



**USING PHYSICS OF SEISMIC WAVES PROPAGATION IN 3-D ORTHOGONAL
GEOMETRY FOR HYDROCARBON EXPLORATION IN BENUE TROUGH,
NIGERIA**

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Abstract

The need for Nigeria's improved revenue base necessitated exploration for hydrocarbon in the frontier basins in addition to such exploration going on in the Niger Delta. This study is aimed at showing the role of Physics in the exploration for hydrocarbon using seismic waves in 3-dimensional orthogonal geometry acquisition design to locate hydrocarbon traps in Benue Trough. The method begins with the acquisition geometry design with a swath consisting six receiver lines orthogonal to source lines and having 200m lines spacing each, 48 shots per salvo, 12.5m by 25.0m bin size, 25.0m receiver stations interval, 50.0m source points intervals, maximum offset of 5261m, maximum multiplicity of 150 and 2400 ($400 * 6$) active channels. The recording materials and equipment were deployed as designed above and Sercel SN 428XL recording instrument was used for the seismic data acquisition while 2ms sample rate and 8 seconds record lengths were retained throughout the study. The result of the preliminary field processing showed a subsurface image with stratigraphic traps for hydrocarbon (oil and gas) between 400ms and 2000ms travel time on the unmigrated brute stack section.

Keywords: *Seismic waves, stack section, traps, Nigeria*

Introduction

Nigeria as a nation needs strong economic bases. Since oil and gas has been the major revenue source on which Nigerian economy depends, the need to improve such economic base is compelling for sustained economic growth and development. Hence, this articles demonstrates the importance of Physics in this regards. The aim of this study is to show the role of Physics in the exploration for hydrocarbon using seismic

waves in 3-dimensional orthogonal geometry acquisition design is Benue Trough, Nigeria. The method begins with the acquisition geometry design with a swath consisting of six receiver lines orthogonal to source lines and having 200m lines spacing each, 48 shots per salvo, 12.5m x 25.0m bin size, 25.0m receiver stations interval, 50.0m source points intervals, maximum offset of 5261m, maximum multiplicity of 150 and 2400 ($400 * 6$) active channels. The recording



materials and equipment are deployed as designed and Sercel SN 428XL recording instrument was used for the seismic data acquisition using 2ms sample rate and 8 seconds record length. This study demonstrates the methods and processes of using seismic waves to explore and located hydrocarbon traps (structural, stratigraphic and combination of traps). Hamid (1982, p.130) stated that in seismic prospecting, the travel time is required for defining the subsurface anomalous structures while the waveform studies are required for enhancing the signal-to-noise ratio and for investigating subsurface stratigraphic anomalies. During the course of seismic data acquisition, low velocity layer (LVL) information needed for static corrections were also obtained with seismic refraction method as required by Coffeen (1986, p. 290).

1.1 Scope of Article

The scope of the work is delimited by the geographical and subsurface geology of the study area, Benue Trough, Nigeria. The study focuses exclusively on use of seismic waves in surface geophysics to explorer the subsurface excluding other uses in borehole geophysics. It is also delimited by use of some simplified model assumption which may not capture the full complexity of seismic wave propagation. These assumptions include flat/horizontal layer assumption and simple velocity model where velocity is assumed to vary in a simple and predictable way with depth or location.

1.2 Area of study and its geology

The area of this study is the Benue Trough of Nigeria, located in latitude $6^{\circ} 25'$ to $8^{\circ} 8'$ North and Longitude $7^{\circ} 47'$ to $10^{\circ} 0'$ East in Nigeria. The geology of the Benue Trough is fairly well established. In Obaje (2009), the trough contains a thick sequence of sedimentary rocks that include Albian-age sediments of sandstones, shales and limestones called Asu River Group; a Cenomanian-age sediments of sandstones, shales and limestones called Awe Formation; Turonian-age sediments of sandstones and shales called Makurdi Formation and Awgu Shales which are Coniacian-age sediments comprising of shales and sandstones.

Theoretical background and Review of Relevant Literatures

A seismic wave is acoustic energy transmitted by vibrating particles of rock. Low-acoustic waves are nearly elastic and the mass of rock are unchanged by their movement, though close to their source point the rock could be shattered (Milsom, 2003 P.179). Propagation of seismic waves follow Huygen' Principle, Fermat's Principle, Superposition Principle and Reciprocity Principle, Hamid (1982, p.28-34). In nature, media are heterogeneous and often stratified into layers of varying physical properties. Thus, at an interface, wave propagation follows the laws of seismic energy partition. Zeoppritz equation describes the partitioning of seismic energy at a plane interface between two elastic media of acoustic impedance contrast. The reflected waves are received by geophones/hydrophones planted in

accordance with the acquisition geometry and recorded on a plot of travel time versus offset distance as seen in a monitor record. These acquired seismic data are then processed. Wail (2019, p.269) stated that seismic data processing is an arrangement of cascaded operations that attenuate noise accompanying seismic data while also making geometrical corrections such that the stack section shows a true image of the subsurface. Processing of seismic data encompasses of (but not limited to) demultiplexing, recovery gain, common mid-point (CMP) gathers, velocity analysis, deconvolution, filtering and normal move-out (NMO) correction . Combining all the traces in a CMP gather (a process known as stacking) will average out noise and increase the signal-to-noise ratio (SNR) according to Kearey et al. (2002).

Egor et al. (2022) in their work on deployment of P-S wave reflection techniques concluded that seismic reflection techniques led to identification of gas traps in mud stone at around of 4300m. Similarly, Obiekezie (2014) in his work on Hydrocarbon Exploration in Odo Field, Niger Delta Basin, Nigeria concluded that 3-D seismic reflection survey was used to identify and delineate growth faults (structural traps) in Odo field.

Materials and methods

The method involves shooting explosives (dynamites and detonators) as seismic sources into a seismic spread described in the acquisition geometry and recording the

seismic response in a magnetic tape for quality control, processing and interpretation. The recording instrument is Sercel SN 428XL while workstation used for seismic data quality control, analysis and processing was run on ProMAX software.

Results

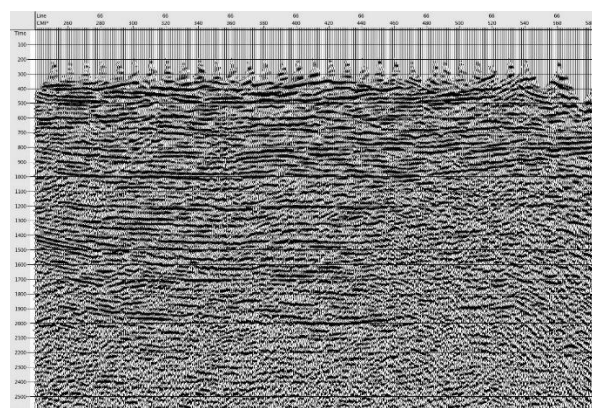


Fig 1.0 showing (unmigrated) brute stack section on a receiver line with reflection events seen from 400ms to 2000ms.

Discussions

The fig 1.0 above is an unmigrated brute stack section of a receiver line in the study area showing reflection events from 400ms down to 2000ms. Detailed processing would give much improved section. The most common activity in interpretation is picking a horizon. The horizon is the reflection that appears on section over some geographical extent. The reflection is identified as representing a certain geological formation. The reflection is picked, that is, marked at shot points along the vertical section over the area. The picks are timed by reading the reflection times. These times can be plotted on a map and



contoured to show locally high places or other places for drilling. Vertical seismic profiling (VSP) with perfect velocity helps to locate the exact depth of a formation. However, VSP is not part of this study but this study established by two-way travel time the varying sequence of formation stratigraphy that represent the stratigraphic traps and the extent and location of these traps which could be housing the hydrocarbon (oil and gas). With migration and other additional processing, faults (structural traps) would become clearer.

5.0 Conclusions

The result of the preliminary field processing showed a subsurface image with stratigraphic traps for hydrocarbon (oil and gas) between 400ms and 2000ms travel time on the unmigrated brute stack section. The use of principles of physics, in this case, seismic wave propagation has been demonstrated by this study to be useful in the search for hydrocarbon which our country, Nigeria so much needs for economic growth and development. This article also demonstrated the use of seismic wave propagation to determine the existence of hydrocarbon traps in the Benue Trough. Hence, further research is needed to confirm the presence of hydrocarbon in those traps. This will no doubt help to improve the nation's hydrocarbon reserves that would jumpstart new economic boom for the country.

Another indirect advantage is that most students of Physics who do not know the usefulness of their course of study would begin to appreciate Applied Physics

as a course of study as well as its importance to the national economy after going through this article.

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Conflict of Interest/Ethics Statement

The author has no conflict of interest

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