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# SEISMIC REFRACTION INVESTIGATION OF GROUNDWATER POTENTIAL IN PARTS OF THE OBAN MASSIF, SOUTH-EASTERN, NIGERIA

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## ABSTRACT

A seismic refraction survey was conducted in parts of the Akampka Basement Region of the Oban Massif, South-Eastern Nigeria, using a portable MOD. S79 3- channel digital type signal enhancement seismograph. The objectives were to determine the depth to the water table, the thickness of the saturated overburden, and the depth to basement, for purposes of groundwater development.

The result showed that for the three selected areas, the average depth to the basement was 16.4m, the average aquifer thickness was 10.6m, and the average velocities of 492m/s, 969m/s, 1811m/s and 3759m/s for the first, second, saturated aquifer and bedrock respectively were obtained. The mean depth to the water table was determined to be 8.7m at Aiyebam 10.1m at Awi and 1.7m at Mbarakom. There was a good correlation between seismic interpretation and borehole lithologic section within the study area. With a considerable saturated thickness, areas of good potential aquifers for groundwater development abound in the study area.

**KeyWords:** Seismic refraction, groundwater development, basement, Oban Massif, South-eastern Nigeria.

## INTRODUCTION

The areas of study are Awi, Aiyebam and Mbarakom, which are located within the Oban Massif in South Eastern Nigeria (Fig. 1). The Basement Complex rocks in this geological zone are naturally poor aquifers, as they have low porosity and negligible permeability (Asseez, 1972). However, by providing an overburden of relatively more porous and more permeable material from the rocks, deep weathering had proved to be one of the most important factors in the groundwater hydrology of such geological environments, especially in the tropics. The present study is primarily carried out to determine water table, thickness of the saturated overburden and depths to the underlying basement, for purpose of groundwater development.

## GEOLOGY

The study area is situated within the Oban Massif, located between latitudes 5°00' and 5°50' N and longitudes 8°00' 8°00' E. The Oban Massif forms part of the South-Eastern Basement Complex of Nigeria and is surrounded by Cretaceous and younger sedimentary rocks. Lithologically, the three major rock group recognized in this region are migmatitic and sheared gneissic rocks, older granite intrusive and unmetamorphosed dolerite to microdolerite intrusive rocks (Fig. 1). The occurrence of groundwater in this area is either within the weathered rocks or in the joints and fracture' system in the bedrock. According to Petters (1989) low values of aquifer characteristics as obtained in the study area are strong indications for poor water storage potential

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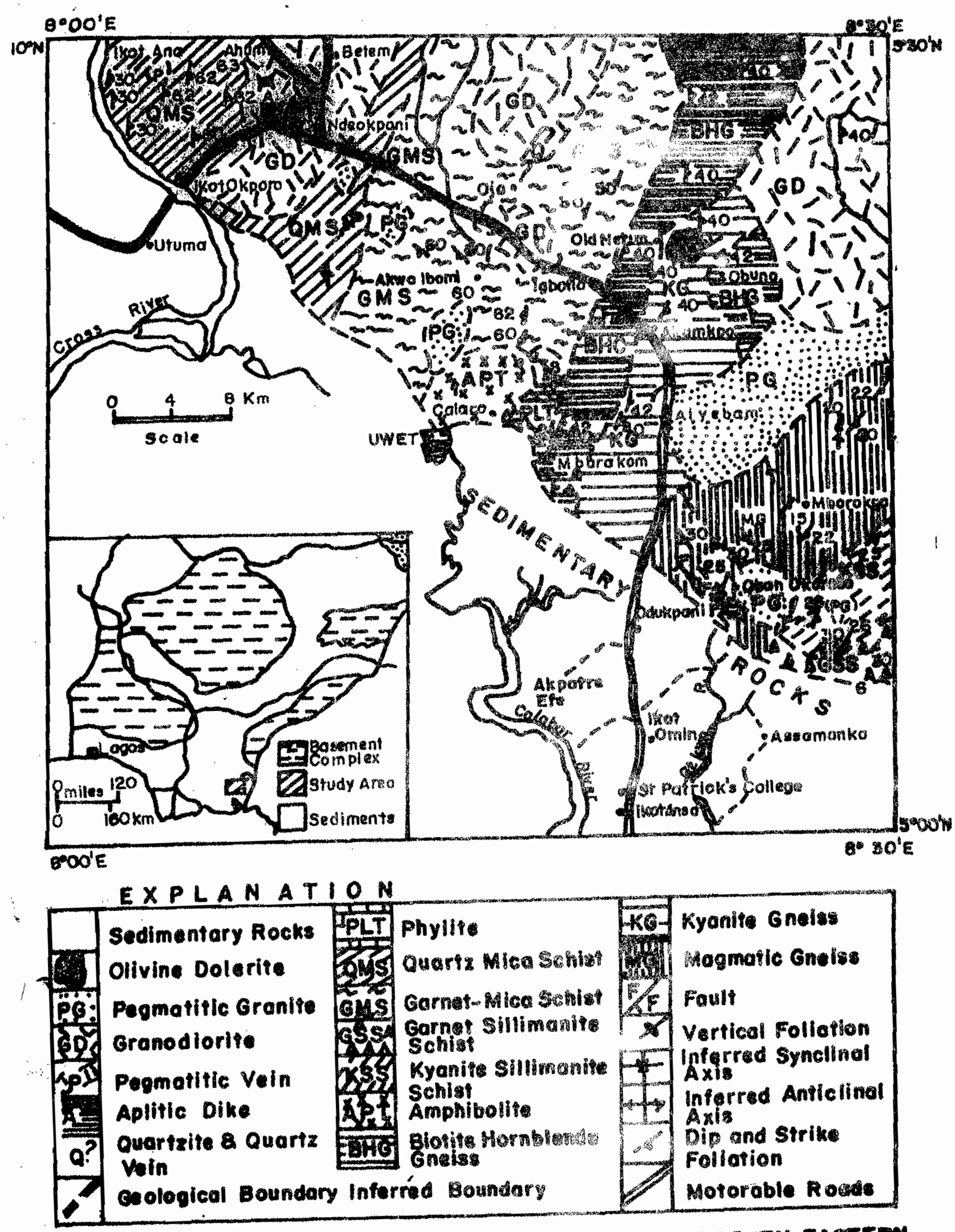


Fig. 1. GEOLOGICAL MAP OF PARTS OF OBAN MASSIF SOUTH EASTERN NIGERIA (Courtesy of Geological Survey of Nigeria)
Source : Adapted after Ekwueme, (1985).

of the basement complex province. Though jointing and cracks may occur in the bedrock, its water retaining capacity is poor. The presence of groundwater in this area would then depend on whether a sufficient thickness of the decomposed material is present to provide a reservoir. According to Edet (1993), the character and thickness of the weathered zone in the study area are influenced by the bedrock lithology. Areas underlain by schists, phyllites amphibolite and biotite gneisses have thick overburden. In general, the surficial deposit overlying the basement is believed to be products of Pleistocene accumulation cycles (Asseez, 1972). These consist of laterite, alluvial deposit, silt, sandstone and clay.

## INSTRUMENTATION AND DATA COLLECTION

The seismic equipment used for this survey consisted of a portable MOD. S79, 3-Channel digital type signal enhancement seismograph designed for simultaneous acquisition of data in the 3-channel from a source. Incorporated in the seismograph is a signal enhancement device for improved signal to noise ratio and a DPU – 411 type 11 thermal printer. With a 12V in-built accumulator, over 50 hours of operating time is obtainable before recharging. The detector used in this study was a 10Hz electromagnetic type geophone with a 9kg sledge hammer and striking plate as the source

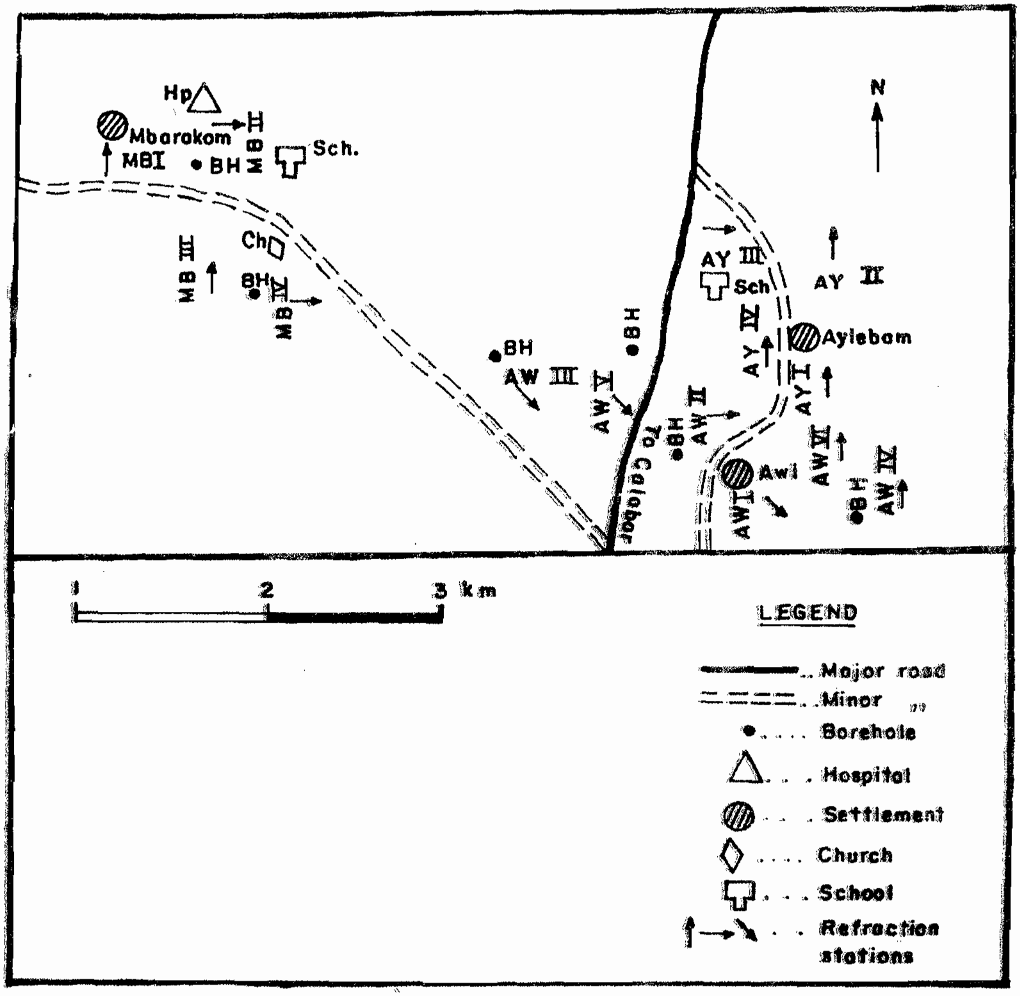


Fig. 2 : MAP OF STUDY AREAS SHOWING SEISMIC REFRACTION SPREAD STATIONS

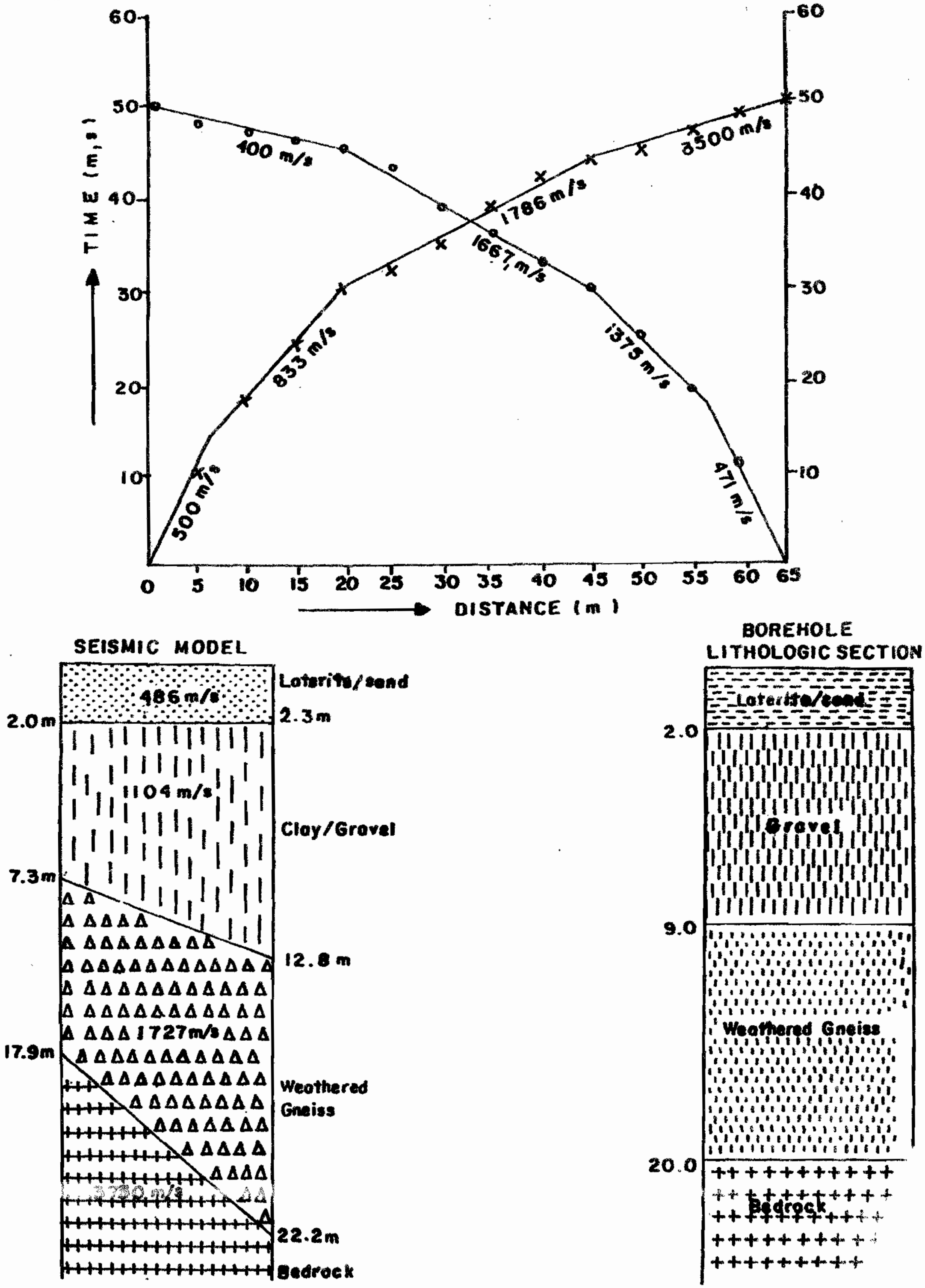


Fig. 3 : SESIMIC REFRACTION MODEL, BOREHOLE LITHOLOGIC SECTION A
(T–X) CURVE AT AWI

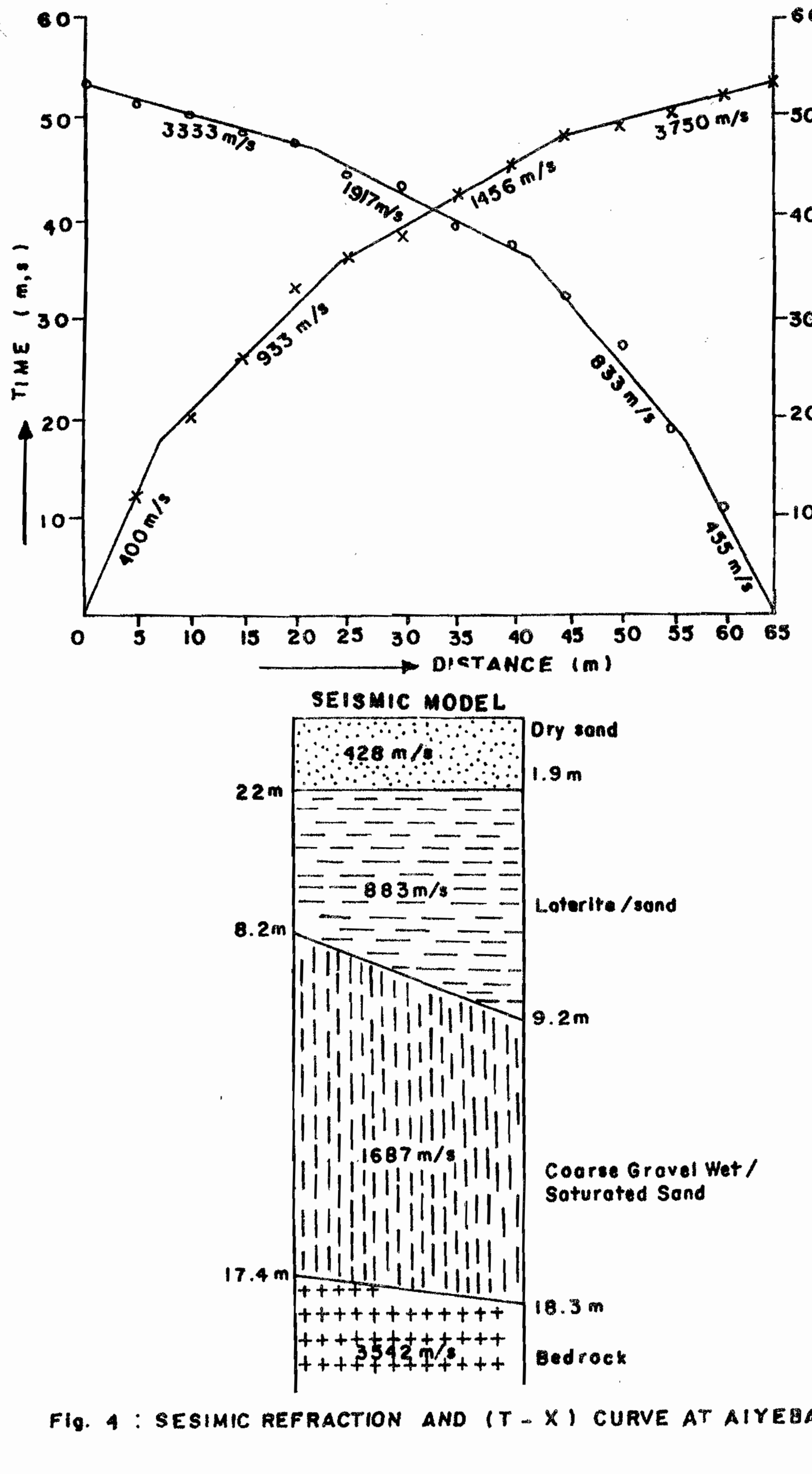


Fig. 4 : SESIMIC REFRACTION AND (T - X) CURVE AT AIYEBAM

A single three (3) geophone string with inter-geophone spacing of 5m and a spread of 65m was used at each sample station. The spread lengths ranged between 45m and 65m. Reverse profiles were used in all cases. A total of 14 seismic refraction surveys was completed within the three selected areas. Seven traverses were aligned in the N-S direction, four in the W-E direction, while three had a NW – SE orientation. The field situation did not permit a regular grid due to rugged nature of some pre-selected stations. The inter-station spacing ranged between about 100m and 400m. the seismic spread station is as shown in Figure 2.

## DATA PROCESSING AND INTERPRETATION

The arrival times of seismic wavelets from subsurface refractors for the various source receiver distances were picked directly from the portable MOD. S 79 3- channel seismograph. These travel times were plotted against source receiver distance for both forward and reverse profiles. The compressional wave velocities of various subsurface layers, depths to refractors and dips (where applicable) were obtained from the resulting time distance (T-X) curves. The time intercept method as developed by Hawkins (1961) was used in the calculation of the seismic parameters. For dipping refractors, the formulae used in obtaining true velocities, depths and dips in these circumstances were adapted from Okwueze (1988). Seismic velocities of the various subsurface layers and their depths were calculated for all the 14 seismic stations.

All the travel time curve for the sample points at Awi portray a 4 – layer case with mean velocities of 486m/s, 1104m/s, 1727m/s and 3750m/s for the first, second, third layers and basement respectively. Figures 3, shows (T-X) plot and seismic model in one of the locations. The mean thickness for the various layers in this locations were 2.1m, 7.9m and 10m for the top layer, second layer and third layer, respectively. This corresponds to thin laterite/sand, thick clay/gravel underlain by a probable saturated weathered gneiss. The mean depth to the water table at this location was estimated to be 10.0m from the ground surface with a mean aquifer thickness of 10.0m. The basement which is probably gneiss was estimated to be 20.1m on the mean from the ground surface. The borehole model in figure 3 shows that there is a fairly good agreement between the seismic and the lithology penetrated at borehole. The seismic method takes into account the dipping of the interface in its modeling which was not considered in the borehole model.

The interpretation at Aiyebam shows a 4-layer case with means P-wave velocities of 428m/s, 833m/s, 1687m/s and 3542m/s. The geological sequence (Fig. 4) shows a weathered surface material of dry sand first layer, laterite/sand second layer and wet coarse gravel/saturated sand third layer overlying a probable granite bedrock at a mean depth of 17.9m from the surface. The mean thickness of the first three layers in these locations are 2.1m, 6.7m and 9.2m respectively. The groundwater aquifer in this location is the third layer with water table at a depth of about 8.7m from the surface.

The spread at Mbarakom portrays a 3-layer case as observed in one of the location in figures 5. The mean velocities of these layers are 563m/s, 2019m/s and 3984m/s respectively. The geological sequences shows laterite/sand first layer with a mean thickness of 1.7m underlain by granite at a mean depth of 13.7 from the surface . The aquifer at Mbarakom is probably the weathered granite with the water table at about 1.7m below the ground surface.

Though fewer seismic spread were covered within Mbarakom, (see figure 2), interpretation of depth to water table, depth to bedrock and thickness of satureated aquifer showed good agreement with the borehole lithologic section (see figure 5).

## DISCUSSION OF RESULTS

At Awi where there was a control borehole, a comparison of the seismic model with borehole lithologic section (fig.3) shows that there is a fairly good agreement, between the two. Both models show a 4-layer case with slight different in

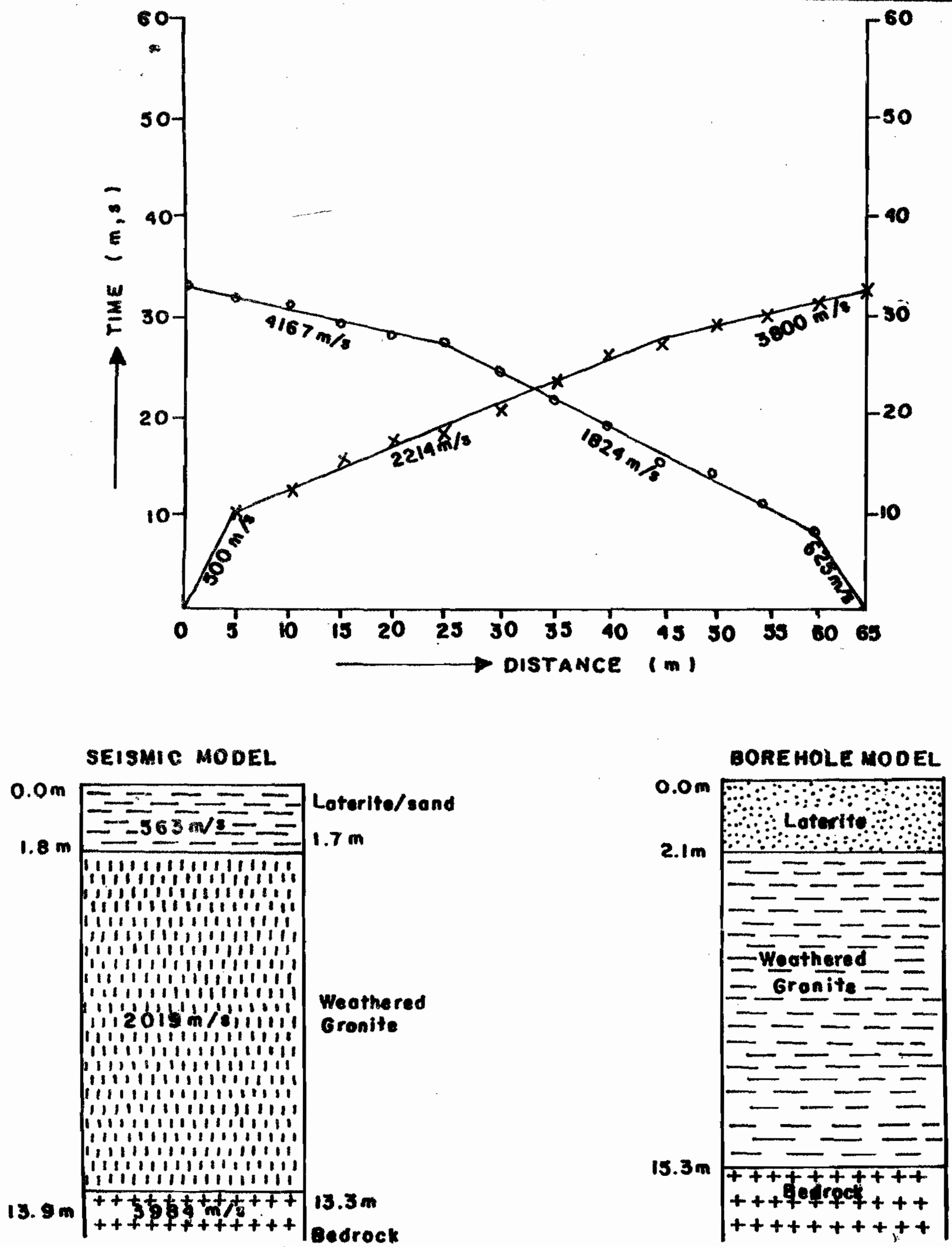


Fig. 5 : SESIMIC REFRACTION MODEL, BOREHOLE LITHOLOGIC SECTION AND (T- X ) CURVE AT MBARAKOM

the thickness of each layers. The seismic model however highlighted the dipping of the interfaces.

At Mbarakom with a control borehole, the two models were in a good agreement, as both showed a three-layer case, with a slight difference in the thickness of the first and second layer and the depth to the bedrock. There was no control borehole at Aiyebam. The seismic refraction model in this location showed a 4- layer case.

## CONCLUSION

From the result obtained in this work for the three selected areas of Awi, Aiyebam and Mbarakom, the following conclusions can be made:

(a) With aquifer thickness of about 10m, 9m and 12m respectively, Awi, Aiyebam and Mbarakom have potential sources of groundwater supply.

(b) Except for Mbarakom, where the aquifer is very shallow, depths to probable water table and bedrock range from 5m to 12m and 18m to 27m, respectively at Awi, and Aiyebam. At Mbarakom, the depth to water table and bedrock range from 1.5m to 4m and 15mto 25m, respectively.

This paper has demonstrated that seismic refraction surveys are invaluable in identifying aquifers in areas underlain directly by crystalline basement complex rocks.

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