = (18ms/1000) = 0.018 seconds.

Therefore F = 1/T in 1/0.018 second = 55.55Hz.

tiN = 260ms = 0.260sec.

Therefore;

F = 1/(0.260sec) = 3.85Hz.

Where ti_1 = minimum period and tiN = maximum period of the waves.

The mean range of the frequency was computed statistically using the relationship: $F(av)_I = \sum Ti/N = 1/(\sum Ti/N)$.

The tabulated results of the frequency computations are presented in (Table 1).

Wavelength Computation

The wavelength "λ" was determined based on ground roll of greatest disturbance to be attenuated in the area. The computation of wavelength (Table 3) was based on the fact that velocity of seismic wave equals the product of its frequency and wavelength, Sheriff (1982). From the relationship:

$V = \lambda f$

Therefore $\lambda = V/f$

Where V = velocity propagation of wave in meters per seconds, and "f" is frequency of the wave in hertz.

For V = 470m/s, F = 5.0Hz

Therefore λ= (470m/s)/5.0Hz = 94m.

For f = 50Hz

Therefore, λ = 470m/s/50Hz = 9.4m.

Table 2 Frequency Computation Results (OML Q FIELD)

SP	Min. period (milliseconds) Ti1	Max period (milliseconds) TiN	(Ti1/1000) (seconds)	TiN/1000 (seconds)	F_{min} = 1/Ti1 (Hz)	F_{max} =1/TiN (Hz)
5046	18	260	0.018	0.260	55.56	3.85
5048	25	-	0.025	-	40.00	-
5051	20	272	0.020	0.272	50.00	3.68
5053	20	270	0.020	0.270	50.00	3.70
5055	19	250	0.019	0.250	52.63	4.00
5059	18	237	0.018	0.237	55.56	4.22
5062	20	232	0.020	0.232	50.00	4.31
5064	16	245	0.016	0.245	62.50	4.01
5066	22	242	0.022	0.242	45.45	4.13
5068	20	225	0.020	0.225	50.00	4.44
5072	28	-	0.028	-	35.71	-
5074	17	202	0.017	0.202	58.82	4.45
5076	20	200	0.020	0.200	50.00	5.00
5078	19	189	0.019	0.189	52.63	5.29
5082	22	183	0.022	0.183	45.45	5.46
5094	18	158	0.018	0.158	55.56	6.33
5110	22	160	0.022	0.160	42.45	6.25
5114	18	167	0.018	0.167	55.56	5.99
5116	17	167	0.017	0.167	58.82	5.99
5126	17	160	0.017	0.160	58.82	6.25
5142	18	157	0.018	0.157	55.56	6.67
5158	20	174	0.020	0.174	50.00	5.75
5174	22	170	0.022	0.170	42.45	5.88
5190	20	170	0.020	0.170	50.00	5.88
5206	22	166	0.022	0.166	42.45	6.02
					$\sum F_{(max)}$	$\sum F_{(min)}$
					= 1266.04	= 113.99

$F(Av) = \sum F_{(min)}/N$

Therefore $F_{max}(Av) = \sum Fi1_{(max)}/N$

= 1266.04/25

= 50.64Hz

Similarly,

F_{min} (Av) = $\sum$FiN $_{(min)}$/N
= 113.99/23
= 4.956Hz
Where N = total number of shots. This gives the average frequency range as 5.0Hz to 50.0Hz

Table 3 wavelength computation results (OML Q FIELD)

SP	F_{max} Hz	$F_{(min)}$ Hz	V(m/s)	$\lambda_{(min)} = V/F_{(max)}$	$\lambda_{(max)} = V/F_{(min)}$
5046	55.56	3.85	480	8.64	124.68
5048	40.00	-	490	12.25	-
5051	50.00	3.68	470	9.40	127.71
5053	50.00	3.70	470	9.40	127.03
5055	52.63	4.00	490	9.31	122.50
5059	55.56	4.22	520	9.36	123.22
5062	50.00	4.31	560	11.20	129.93
5064	62.50	4.01	450	7.20	112.22
5066	45.45	4.13	480	10.50	108.11
5068	50.00	4.44	480	9.76	108.11
5072	35.71	-	650	18.20	-
5074	58.82	4.95	490	13.43	98.99
5076	50.00	5.00	550	11.00	110.00
5078	52.63	5.29	610	11.59	115.31
5082	45.45	5.46	670	14.74	122.71
5094	55.56	6.33	710	12.78	112.16
5110	42.45	6.25	480	11.30	78.80
5114	55.56	5.99	700	12.60	116.86
5116	58.82	5.99	680	11.56	113.52
5126	58.82	6.25	670	11.39	107.20
5142	55.56	6.67	610	10.96	91.45
5158	50.00	5.75	520	10.40	90.43
5174	42.45	5.88	960	22.63	163.27
5190	50.00	5.88	830	16.60	141.16
5206	42.45	6.02	740	17.43	122.90
				$\sum\lambda_{(min)}$	$\sum\lambda_{(max)}$
				=304.19m	= 2560.76m

λ (min)(Av) = $\sum\lambda$(min)/N
304.19m/25 = 12.17m
λ(max)(Av) = $\sum\lambda$ (max)/N
= 2560.76m/23
= 111.34m

This gives the approximate wavelength range of the ground rolls in the area as 12m to 111m.

LVL and Weathering Computation Results

The LVL and weathering computation results comprise the travel time results, and weathering analysis results. The main properties of the weathering layer studied are the velocities "Vw", "Vc" of the seismic waves and the thickness of the weathering layer.

Travel Time Results (First Break Timing Record)

The correlated up-hole timing and the master timing records of the signals first break arrivals were tabulated. The results are presented, first arrival times from the monitor records. Accurate timing of events (signal receptions) is very important in seismic exploration as the time is used in various data reduction/correction computations such as velocity determination, LVL and weathering computations, determination of depth to end orientation of reflectors and other static and dynamic correction computation etc. Any error in the time measurement automatically leads to multiplicity of errors in subsequent field design, processing, interpretation and overall data resolution.

LVL and Weathering Analysis Time Register

The travel time for each receiver station from both the UTH (Up-hole time screen register) of the 1/0 unit blaster machine and the time synchronizer of the main recording equipment was simultaneously recorded and correlated (Table 4).

Table 4 First Arrival Times from the Monitor Record of OML Q Field

RS/SP	1	2	3	4	5	6	7	8	9	10	11	12
5046	18	38	65	106	133	161	190	210	228	250	255	260
5048	25	45	70	110	140	162	182	210	228	240	250	-
5051	20	42	57	100	123	145	190	217	237	258	266	272
5053	20	46	72	110	130	158	198	220	239	242	265	270
5055	19	40	70	109	126	145	180	190	205	230	240	250
5059	18	37	52	88	110	120	155	184	200	220	230	237
5062	20	35	53	98	122	147	180	197	202	214	228	232
5064	16	38	66	105	126	154	176	197	213	238	237	245
5066	22	42	68	105	135	154	180	197	215	228	236	242
5068	20	41	50	97	112	125	150	170	202	-	220	225
5072	28	-	63	82	102	140	155	175	190	207	215	-
5074	17	38	61	89	108	120	148	160	173	190	198	202
5076	20	39	65	86	103	123	145	158	172	184	193	200
5078	19	35	39	63	98	116	140	154	165	176	185	189
5082	22	36	49	71	99	117	139	149	164	172	180	183
5094	18	31	40	62	75	95	110	120	132	142	153	158
5110	22	41	48	60	73	88	107	122	135	147	155	160
5114	18	32	46	54	79	92	112	123	140	152	162	167
5116	17	30	40	60	78	90	110	126	140	152	163	167
5126	17	31	34	57	68	81	102	115	127	148	157	160
5142	18	33	48	63	76	89	108	118	132	145	153	157
5158	20	39	50	78	97	106	112	136	147	158	167	174
5174	22	32	42	62	79	95	109	130	143	157	166	170
5190	20	32	46	70	89	100	120	130	143	156	164	170
5206	22	34	46	60	75	90	111	127	140	153	162	166

SP = shot points, RS = Receivers (Geophone stations).

Velocity and Depth Computation Results

Although DIX (1955), formula gave the root mean square velocity (Vrms), as a very good theoretical approximation of velocity. Based on time analysis, the average velocity V(av) was simply determined by summing the interval velocities and dividing by the total number of intervals "N". The process was repeated for both the surface layer and the intermediate layer.

Therefore, $V = \Delta x / \Delta t$

$V(av) = \sum V_i t_i / \sum t_i = \sum V_i / N$

Where "Vi" is the interval velocities, Ti is the interval time and "N" is the number of intervals or gathers.

Δx = change in geophone offset,

Δt = change in signal arrival time.

Depth of Weathering

The depth "Dw" to base of weathering at each location was determined using the following equations,

Dw (weathering) = $Ti/2\ (Vc^{-} Vw)/(Vc^2-Vw^2)^{1/2}$ ….. (3a)

$H = X_c/2\ [(Vc-Vw)/(Vc+Vi)]^{1/2}$ ………. (3b)

Where h is the depth to the reflector and Xc is the cross over distance. The summarized results of the LVL/weathering layer monitoring are presented in table-summarized result of LVL/ weathering.

From the computation (Table 5) the average velocities ("Vw" and "Vc" for the surface and consolidated layers respectively), were found to be:

Vw (average)=(15690m/s)/25= 630m/s

Vc (average)=(42490m/s)/25

= 1700m/s

The average weathering depth "Dw" (Average) was computed from the interval depths by summing the total interval depth "Dw", and dividing by the number of interval N, (in this case, N = 25), using the relationship:

Dw (weathering) $=Ti/2(VcVw)/(Vc^2Vw^2)^{1/2}$…… (3c)

Dw (average) $=\sum Dwi/N$ ………. (3d)

Therefore Dw (average) =(499m)/25=19.96m

This gives the average depth of weathering to as 19.96m (Table 5).

Table 5 The summarized results of the LVL Monitor Records and Weathering Analysis

SP	Vw	Vci	Ti	$Vw^2/(100)$	$Vc^2/(100)$	$(Vc^2-Vw^2)^{1/2}$	Dw
5046	570	1460	95	3249	21316	1344	30
5048	580	1670	110	3364	27889	1566	38
5051	610	1430	98	3721	20449	1293	31
5053	560	1430	102	3136	20449	1316	34
5055	550	1350	67	3025	18225	1233	22
5059	530	1300	46	2809	16900	1187	15
5062	540	1580	80	2916	24964	1484	28
5064	530	1460	79	2809	21316	1316	27
5066	520	1460	88	2704	21316	1864	22
5068	500	1450	55	2500	21025	1361	19
5072	650	1450	54	4225	21025	1296	17
5074	580	1760	64	3364	30976	1662	23
5076	560	1890	69	3136	35721	1805	25
5078	610	1880	61	3721	35344	1770	22
5082	640	2050	66	4096	42025	1948	24

5094	710	1980	35	5041	39204	1848	12
5110	670	1970	36	4489	38809	1853	13
5114	730	1850	35	5329	34225	1700	12
5116	750	1760	28	5625	30976	1592	9
5126	700	1800	23	4900	32400	1658	8
5142	680	2050	37	4624	42025	1934	13
5158	530	2000	51	2809	40000	1920	19
5174	830	1760	32	6889	30976	1552	10
5190	810	2050	50	6561	42025	1883	17
5206	780	1790	30	6084	23041	1788	9

Dw (weathering) = $Ti/2\ (Vc-Vw)/(Vc^2-Vw^2)^1/_2$

Dw (average) = $\sum Dwi/N$

Therefore, Dw (average) = (499m)/25 = 19.96m

Vw (average)=(15690m/s)/25=630m/s

Vc (average)=(42490m/s)/25=1700m/s

The 3-D Seismic Data Acquisition in the OML Q Field of Niger Delta (Edo State/Delta State) is a significant development in the exploration of oil and gas resources in the region. The use of dynamite as an energy source, an array of geophones and shot points, protective copper transmitting cables, and a sercel 408 recording instrument has proved to be effective in mapping subsurface structures and determining the properties of the geological formations in the area.

The use of 3-D seismic data acquisition techniques has several advantages over conventional 2-D seismic data acquisition methods. With 3-D seismic data, it is possible to generate a comprehensive and accurate image of the subsurface geology of the region, which can lead to better reservoir characterization and ultimately improve the accuracy of drilling and production decisions (Mukherjee, 2018). The use of 3-D seismic data also allows for the identification of subtle subsurface features that may be missed with 2-D seismic data, thereby increasing the chances of discovering new hydrocarbon reservoirs (Yilmaz, 2001).

The surveying, drilling, recording, and seismology sections of the acquisition process were critical in ensuring the success of the study. The surveying section produced accurate seismic lines, which defined the coordinates, elevations/depressions, and positions of the shot points and geophone stations. The drilling section ensured that the seismic holes were drilled according to the pre-defined pattern hole geometry, and the recording section charged and detonated sources in the seismic holes, generating seismic wave energy and mapping the subsurface.

The seismology section played a crucial role in the data reduction computation, ensuring data quality control, pre-survey, design/parameter definitions, and noise test experimentation and analysis. The noise attenuation design was optimized based on the velocity, frequency ranges, and wavelength of the most disturbing ground rolls in the area, which were determined using the fixed shot, split spread array technique. The LVL/weathering analysis helped to determine the velocities, "Vw" and "Vc" distribution in the surface, intermediate, and consolidated layers, respectively, and the weathering depth, "Dw," in the area. These analyses were applied in the static correction to achieve cophasal alignment of seismic reflection events and ensure optimal signal resolution.

The 3-D seismic data acquisition in the OML Q Field of Niger Delta (Edo State/Delta State) has provided valuable insights into the subsurface geology of the region, which can aid in the exploration and production of hydrocarbons. The use of 3-D seismic data acquisition techniques has several advantages over conventional 2-D seismic data acquisition methods, and the surveying, drilling, recording, and seismology sections of the acquisition process were critical in ensuring the success of the study.

The successful completion of the 3-D seismic data acquisition in OML Q Field provided accurate and detailed data for further analysis, contributing to the exploration and production of hydrocarbon reserves in the Niger Delta. The use of the fixed shot, split spread array technique for noise test experimentation and analyses, as well as the LVL/weathering analysis, enabled effective noise attenuation design and optimal signal resolution. The LVL/weathering analysis also provided valuable information for static correction and cophasal alignment of seismic reflection events. Overall, the 3-D seismic data acquisition in OML Q Field was a comprehensive and multi-step process that utilized various techniques and instruments to achieve accurate and detailed mapping of the subsurface geology.

Conclusion

The 3-D Seismic Data Acquisition was carried out in OML Q Field of Niger Delta (Edo State/Delta State) to generate seismic wave energy and map the subsurface. The 3-D seismic data acquisition in OML Q Field of Niger Delta was a comprehensive and multi-step process that utilized dynamite as an energy source, an array of geophones and shot points, and recording instruments to map the subsurface geology

The field acquisition involved four major operational sections, namely surveying, drilling, recording, and seismology, with other auxiliary units. The survey produced the finished seismic lines, defining the coordinates, elevations/depressions, and positions of the shot points and geophone stations. The drilling section drilled the seismic holes according to pre-defined pattern hole geometry. The recording section charged and detonated sources in the seismic holes to generate seismic wave energy and map the subsurface. The seismology section carried out base station data reduction computation ensuring data quality control, pre-survey, design/parameter definitions, and noise test experimentation and analyses using the fixed shot, split spread array technique to study the velocity, frequency ranges, and wavelength of the most disturbing ground rolls to be attenuated in the area.

LVL/weathering analysis was carried out to determine the velocities, "Vw" and "Vc" distribution in the surface, intermediate, and consolidated layers, respectively, and to determine the weathering depth, "Dw" in the area. These pieces of information are applied in the static correction to enable the achievement of cophasal alignment of seismic reflection events and ensure optimal signal resolution.
The records were both vertical and CDP stacked. The vertical stacking of events was achieved by the use of multiple source-geophone arrays, while the CDP stacking of events was achieved by the use of CDP Roll along Cables and stacking box migratory switch.
Overall, the 3-D Seismic Data Acquisition in OML Q Field of Niger Delta was successfully carried out, and the acquisition parameters used were appropriate for the study area, enabling high-quality data acquisition and processing. The acquired data can be used for further interpretation and analysis for exploration and production activities in the area.

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Conflict of Interest
The authors declare no conflicts of interest in this work.

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