Earth Sciences Pakistan (ESP)

DOI: http://doi.org/10.26480/esp.01.2022.27.29

ZIBELINE INTERNATIONAL PUBLISHING

ISSN: 2521-2893 (Print)
ISSN: 2521-2907 (Online)
CODEN: ESPADC

CrossMark

RESEARCH ARTICLE

VELOCITY LAYERING IN THE MIDDLE BENUE TROUGH NIGERIA USING SEISMIC REFRACTION DATA

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ARTICLE DETAILS

Article History:

Received 23 February 2022
Accepted 28 March 2022
Available online 30 March 2022

ABSTRACT

Seismic refraction data was acquired in the Middle Benue Trough which is located in the north central Nigeria with latitude 07.5-08.5°N and longitude 08.00-09.30°E. The aim was to find out how velocity vary in the near-surface layers in the area using seismic refraction data. The seismic survey was investigated at 14 acquisition stations. Two overlapping reversed profiles were shot into 14 stations. Each acquisition station was primed with 0.20kg dynamite loaded at 1.5m below the surface. The recording equipment was McSeis-160MXTM, and monitor record was processed with Microsoft Excel software to determine the velocities from both the forward and reversed shot-points. The results show two distinct layers cases. The thickness of the topmost layer varies between 2.75m and 5.45m with a mean of 4.1m. The velocity of this topmost layer varies between 399.0 ms^{-1} and 767.0ms^{-1} with a mean of 604.8ms^{-1}. The velocity of the underlying layer (V_1) varies between 1212.5ms^{-1} and 3257.0ms^{-1} with a mean of 1757.9ms^{-1}. The velocity increases with depth into the subsurface. The results are useful in locating groundwater aquifer, and in the design of source-receiver arrays for reflection seismic.

KEYWORDS

Refraction Seismic, Velocity, Layers, Middle Benue Trough, Nigeria

1. INTRODUCTION

Layering, or bedding, is the most observable attribute of sedimentary rocks. Seismic velocity passing through a rock layer can increase with depth vertically due to compaction. The primary aim of this work is to establish the wave velocities in the near sub-surface layers in a part of Middle Benue Trough using seismic refraction data. Middle Benue Trough region is one of Nigerian inland basins rich mineral deposits (Ajayi et al., 1991; Ofoegbu et al., 1990; Onuoha, 1981b; Clifford et al., 2018; Labe et al., 2018; Adetona et al., 2013). The outcome of this research can be applied to assess rock quality static and dynamic corrections in reflection work, ground water exploration, and other economic and engineering applications (Uko et al., 1992; Reynolds et al., 1992; Varughese et al., 2011).

2. AREA OF STUDY AND ITS SOILS

The research was carried out in Nasarawa State within the Middle Benue Trough (Figure 1). It prospect area has a surface coverage bounded by Latitudes 07.50° - 08.50° N and Longitudes 08.00 and 09.30°E. The near-surface soils and rocks are shown in Figure 2, and consist, predominantly, of sandstones intercalated with calcareous shale and claystone, laterite and volcanic rocks (Patrick et al., 2013; Reyment, 1964; Akande et al., 1988; Reyment, 1965; Jauro et al., 2008; Benkhelil, 1988; Offodile, 1976; Nwajide, 1985; Offodile et al., 1977; Reyment et al., 1977; Umoetok et al., 2018; Mgbemere et al., 2018; Mbachi et al., 2018; Akpan et al., 2020).

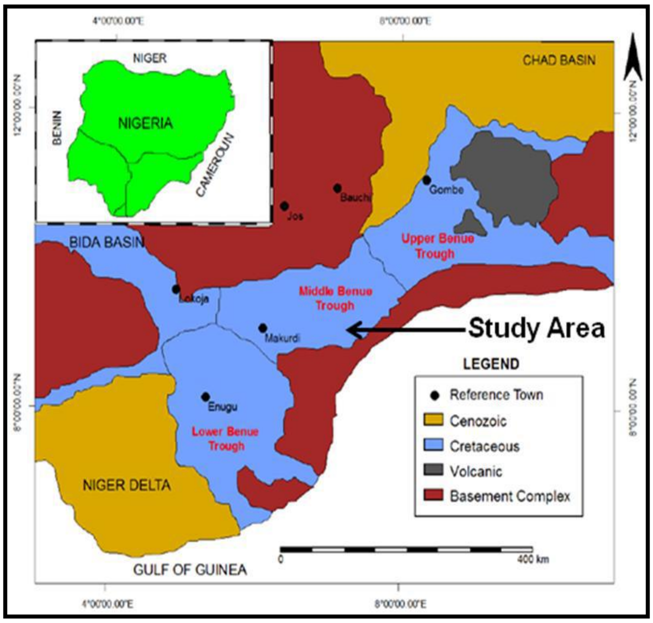

Figure 1: Map of the Middle Benue Trough showing the Study Are.

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Cite the Article: Abdullateef H. Abidemi, Etim D. Uko, Olatunji S. Ayanninuola (2022). Velocity Layering in the Middle Benue Trough Nigeria Using Seismic Refraction Data, *Earth Sciences Pakistan, 6(1): 27-29.*

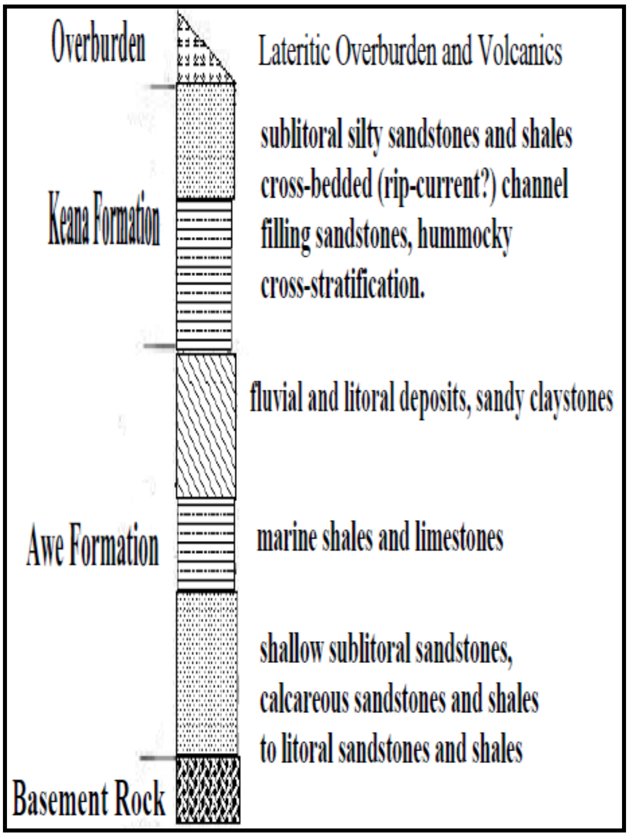

Figure 2: Generalized structural succession of the area of study.

3. Materials and Methods

The materials used for this work includes; Global Positioning System (GPS), matches, staff, geophones, McSeis oscilloscope, blaster, dynamite, Radio controlled firing command decoder and time break modulator. The source-detector array is illustrated in Figure 3. At each data acquisition point, two reversed traverses were shot into 12 stations of receivers from each end of the spread. The depth of each source hole was 1.5 metres loaded with 0.20kg of dynamite. The near and far source-detector offsets of 5m and 75m respectively were maintained. The first 5 geophones were spaced 5m apart near the source; the others were spaced 10m towards the centre and 5m towards the end of the spread. Each layer was assumed to be laterally homogeneous, horizontal and isotropic. Each layer velocity and thickness were separately computed for the forward and reversed recording, and then the mean calculated for each layer.

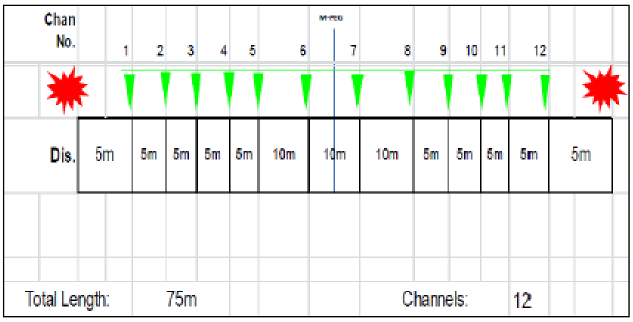

Figure 3: Source-Detector Array

The McSeis-160MX Instrument was used for recording the arrival times from the refractors. Figure 4 demonstrates a typical refraction monitor records and Travel-Time (T-X) graph for UP-34 station (Rucker, 2000; Clifford et al., 2018).

4. Results and Discussion

The results are presented in Figure 4 and in Table 1.

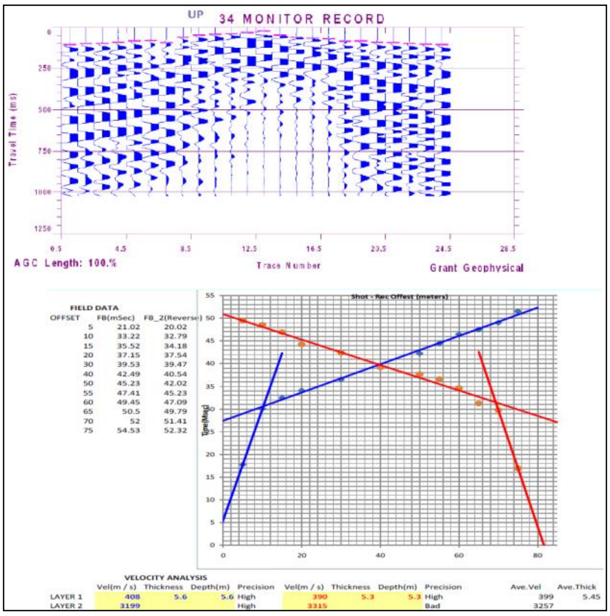

Figure 4: Seismic Monitor Record and T-X Crossplot for Station UP34, Example

Table 1: LVL Characteristics in Middle Benue Trough, Nigeria									
LVL NO.	**Weathered Layer Velocity, V_o (ms^{-1})**			**Weathered Layer Thickness, D_w (m)**			**Consolidated Layer Velocity, V_1 (ms^{-1})**		
	Direct Shot	**Reverse Shot**	**Average**	**Direct Shot**	**Reverse Shot**	**Average**	**Direct Shot**	**Reverse Shot**	**Average**
34	408	390	399.0	5.6	5.3	5.45	3199	3315	3257.0
35	781	731	756.0	2.8	2.7	2.75	1410	1403	1406.5
36	478	511	494.5	4.8	4.3	4.55	1231	1194	1212.5
37	516	525	520.5	5.5	4.2	4.85	1259	1164	1211.5
38	589	595	592.0	5.0	4.8	4.90	1618	1585	1601.5
39	686	686	686.0	4.3	4.0	4.15	1807	1682	1744.5
40	548	491	519.5	5.0	4.9	4.95	1933	1977	1955.0
41	698	707	700.5	3.3	3.5	3.4	2168	2196	2182.0
42	655	630	642.5	3.5	3.3	3.4	1397	1365	1381.0
43	761	773	767.0	3.3	2.8	3.05	1787	1722	1754.5
44	689	754	721.5	2.9	2.8	2.85	1753	1589	1621.0
45	568	622	595.0	4.0	4.7	4.35	1617	1636	1626.5
46	568	579	573.5	4.1	4.7	4.4	1613	1687	1650.0
47	504	496	500.0	3.8	3.9	3.85	2022	1992	2007.0
Average			**604.8214**			**4.064286**			**1757.893**

5. Discussion

The topmost layer velocity ranges between 399.0ms^{-1} and 767.0ms^{-1} with a mean of 604.8ms^{-1}. The underlying layer has a velocity which varies between 1212.5ms^{-1} and 3257.0ms^{-1} with a mean of 1757.9ms^{-1}. The depth of refractor is observed to vary erratically with no trend and varies between 2.75m and 5.45m with a mean of 4.1m.

Velocity value is higher in the up-dip direction and is reduced in the down-dip direction. Using the principle of reciprocity, it is expected that seismic arrival times for both direct and reverse shots would have been equal between two points, if the source and detector are interchanged. This principle failed in this research (Ewing et al., 1939). The travel arrival times were not equal in the forward and reverse directions. It is seen that the horizontal and isotropic layer assumptions did not hold in the survey. However, velocity generally increase with depth at the 14 stations.

6. Conclusion

Based on the results gotten, the following conclusions have been reached:

(i) Two soil layers were encountered.

(ii) The velocity of the topmost layer varies between 399.0ms^{-1} and 767.0ms^{-1} with a mean of 604.8ms^{-1}.

(iii) The velocity of the underlying layer varies between 1212.5ms^{-1} and 3257.0ms^{-1} with a mean of 1757.9ms^{-1}.

(iv) Velocity value is higher in the up-dip direction than in the down-dip direction.

(v) The refractor layer is not horizontal but greatly rising and falling and varies between 2.75m and 5.45m with a mean of 4.1m.

Acknowledgment

The researchers are thankful to Nigeria National Petroleum Corporation (NNPC) for providing the data.

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