2D RAY-TRACING AND SEISMIC VELOCITY STRUCTURE MODELING WITHIN SPECIFIC AREA OF THE NILE DELTA, EGYPT

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Abstract:The purpose of this investigation was to obtain information about the nature of the shallow sedimentary layers of the Quaternary depositional styles in the Nile Delta by using new processing techniques. Seven reversed shallow seismic refraction profiles conducted by Essawy (2001) in the northern part of Egypt, as a part of the Nile Delta were re-interpreted. New analysis of these refraction profiles using travel time tomography methods and 2D ray-tracing modeling reveals that the area consists of homogeneous layers. A 3D model has been constructed to describe the shape of the layer boundaries and the presence of an anomaly representing buried archaeological relics below the ground surface. The distributions of P-wave velocity of these layers concordant with their thickness are much similar to the Quaternary Nile Valley layers.

Key words: *2D Ray-tracing, Nile Delta, Velocity Structure Modeling, Egypt.*

INTRODUCTION

The Nile Delta area is located in the mid-north of Egypt and between two branches of the River Nile, (Rosetta & Damietta) (Fig. 1).
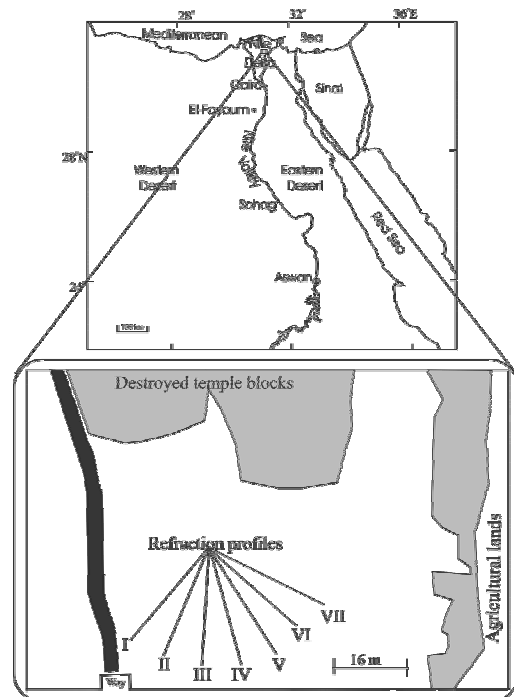

FIG. 1. Location map of the shallow refraction profiles in the study area (El-Essawy, 2001).

It was mainly formed during the Quaternary and covered by the recent fluviatile sediments. These Quaternary sediments were subdivided into two rock units (Rizzini et al., 1978; Said, 1962, 1971, and 1981). The first is Mit Ghamr Formation (Middle Pleistocene) which is overlaid by the second one, Bilgas Formation (Late Pleistocene). The Mit Ghamr Formation constitutes the main bulk of the Quaternary deposits of the Nile Delta area and consists mainly of loose sands and gravels varying to clay facies northward. The Bilgas Formation consists mainly of River Nile muddy deposits that overlaying the Mit Ghamr Formation.

The extensive seismic refraction survey on this area conducted by El-Essawy (2001) shows travel time curves, different velocities representing the number of layers and their thickness for some profiles crossing the study area. In the present study, new processing for these data have been performed by using SeisREFA, V. 1.30, Rayamp-pc, 1987, Golden Software Surfer 8 and Coral Draw 9 to get 2D modeling for investigating the nature of the above mentioned rock units, the synthetic seismograms with observed T-X data, the ray path diagrams through these geological units, the velocity

structure models of these layers and the shape of the discontinuity surface by 3D modeling. Moreover, we discuss the final seismic wave velocity structure at the Nile Delta in view of the other geological and geophysical features of a variety of locations in the Nile Valley.

SEISMIC REFRACTION PROFILING

Seven forward-reversed seismic refraction profiles were laid out in a fan–like pattern (Fig. 1). Small energy was generated at the ends of each profile in order to ensure effective penetration of the represented shallow rock units. This seismic energy propagation was efficient along these profiles to obtain detectable signals. The total number of detection points recovered from each profile was seventeen. We have calculated shot-receiver distances using their location and checked them using arrival times which were clearly identified in the T-X curves.

DATA ANALYSIS

In the present study, the shallow refraction seismic survey has been carried out by using a signal enhancement seismograph of the Geometrics Inc. (Model ES-125), two geophones as the recording system. A sledgehammer was used as the source of shooting. This field survey was utilized by a forward-reversed configuration. The data were recorded digitally. The data acquisition parameters were mainly decided on the first arrivals of P-waves. The travel time curves were plotted by the application of the least square fit technique. The travel time curves consist of a number of segments, each representing one layer. The apparent velocity of each layer can be obtained from the slope of corresponding segment. The thicknesses of layers were calculated by the application of some methods such as intercept time, delay time, and critical distance methods (Matsuda, 1975; Telford et al. 1992, and Dobrin and Savit 1988).

A 2-D (two-dimensional) velocity-depth model was obtained for each profile by using velocity and depth parameters. A 2-D ray-tracing model was also obtained for each profile depending on these parameters. The ray-tracing program (Rayamp-pc, 1987) is based on asymptotic ray theory and it also allows ray-tracing and synthetics. The ray method was incorporated to calculate the wave field in the two-dimensionally varying velocity models (Červenỳ et al., 1977; Červenỳ and Pšenčik, 1983; Hirata and Shingo, 1986). Preliminary 2D P-wave velocity model was presented for each profile across the study area. Using this ray tracing method, we obtained synthetic seismograms which were compared with the observed data in order to check the conventionally interpreted models. We also derived a new lookout for the study area by performing forward and backward modeling of a P-wave field in a two dimensionally varying velocity. We used a relatively simple τ-sum inversion method (Diebold and Stoffa, 1981) with the assumption of a model subdivided by plane interfaces.

RESULTS

The final seismic models (Fig. 2) indicate that the first medium is a sedimentary one (Bilgas Formation) with P-wave velocity and thickness ranging between 790 - 840 m/s and 3.1-7.0 m, respectively. The second layer is also a sedimentary medium (Mit Ghamr Formation) with P-wave velocity ranging between 2100 and 2500 m/s.
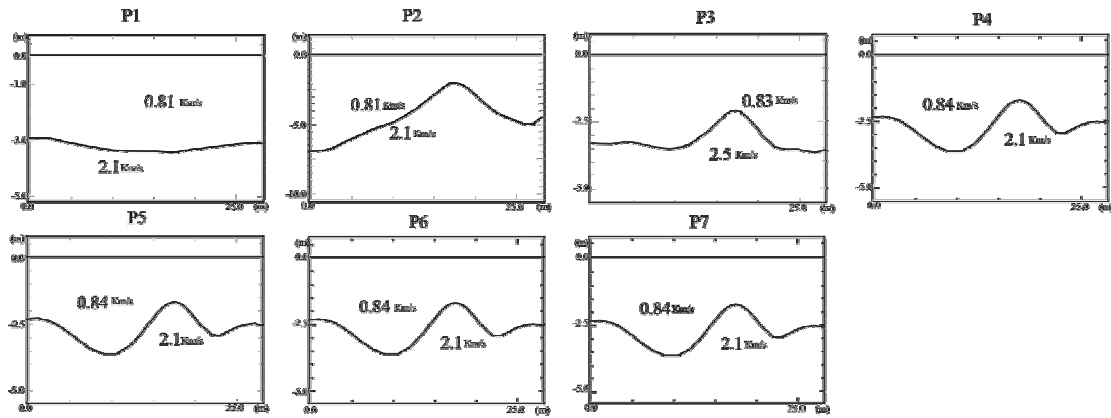
The constructed seismic velocity models were illustrated in Figure 3. The velocity models were estimated by using the method that described in Iwasaki (1988) and Iwasaki et al. (1989, 1990). The models consist of the P-wave velocities increasing with depth.
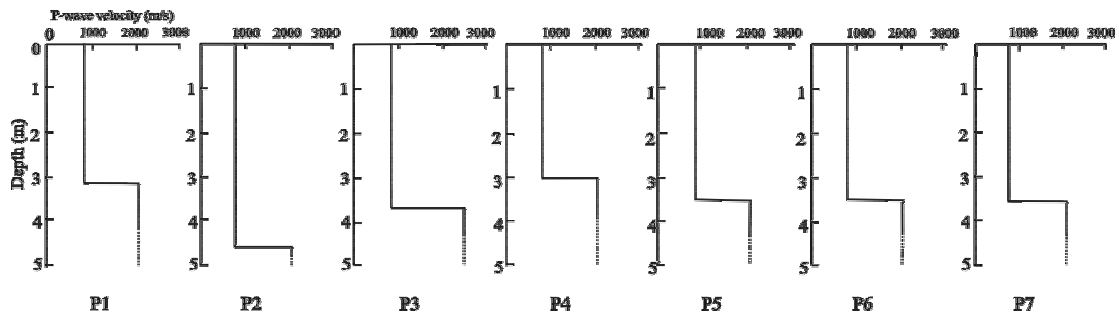
These velocity models were correlated and integrated with the geology of the area to derive composite cross-section of the integrated seismic velocity structure within the Nile Delta (Fig 4).
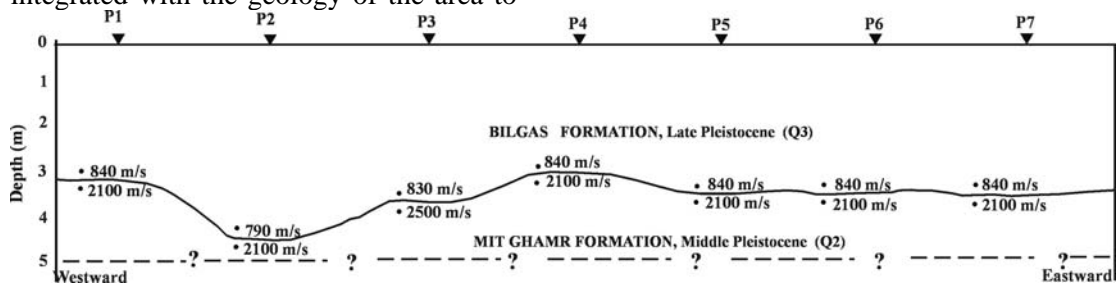
The correlation of these models reveals the existence of two sedimentary horizons. The first horizon has a velocity value of about 840 m/s and an average thickness of 3.5 m. The second one has a velocity about 2100 m/s. The contact Bilgas and Mit Ghamr formations has been represented by a 3D model that illustrates an obvious anomaly towards the south-western direction (Fig. 5). This anomaly has been obtained in certain location where the calculated velocities were abnormally high (3600 and 3000 m/s) for the second layer, departing from the common velocities of 810-2500 m/s

observed at the remaining of interpreted sections. The anomaly points out the presence of buried archeological relics below the ground surface in the investigation site. These relics are either hard blocks of different shapes and sizes that are buried randomly below the ground surface or regular structure of a temple building. This site lies on the western bank of the Damietta branch of the Nile River, at the central part of the Nile Delta. This area comprises the archaeological site of the Isies Pharaonoic Temple (the Thirty Pharaonic Family, 380-343 BC) which

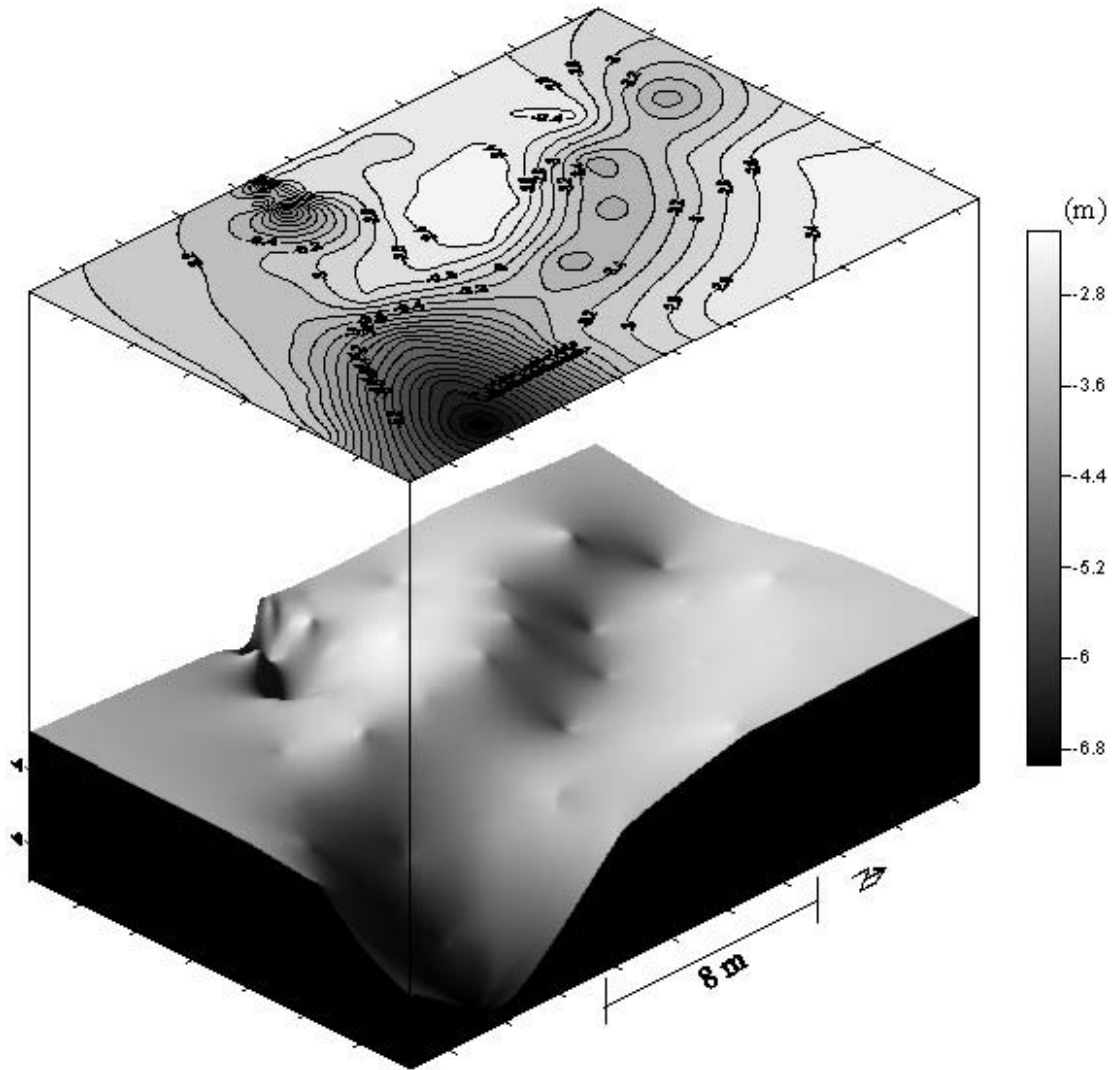was the center of the worship of Isies   (Shaaban   and   Ghazala   ,   1993).

FIG. 5. 3D volume showing the geometry of the discontinuity surface.

A 2D ray-tracing modeling was carried out to investigate the synthetic seismograms and raypaths (Figs. 6-12). In these figures, we have two seismic phases corresponding to the wave energies traveling along the contact between the upper and lower sedimentary media. The raypaths explain the refraction and the reflection features of these seismograms through these models. Our models explain well features of the observed travel time curves. The raypaths in the wave velocity-depth models indicate a laterally homogeneous media.
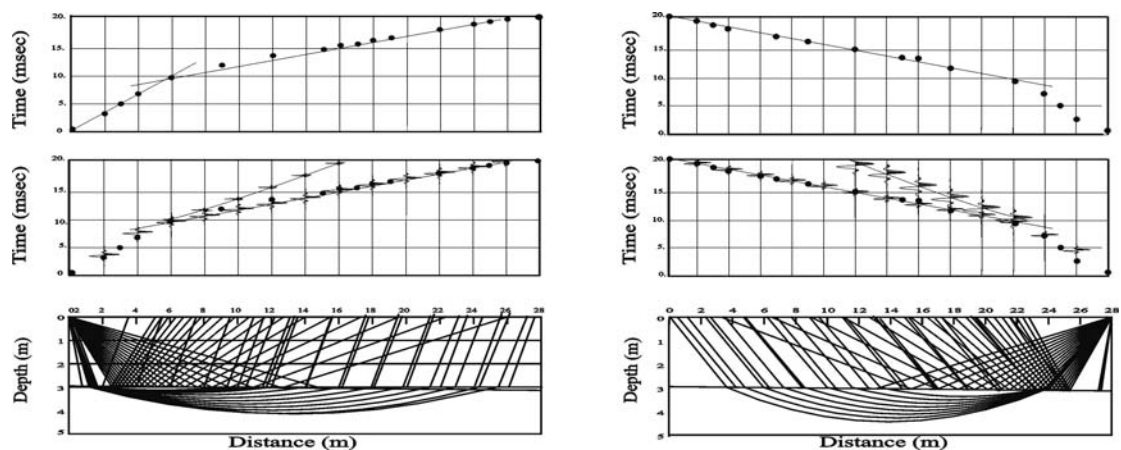
FIG. 6. Observed travel times (top), synthetic seismograms with observed travel times (middle) and wave velocity model and ray paths (bottom) for reversed profile (P1).
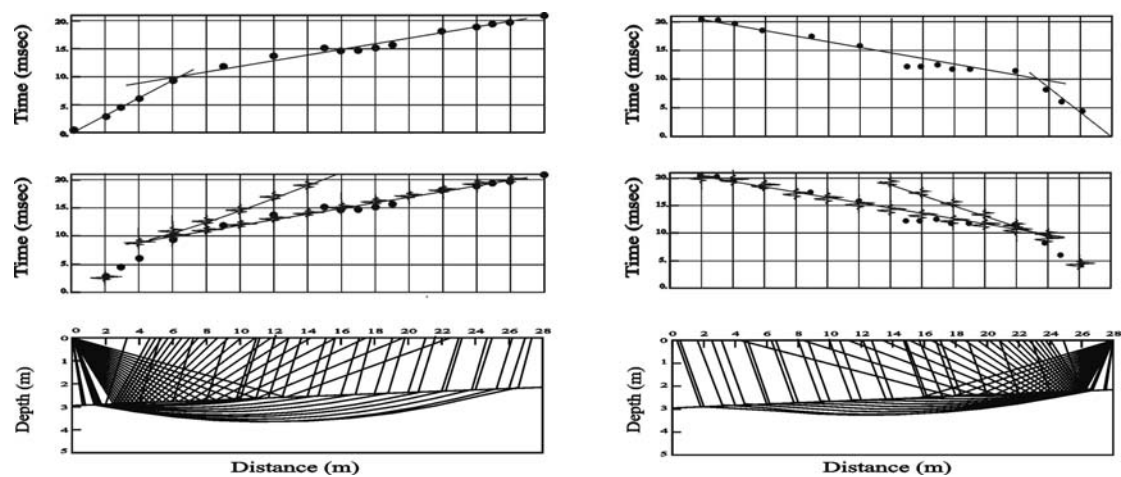

FIG. 7. Observed travel times (top), synthetic seismograms with observed travel times (middle) and wave velocity model and ray paths (bottom) for reversed profile (P2).

FIG. 8. Observed travel times (top), synthetic seismograms with observed travel times (middle) and wave velocity model and ray paths (bottom) for reversed profile (P3).
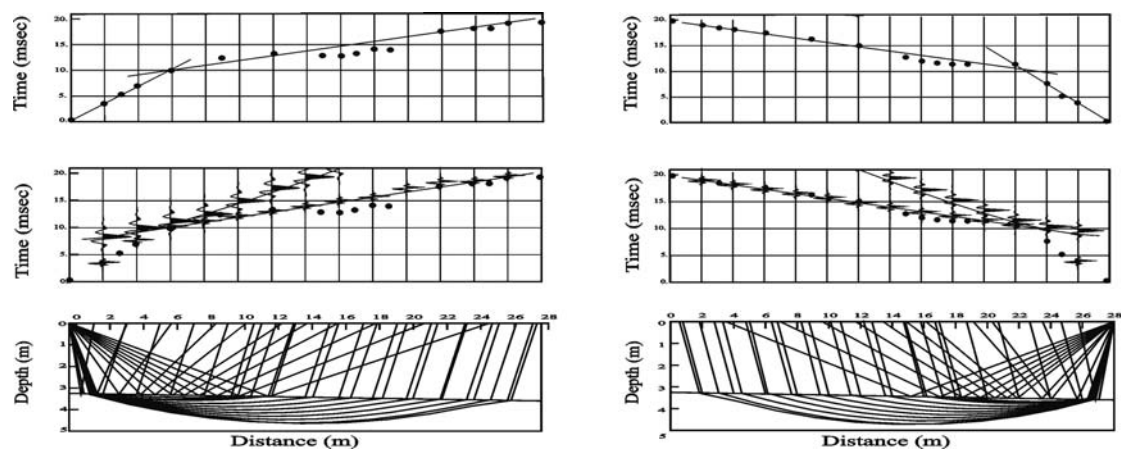
FIG. 9. Observed travel times (top), synthetic seismograms with observed travel times (middle) and wave velocity model and ray paths (bottom) for reversed profile (P4).
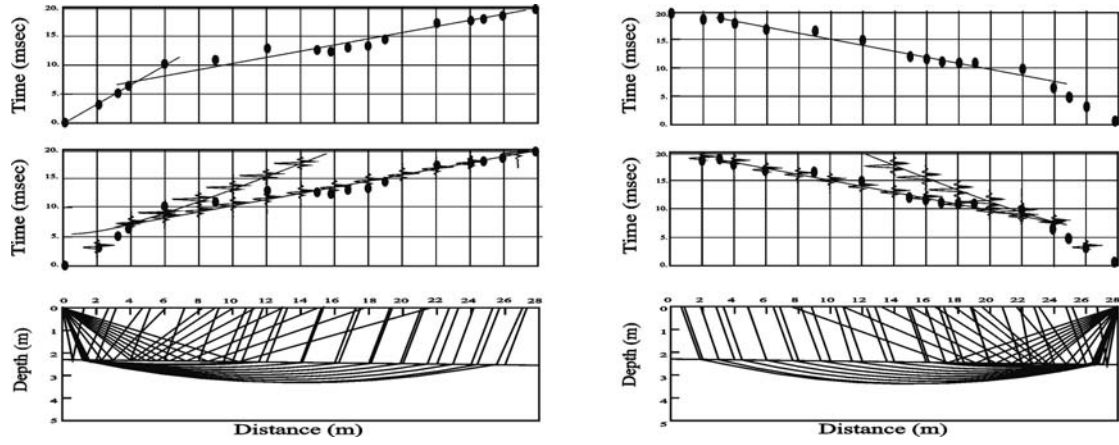

FIG. 10. Observed travel times (top), synthetic seismograms with observed travel times (middle) and wave velocity model and ray paths (bottom) for reversed profile (P5).

FIG. 11. Observed travel times (top), synthetic seismograms with observed travel times (middle) and wave velocity model and ray paths (bottom) for reversed profile (P6).
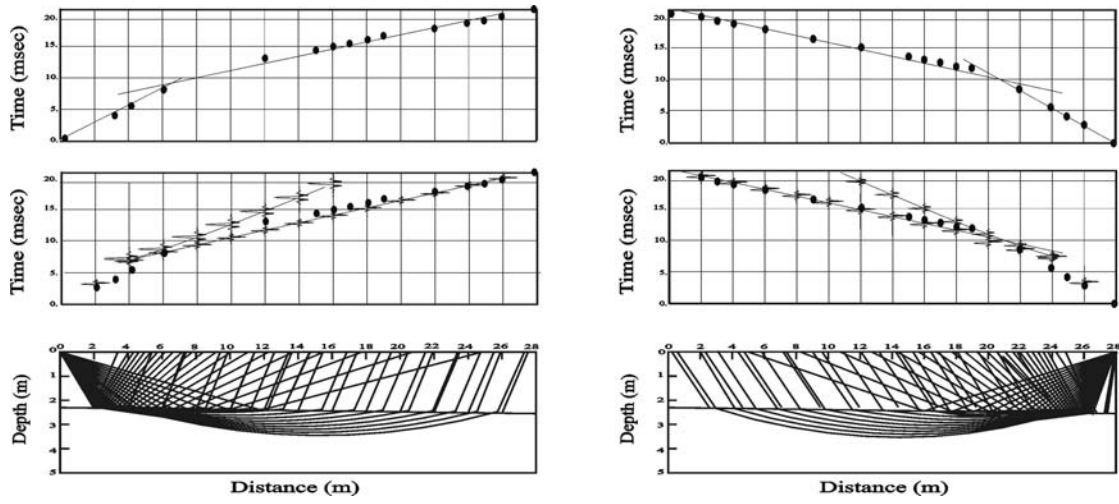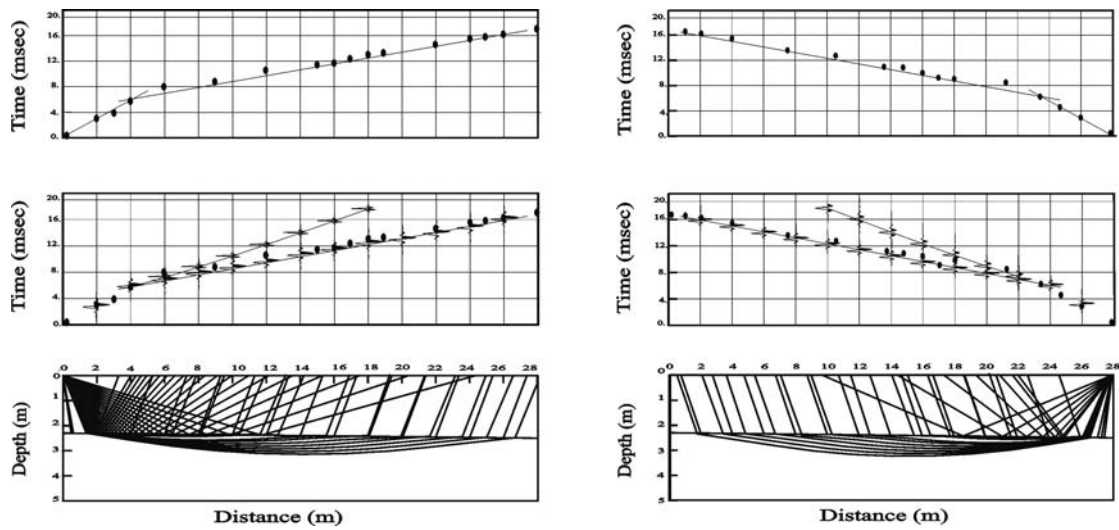
FIG. 12. Observed travel times (top), synthetic seismograms with observed travel times (middle) and wave velocity model and ray paths (bottom) for reversed profile (P7).
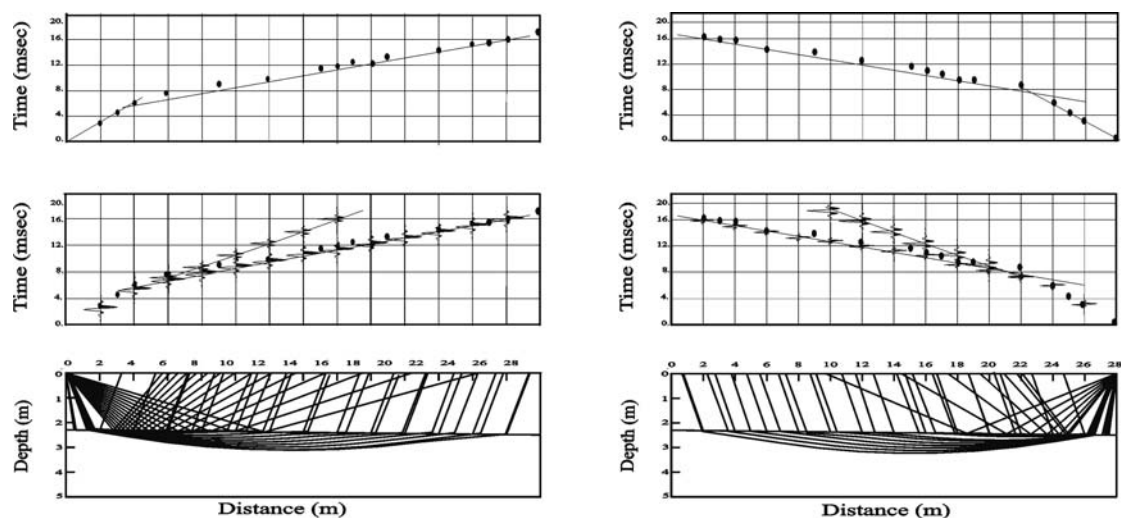
DISCUSSION

An attempt has been done to compare the nature of the shallow sediments (Quaternary deposits) in the study area with those of the same types along the Nile Valley in view of the geological and geophysical data. Said (1962, 1971, and 1981) stated that the Quaternary deposits in the Nile Valley include some rock units, two of them are Prenile (Q2) and Neonile (Q3) (Fig. 13).
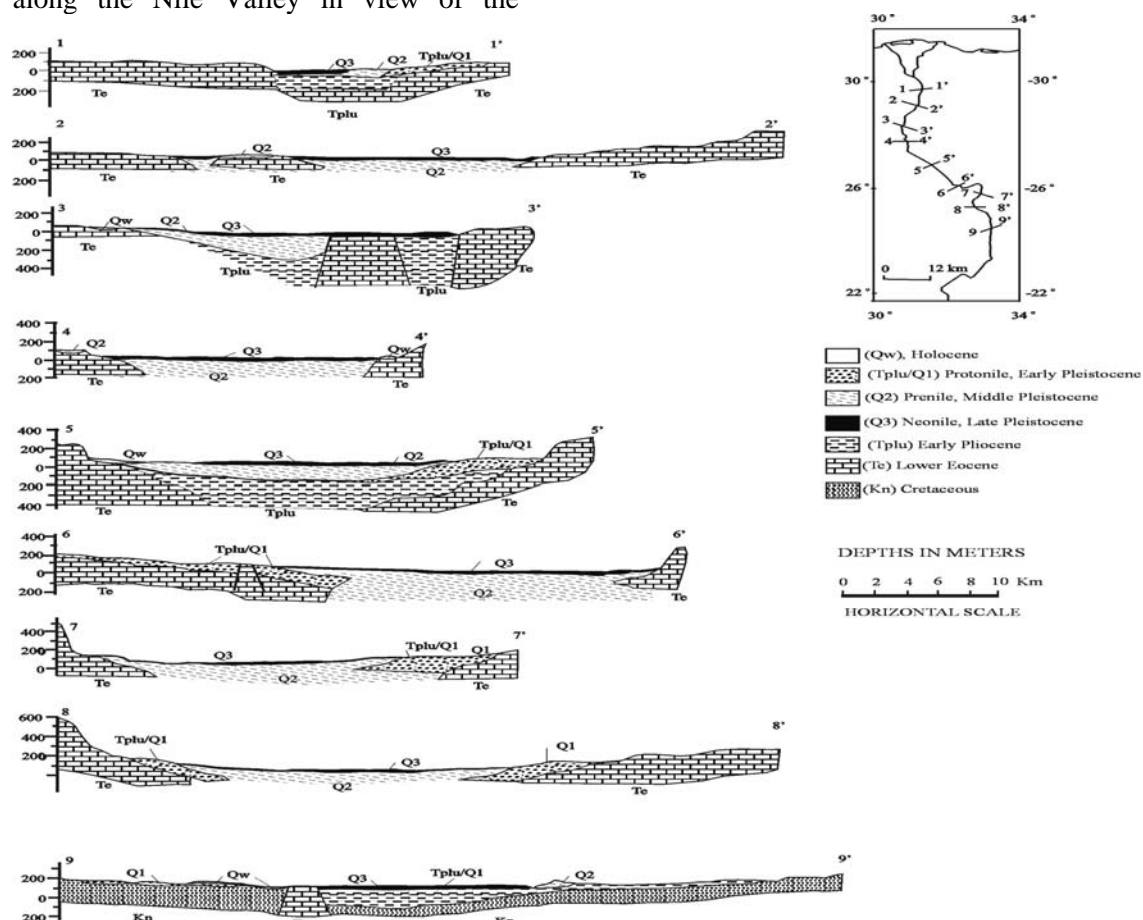

FIG. 13. Modified cross section across the Nile Valley (Said, 1981).

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These two units correspond to Mit Ghamr (Q2) and Bilgas (Q3) formations in the Nile Delta (Rizzini et al., 1978) and Kasr El Basil and Abbassia formations in El-Fayum area across the Nile Valley (Hamdan, 1992). The sediments of the first one (Q2) are coarse, massive and thick and easily recognizable unit made up mainly of sands. Its sources seem to have been outside of Egypt and there is evidence that the Ethiopian highlands are possible sources of sediments. This river flowed for a long period of time covering most of the middle Pleistocene. During this long period, great changes took place in the Nile Valley and in the draining area. The graded sand-gravel unit belonging to this formation lies uncomfortably beneath the well-known agricultural silt layer of the fertile land of Egypt. The deposits of the second one (Q3) are made up of silts and clays indistinguishable in aspect and composition from those were deposited over the land of Egypt by the modern Nile up to the very recent past. They rest the eroded surface of the Prenile sediments with a marked unconformity. These deposits form the top layer of the flood plain of the modern Nile and are also found outside this plain in the form of benches that fringe the valley at elevations ranging from 1 to 12 m above the modern flood plain. These sediments seem to have been deposited by a river which could not have been very much different regimen and sources from the modern river.

The present results of the shallow seismic refraction survey revealed that there are two subsurface units (Fig. 4).

The first one (Q3) has a P-wave velocity ranging from 790 to 840 m/s and its thickness ranging between 3.1 and 7.0 m, while the unit below (Q2) has a P-wave velocity range from 2100-2500 m/s. A shallow seismic survey in El-Fayoum area across the Nile Valley was performed by Abd El-Aal (2002). He concluded that the area is characterized by two subsurface layers. The first one has P-wave velocity ranging from 455 to 887 m/s and thickness from 1.2 to 10 m. The other one has P-wave velocity ranging from 2081 to 2485 m/s. From the two results of El Fayoum and Nile Delta, one can state that there is a slight deviation in the values of velocities and thicknesses of these layers. Our observation is also in agreement with the geological interpretations along the Nile Valley where the nature of the Quaternary sediments is almost the same.

are produced by analyzing the results of 2D synthetic seismograms and raypath diagrams. The geometry of the discontinuity surface between two sedimentary layers and the presence of the elongated narrow and shallow topography of the lower layer are interpreted as an anomaly representing a buried archaeological relic by a 3D diagram. In order to clarify the features of these layers in the study area within the Nile Delta, we have compared the present results with those obtained from the other geological and geophysical studies along the Nile Valley and we have found a good correspondence. An integrated seismic model representing the Quaternary formations (Bilgas and Mit Ghamr) was also carried out. By the combination of all results, it could be concluded that the suggested model essentially consists of homogeneous layers.

CONCLUSIONS

The present study covers the southern part of the Nile Delta area. The acquired data which represented by seven shallow seismic refraction profiles were reprocessed and reinterpreted to give a clear picture about the nature of the shallow subsurface layers representing the study area. The velocity structure models

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