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INVESTIGATION OF SUBSURFACE GEOLOGY IN THE TANO BASIN OF GHANA USING SEISMIC REFRACTION METHOD

Hafiz MOHAMMED NAZIFI (ORCID: 0000-0002-3762-6563)*

**Sakarya University, Dept. of Geophysical Engineering, Esentepe Campus, Serdivan, 54187 Sakarya, Turkey*

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ABSTRACT

2D seismic refraction data, from seven traverse lines, were used to investigate subsurface geology in the Appollonian Formation of the onshore Tano Basin of Ghana. Tano Basin is one of the four basins of Ghana and the most important one when it comes to oil potential of Ghana. The survey covered approximately a total area of about 113,000 m^2. With the exception of one traverse line which had the length of 60 m, each of the remaining traverse lines had a length of 120m. The results from the data analysis indicated that, the surveyed area is underlain by three geological units although results from two traverse lines revealed two geological units. The P-wave velocity of the first layer ranges between 335.00 - 468.00 m/s and the average velocity of 391.57 m/s. It has a thickness range of 5.0 – 27.5 m with an average thickness of 16.25 m. The layer is interpreted as a weathered layer and consist of soil and dry loose sand which might be formed as beach deposit. The second layer has P-wave velocity range of 590.00 – 1133.00 m/s and the average velocity of 881.71 m/s. The layer thickness ranges between 14.5 – 31.0 m and the average of 25.80 m. The layer may consist of unconsolidated water- saturated sand and clay. The last layer detected by this survey has P- wave velocity range of 1068.00 – 2724.00 m/s and the average of 2074.20 m/s. The layer is interpreted as the bedrock underlining the surveyed area. The layer may consist of gravel, sandstone and limestone.

Keywords: Ghana, Tano Basin, Appollonian Formation, Seismic Refraction, Subsurface Geology.

1. INTRODUCTION

Seismic Refraction (SRF) was used to investigate shallow subsurface geological unit of the onshore Tano Basin of Ghana. The SRF is known as one of the best geophysical method for lithological studies. Researchers such as [1], [2], [3], [4] and others have successfully used seismic refraction method for various forms of geotechnical investigations such; shallow geological units investigation, depth to bedrock investigation, geological structural investigations etc.

Further information about SRF and its applications can be obtained from literature such as; [5], [6], [7], [8], [9] and [10].

The aim of this work was to determine the geological units (sedimentary rock types) within the shallow subsurface of the study area and also to understand the seismic refraction characteristics of the Appollonian Formation of Ghana which underlies the study area.

There is no previous geophysical investigation conducted in this study area and this study provides valuable information on the subsurface geology of the area. The study provide us with information about the depth to bedrock and the types materials that consist of the bedrock. This information would be of importance to civil engineers in case a large – scale building construction works need to be undertaken the area. Seismic velocity depends on the elasticity and density of the material through which the seismic energy passes and that from this

*Corresponding author e-mail: mohammednazifi@gmail.com

study the obtained seismic velocity could be used by other researchers or engineers in assessing the strength and the quality of the rocks beneath the area.

The study area is located within the southwestern coastal part of Ghana (Figure 1). The area is located within the Appollonian Formation which is one of the Coastal Sedimentary Basins of Ghana. Hydrocarbon in Ghana was first discovered in this formation. The formation has its large portion in South-eastern Ivory Coast and small portion in Southwestern corner of Ghana. The Ghanaian portion of this formation is known as Tano Basin and it covers 1,165 sqkm between the mouths of the Ankobra River in the east and the Tano River in the west. The formation is made of Cretaceous-Eocene marine sedimentary rocks. The rocks consist of alternating sands, clays and limestones. In depth, the sands and clays are more compact and pass into sandstone and shale. Nodules of pyrite or marcasite are common in the clays and shales. The only prominent stratigraphic marker of the area is a series of thin, highly fossiliferous limestone [11] as cited in [12].

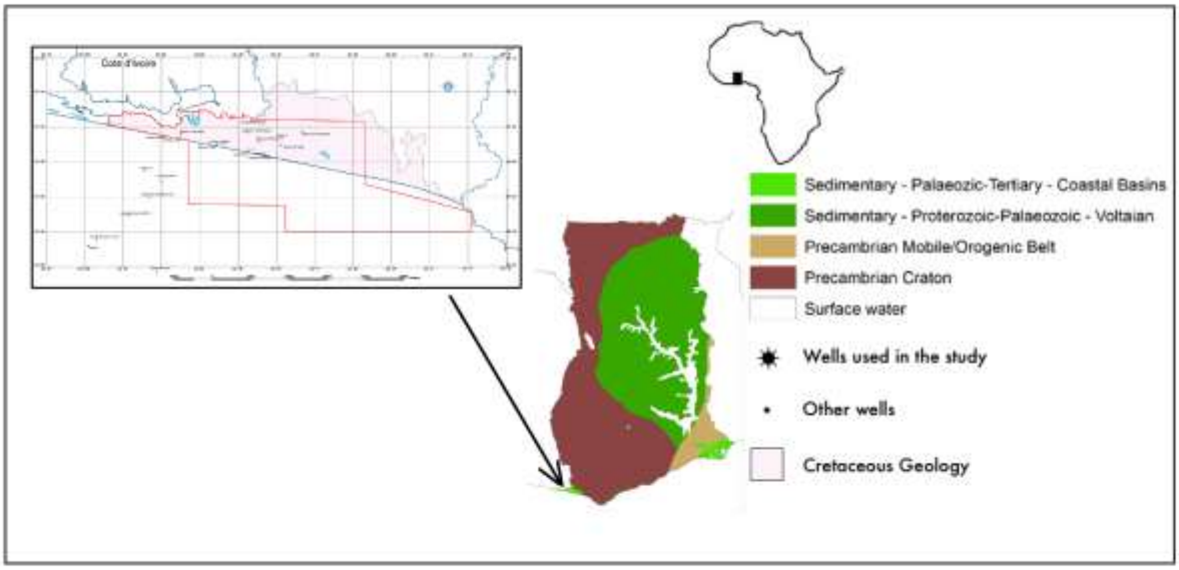

Figure 1. Geological map showing Tano Basin (modified after [13])

2. MATERIAL AND METHOD

The energy source used for this survey was an explosive (a charge of gelignite at a hole drilled for this purpose). Twenty four channel geophones of five meter regular interval was used to detect the seismic signals from the ground and a 368 Digital Telemetry Recording System with central control unit was used to record the signals from the geophones.

The twenty four geophones were planted firmly in the ground at regular interval of five meters along a straight profile line. Several profile lines were made with each one at a distance of twenty five meters from the other. The geophones were connected by means of multi- cables to the 368 Digital Telemetry Recording System.

Seismic energy was generated in the ground at the shot point by the charge of gelignite at a bottom of a hole. The energy passed through the ground and the direct and refracted waves were received on the earth surface by geophones and transmitted by multi – cables to the recorder. A reverse shooting was conducted in the same manner as the forward shooting and the signal also recorded.

Digital data were obtained from the archives of Department of Physics, Kwame Nkrumah University of Science and Technology, Ghana. The researcher processed, modelled and interpreted the data using modern software and programs.

Plotrefa (version 2.9.1.9 of OYO Corporation) was first used for data processing, modelling and interpretation of the SRF data. The 2D models obtained from the Plotrefa program were imported onto CorelDRAW and 2D traverses of the study area were created. It was done by combining the 2D Plotrefa models according to their locations on the on the study area and by extrapolating their boundaries to join one another. This gave a clear 2D view of the study area that was used in the interpretation of the SRF results.

3. RESULTS AND DISCUSSIONS

The seven seismic profile lines are group on three traverse lines namely; Traverse A, Traverse B and Traverse C. Traverse A consist SP 1 and SP 2, Traverse B consist SP3 and SP 4 and Traverse C consist of SP 5 and SP 6 and SP 7.

Traverse A (Figure 2) reveals three layers wıth average P-wave velocity of 368.5 m/s, 691.0 m/s and 2302.0 m/s for the fırst, second and third layers respectively. The thickness of the fırst layer range from 7.0 – 16.0 m wıth the average thıckness of 12.3 m. The second layer has a thickness ranging from 29.0 – 31.0 m and an average thickness of 29.5 m. According to the P-wave velocity, the first layer may consist of soil and dry loose sand; the second layer may consist of dry coherent sand; and the third layer may consist of clay, sandstone and limestone. In general the subsurface beneath the traverse A is undulating and complex. There is a possibility of normal fault beneath the surface of this traverse line. This claim is due to the analysis of the travel time – distance graph of the SP2 (Figure 3).

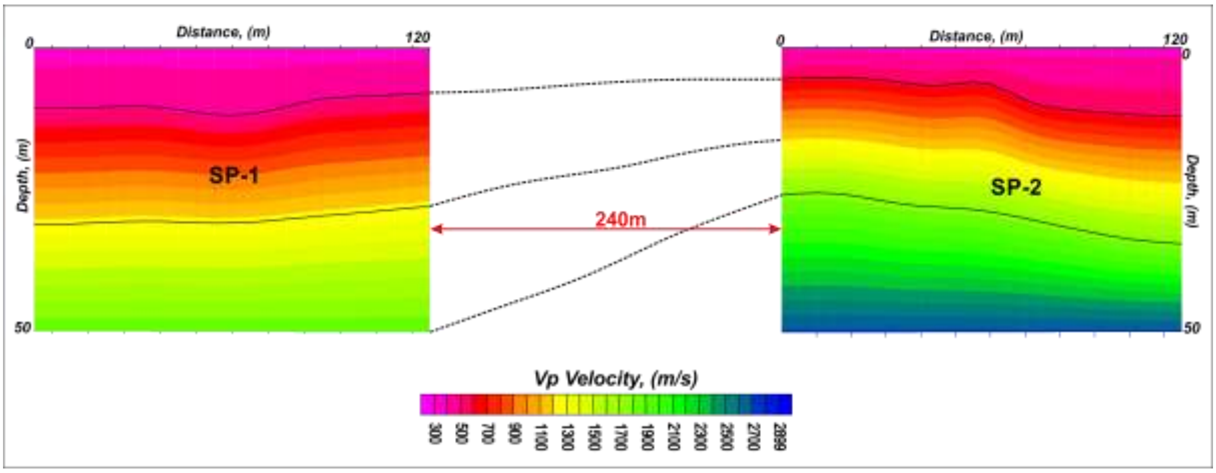

Figure 2. SP1 and SP 2 results on Traverse A

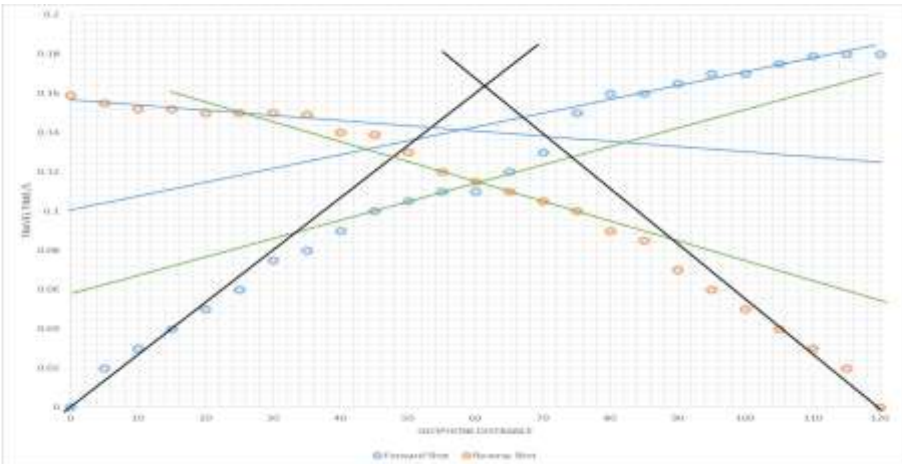

Figure 3. Travel Time – Geophone Distance Graph on Profile SP2

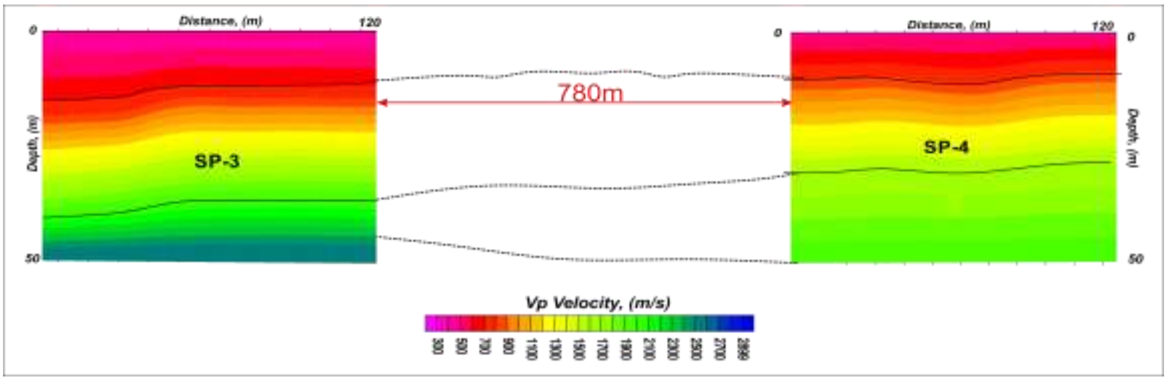

Figure 4. SP 3 and SP 4 results on Traverse B

The result from traverse B (Figure 4) indicated three layers wıth average P-wave velocity of 433.5 m/s, 1112.5 m/s and 2349.5 m/s for the first, second and third layers respectively. The layer thickness ranges from 12.0 – 24.0 m and 26.0 – 29.0 m for first and second layer respectively. From the P-wave velocity, the first layer may consist of soil and dry loose sand; the second layer may consist of clay and unconsolidated water – saturated sand; and the third layer may consist of gravel, sandstone and limestone.

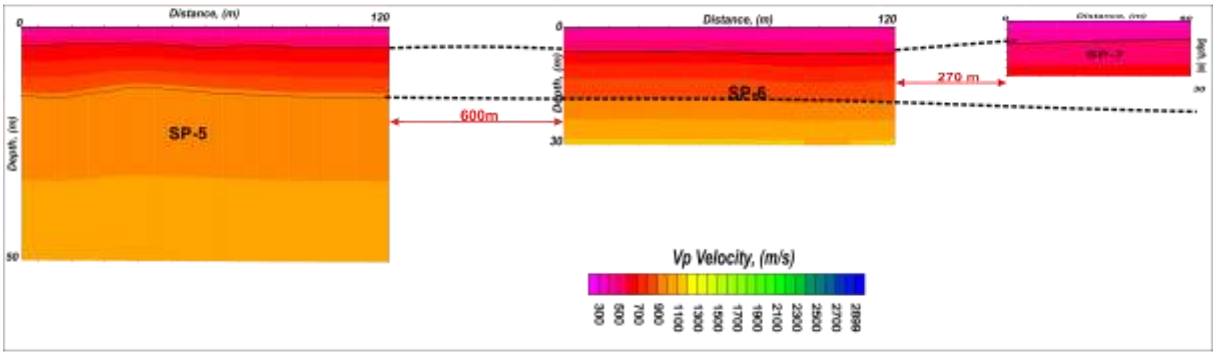

Figure 5. SP 5, SP 6 and SP 7 results on Traverse C

Traverse C (Figure 5) reveals 2 -3 layers with SP 5 indicating three layers whiles SP 6 and SP 7 indicating two layers. The average P-wave velocities obtained are 379.0 m/s, 855.0 m/s and 1068.0 m/s for the first, second and third layers respectively. The average thickness of first layer is 18.2 m and that of the second layer is 14.8 m. According to the P-wave velocities, the first layer may consist of soil and dry loose sand; the second layer may consist of sand; and the third layer may consist of clay.

Generally, the surveyed area is underlain by three geological units. The P-Wave velocity of the first layer ranges between 335.00 - 468.00 m/s and the average velocity of 391.57 m/s. The first layer has a thickness range of 5.0 – 27.5 m with an average thickness of 16.25 m. The layer is interpreted as a weathered layer and consist of soil and dry loose sand which might be due to beach deposit. The second layer has P-Wave velocity range of 590.00 – 1133.00 m/s and the average velocity of 881.71 m/s. The layer thickness ranges between 14.5 – 31.0 m and the average of 25.80 m. The layer may consist of unconsolidated water- saturated sand and clay. The last layer detected by this survey has P- Wave velocity range of 1068.00 – 2724.00 m/s and the average of 2074.20 m/s. The layer is interpreted as the bedrock underlining the surveyed area. The layer may consist of gravel, sandstone and limestone. The subsurface beneath the surveyed area is undulating and complex. There may be a normal fault beneath the surveyed area especially in the site where the profile SP2 measurements were taken.

4. CONCLUSION

The seismic Refraction survey was carried out to investigate the rock types within the shallow surbsurface and to determine other geological features. The velocity sections of subsurface beneath the surveyed area successfully indicated the presence of three distinct geological layers. The third layer was interpreted as the bedrock and may consist of sandstone, limestone and gravel. The maximum depth to the bedrock is 45m. The subsurface is generally dipping or undulating and complex. Fault had been detected beneath the study area. It is recommended that further research to be conducted to verified the detected fault.

By this work we were able to determine the geological units (sedimentary rock types) within the shallow subsurface of the study area. This work has helped us in understanding some of the seismic refraction characteristics of the Appollonian Formation in the Tano Basin of Ghana.

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