Journal of American Science

Websites:
http://www.jofamericanscience.org
http://www.sciencepub.net

Emails:
editor@sciencepub.net
sciencepub@gmail.com

MARSLAND PRESS
Multidisciplinary Academic Journal Publisher

Determination of crustal thickness from the spectrum of P-wave under Nile Delta Region

Awad I. Hassoup[2], Mohamed Sh. Moustafa[1], Amr M.T. Ali-Eldin[1], Ramadan M. Ali[2]

1 Computer Engineering and Control Systems. Dept., Faculty of Engineering, Mansoura University
2 Seismology dept, National Research Institute of Astronomy and Geophysics

Abstract: The crustal structure beneath the Nile Delta region has been investigated using the spectral analysis of the P-wave amplitude ratios. This ratio of the vertical to the horizontal component is utilized to obtain crustal transfer functions using the Thomson-Haskell matrix formulation for horizontally layered crustal models. Earthquakes data recorded by acceleration network established at the Nile Delta region between azimuth 20° to 350° were selected for analysis based on the following criteria: focal depth in the range 5 To 250 km; body wave magnitude greater than 5.0; and epicentre distances in the range of 5° to 20°. Selection criteria for the final model in the forward modelling process were based on the correlation coefficient between observed and theoretical transfer function according to initial model. This initial model was derived by allowing both layer velocities and thicknesses to vary until a theoretical model was reached which fitted the observed data. Our results revealed that the crust beneath the Delta region is divided into five layers, the sedimentary cover; the upper crust; the medium crust; the lower crust; and the uppermost Mantle. The average thickness of the sedimentary cover was 2.4 km; the average P-wave velocity was 3.4 km/s; the average shear wave velocity was 1.8 km/s; and the average density was 2.1 gm/cm3. For the upper crust, the average thickness was 7.4 km; the average P-wave velocity was 5.0 km/s; the average shear wave velocity was 2.6 km/s; and the average density was 2.3 gm/cm3. For the medium crust, the average thickness was 7.0 km; the average P-wave velocity was 6.0 km/s; the average shear wave velocity was 3.5 km/s; and the average density was 2.5 gm/cm3. For the lower crust, the average thickness was ~16.0 km; the average P-wave velocity was 6.8 km/s; the average shear wave velocity was 4.0 km/s; and the average density was 2.9 gm/cm3. While for the uppermost Mantle, the average P-wave velocity was 8.1 km/s; the average shear wave velocity was 4.6 km/s; and the average density was 3.3 gm/cm3. From the obtained results, we can conclude that the crust beneath our study area is characterized by an average crustal thickness of 33.0 km; an average P-wave velocity of ~ 6.1 km/s; an average shear wave velocity of 3.4 km/s; and an average density of 2.6 gm/cm3, which delineates to a normal felsic crust.
[Salma U, EL-Fetoh NMA, Mehmood Y, Alhadi M, Mohammed D, Eid AO. **An overview of Paediatric inguinal hernias, an old problem with new perspectives.** *J Am Sci* 2024;20(4):29-37]. ISSN 1545-1003 (print); ISSN 2375-7264 (online). http://www.jofamericanscience.org. 07. doi:10.7537/marsjas200424.07.

Key words: crustal structure, Delta region, Egypt, felsic crust,

Introduction

The most basic parts of the earth structure consist of the upper solid crust, solid mantle, liquid core and solid inner core, Stein, S. and M. Wysession (2003). Most earthquakes occur in the crust and the crust-mantle boundary. the velocity of the P- wave (V_P) at The crust is about 5-7 km/s and the just below the Moho, V_P is typically 8.0 km/s. The thickness of the crust varies globally from 8 km under the mid oceanic ridges to 70 km under high mountains. A typical thickness under continents is 30 km. In some continental areas, the crust is divided into two parts, the upper crust and the lower crust where the Conrad discontinuity in between the two parts and the upper crust represents granitic rocks and the lower crust basaltic rocks. Jens Havskov Lars Ottemöller (2010)

The Nile Delta is characterized by major and minor faulting originating by compressive forces along period of tectonic movements (Said 1990).Thickness of the sediments increases toward the Mediterranean Sea, It is located in tectonically unstable area of the northern Africa and Mediterranean. The Nile Delta area is a featureless plane covered by a thick late Tertiary and Quaternary sedimentary succession which dip gently toward the north. The majority of the surface area of the present Nile Delta is occupied by the recent alluvial deposits. The most important tectonic event affecting the area and is forming a thick alluvium layer of the Nile deposits of the Pleistocene age. This region is mainly covered by recent alluvial deposits of variable thickness **Figure 1**. The stratigraphy and structure of Nile Delta are mainly concealed under these surfacial sediments. Its geological and sedimentation history have been studied by many authors such as: Said; (1961), Ghorab and Marzouk; (1965), Narton; (1967), Omara and Ouda; (1972), Rizzini et al., (1976&1978) and Abd El-Halim;(1992); Khaled Omar (2010).

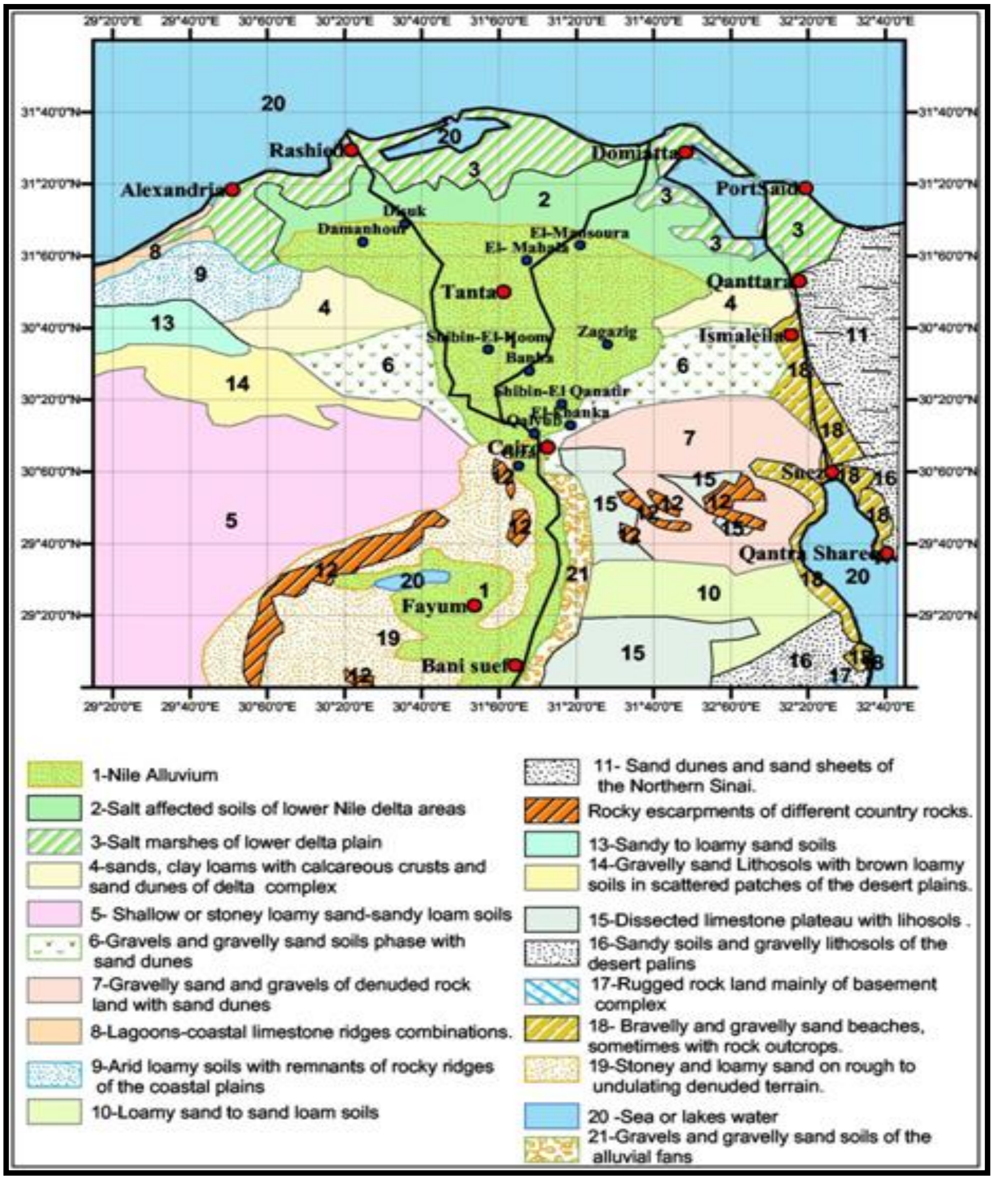

Figure 1: Geological map of the study area, after EGSMA (1981).

Not many seismic studies have been carried out on the Egyptian Nile Delta region to determine the crustal structure beneath this area because the lack of recorded seismic data, since no seismic stations installed to cover seismicity around this area, until year 2008 five acceleration stations installed, Number of stations increased until become 13 stations at the beginning of year 2015. Consequently, the main purpose of this study is to determine the crustal structure beneath the Nile Delta region from spectral analyses of P-waves using Thomson (1950) and Haskell matrix formulation method in which theoretical spectra obtained from horizontally layered earth models have been compared with observed spectra.

Through using the transfer function method it is possible to derive the amplitude and phase of ground motion from the recorded signal or to predict the characteristics of a recorded signal that will result from a given input of ground motion. Abdullah M. S. A1-Amri (1999). The transfer function is a function of the angle of emergence of the P waves at the bottom of the crust and the characteristics of the propagation path. The Transfer function gives different values when a combination of these parameters used. Mainly the values of the transfer function depend on the thickness of the layers system beneath certain seismic station and the emergence of angel. For a given crustal model and angel of incidence the value of the transfer functions versus frequency define the transfer function curves. Hannon. W.J (1964).

Data preparation

The acceleration network in the Nile delta is a 12-station that have been operated since 2008 starting with 5 stations then become 12 stations at the beginning of 2015, **Figure 2** each station involves 3 channel acceleration sensors, and transmits recorded data to the main centre at the National Research Institute of Astronomy and Geophysics (NRIAG).

The earthquakes used in this study selected according to the local bulletin of the Egyptian National Seismic Network (ENSN) at NRIAG, and daily listing of the preliminary determination of epicentres of the acceleration network. Each earthquake source parameters, hypocenter coordinate, origin times, magnitudes, and depth together with the stations coordinates, were used to calculate essential parameters used for analysis , Epicentral distance, azimuth, back azimuth P wave arrival times and angels of incidence of P waves. Epicentral distance is essential parameter in earthquakes selection; azimuth and back azimuth used for components rotation, Jens Havskov Lars Ottemöller (2010); P- wave arrival times used for determination of filtering Hamming window to minimize the later arrivals after the P wave; and angels of incidence of P waves used for tuning the initial model parameters during correlation between observed curves and theoretical.

Before stating data processing signals should be prepared, Data preparation mainly done in two steps the first step started with earthquakes selection, certain selection criteria used for selecting earthquakes, only 87 earthquakes Out of 300 event were clearly recorded at the network during the period 2013 to 2015 and satisfy selection criteria, 24 events recorded at Adfina station; 6 events recorded at Alexandria station; 27 events recorded at Anshas station; 13 events recorded at Banha station; 11 events recorded at Damanhur station; 6 events recorded at Damietta station; 13 events recorded at Mansoura station; 9 events recorded at Tanta station; 16 events recorded at Zagazig station; 22 events recorded at Helwan station; and 16 events recorded at Ismailia station. Considering repeated earthquakes in all stations the total number of the earthquakes become used for this study is 163 earthquakes, selection criteria were critical to make sure that the first arrival of the selected earthquakes is the P wave. Selection criteria used for selection process was as the following: azimuth between 20°to 35° focal depth in the range 5 To 250 km; body wave magnitude greater than 5.0; and epicentre distances in the range of 5° to 20°. **Figure 3** show location of each recorded at the Nile Delta region, due to the lack of recorded data at Port Said station, process of crustal estimate will not used in this station. The second step is to convert the selected earthquakes to ASCII format to be used for signal analysis. ASCII format is standard format and compatible with most signal processing software. \

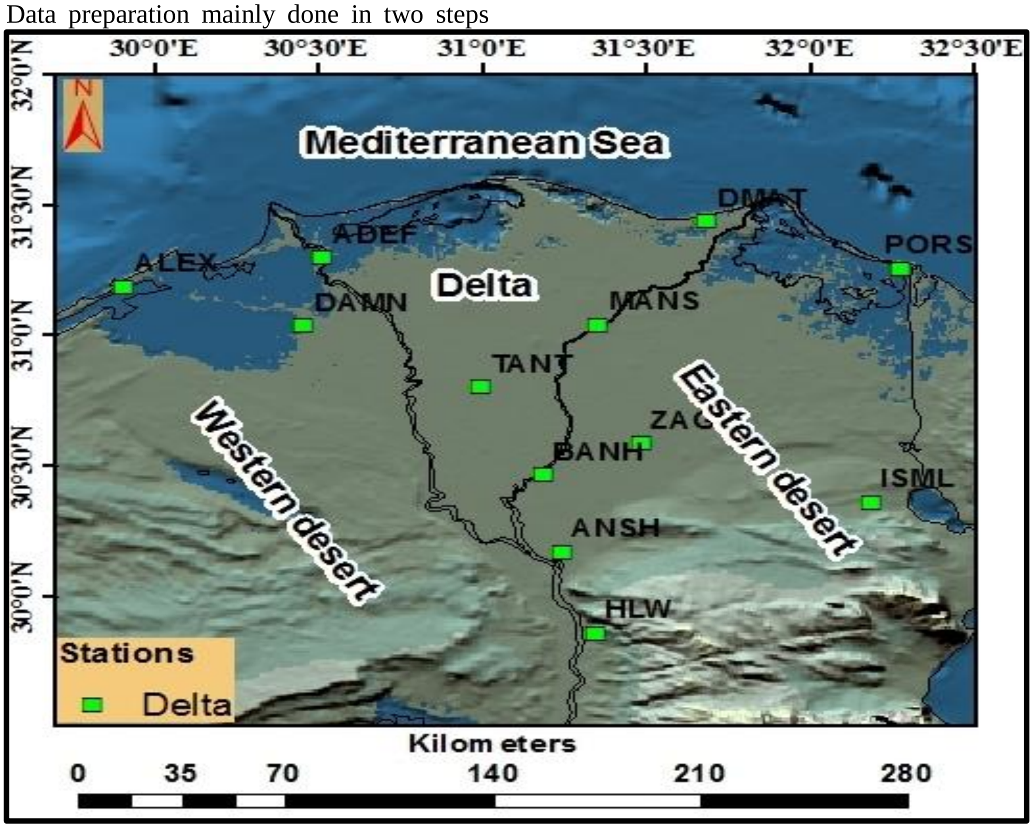

Figure 2: Acceleration network station at Nile Delta region.

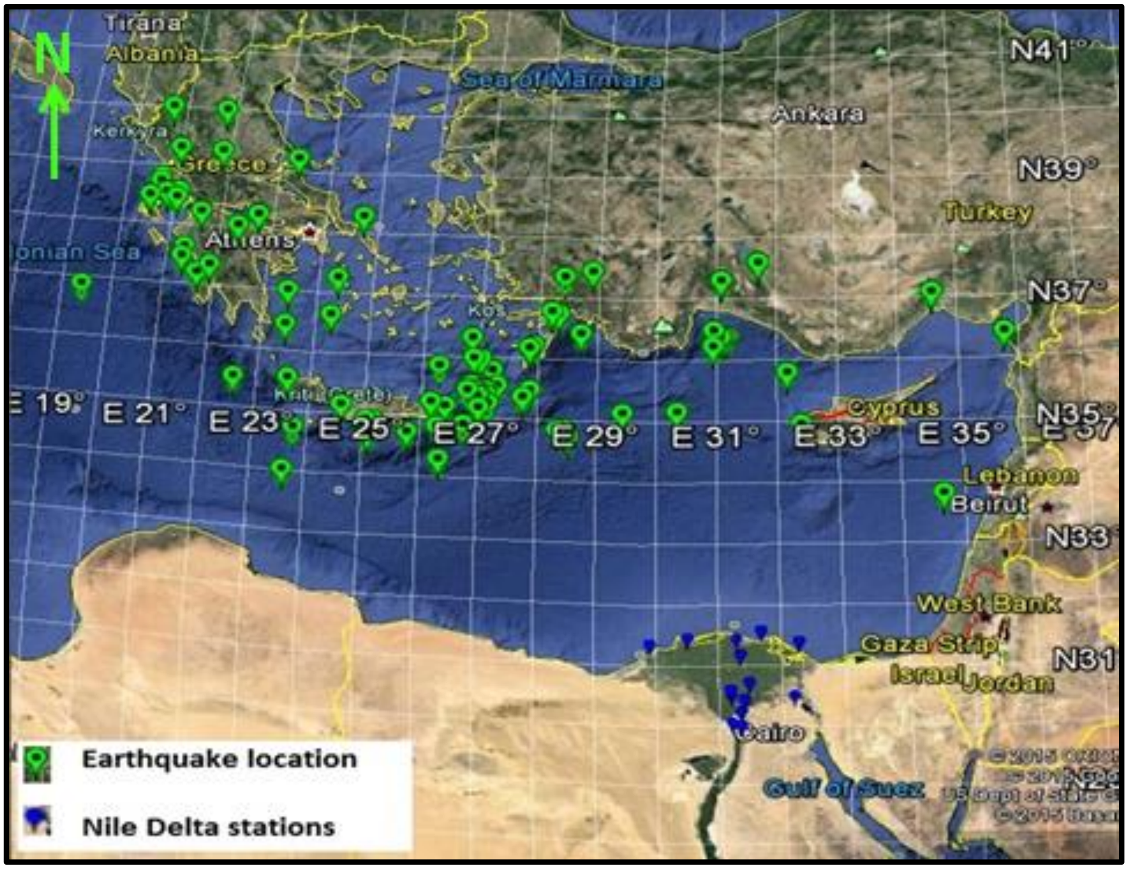

Figure 3 a map show Epicentral of earthquakes used in calculations after applying selection criteria

Methodology and data analysis

The ration between the spectrum of the vertical component and the spectrum of the horizontal component represents the tangent of the angle of emergence; it depends on the angle of incidence of the waves and the crust layers system beneath certain station. The selected data were processed in two main steps to obtain the crustal structure, the first step is obtaining the observed curves for all selected at certain station and repeat this step for all stations. The second step is comparing the observed curves obtained from step one and theoretical curves from initial model for all selected earthquakes at certain station, until we get best correlation between the two curves then the resulting model is the best model for all earthquakes at this station, this process repeated for the remaining earthquakes at all stations. the average crustal structure beneath each station is obtained by calculating the average thickness; P wave; S wave; and density for all earthquakes at each station. Then the total average crustal structure for whole Nile Delta is obtained by calculating the average thickness; P wave; S wave; and density calculated at each stations.

Data in step one were analysed using the **PITSA** program of the **IASPEI** package (**1992**). Scherbaum.F and Johnson.J. (1992). the three seismogram components for each earthquake treated identically; in order to illuminate the effect of signal components outside the pass band of the system the three components were filtered with a band pass filter whose corner frequency matched with instrument response; Different kinds of seismic waves have their practical motion or amplitude in different directions Particle motion or polarization of the waves is best looked at in a coordinate system that points from the earthquake to the seismic station so the two horizontal components (N-S, E-W) rotated into the radial (R) and transverse (T) components. The radial direction is along the line from the station to the event and the transverse direction is in the horizontal plane at a right angle to the radial direction; then Fast Fourier Transform hamming window applied to the radial and vertical components to minimize the later arrivals after the P-wave, resulting new Radial component after filtering; then correlate between the vertical component and the radial component after hamming, this process results a transfer function curve for the earthquake; in order to smooth sharp edges in the resulting transfer curves a low pass filter is applied. in step one the resulting curves are so called the observed curves and compared with theoretical curves from the initial model

The second step is concerned in correlating between the observed curves from step one with theoretical curves assumed in the initial model, the main idea is to change one parameter in the initial model and keep the remaining parameters constant then get the correlation between the two curves until we get the best correlation between the two curves. First both the thickness of the layers and angle of emergence are kept constant and varying the velocities. Next the velocities and angle of emergence were kept constant, but the thicknesses varied: finally, thicknesses and velocities were kept constant and the angle of emergence varied. Pervious calculations continue to reach best correlation coefficient between the theoretical and observed spectra for each earthquake output represent a near optimum crustal thickness beneath station for each event. Crustal structure beneath certain station is obtained by calculating mean value for calculated models for all events at these stations. Previous steps repeated for all stations. then the average crustal structure beneath the entire Nile Delta region is obtained by calculating the average value for calculated models at all stations.

Results

The initial model used in this study assumes that the crusts consist of four layers with a total thickness 27 km a. Ghorab and Marzouk; (1965). The parameters on initial model are tested first by allowing one parameter to vary and the remaining parameters changes, in **figure 4** when by increasing the emergence of angel from 30^0 to 35^0 and keeping the other two parameters constant P wave velocity at 6.2 km, and an angle of emergence at 30^0, the frequency peak stays at frequency 1.95 HZ. While decreasing the emergence of angel from 30^0 to 20^0 results in two more peaks at frequency 1.17 HZ and 2.535 HZ. On the other hand, in **figure 5** increasing the thickness from 32 km to 41 km and keeping the other parameters are constant; the frequency peak stays at frequency 1.95 HZ, while decreasing the thickness from 32 km to 26 km move the frequency peak from 1.92 HZ to 2.145 HZ. Generally, by comparing the peak positions of the observed and theoretical spectral carvers, we can resolve the crustal thickness and velocity of the observed values. The sensitivity of the transfer functions to the changes of the model parameters indicates that the peak at the lowest frequency is directly related to the total thickness of the crust; thicker crust shifts the position to lower frequencies.

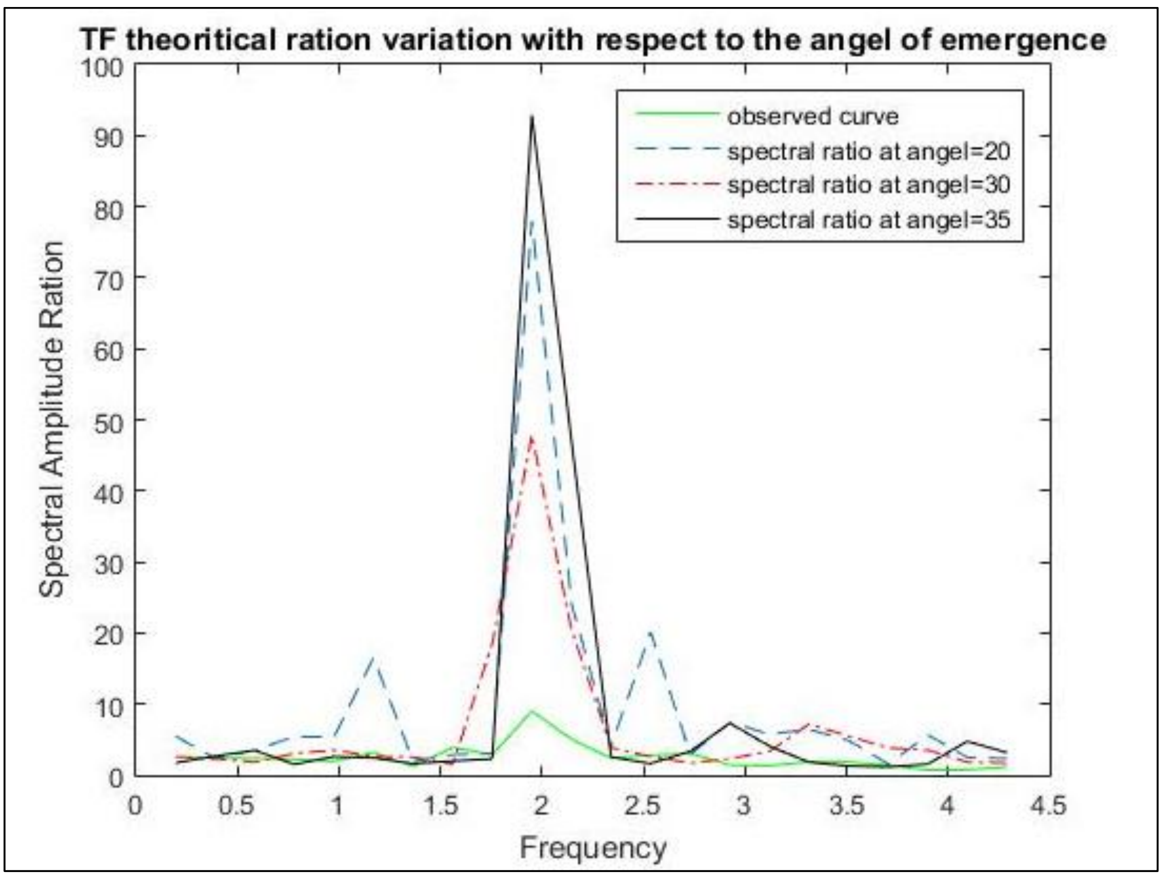

Figure 4: The theoretical transfer function ratio variation with respect to the angel of emergence.

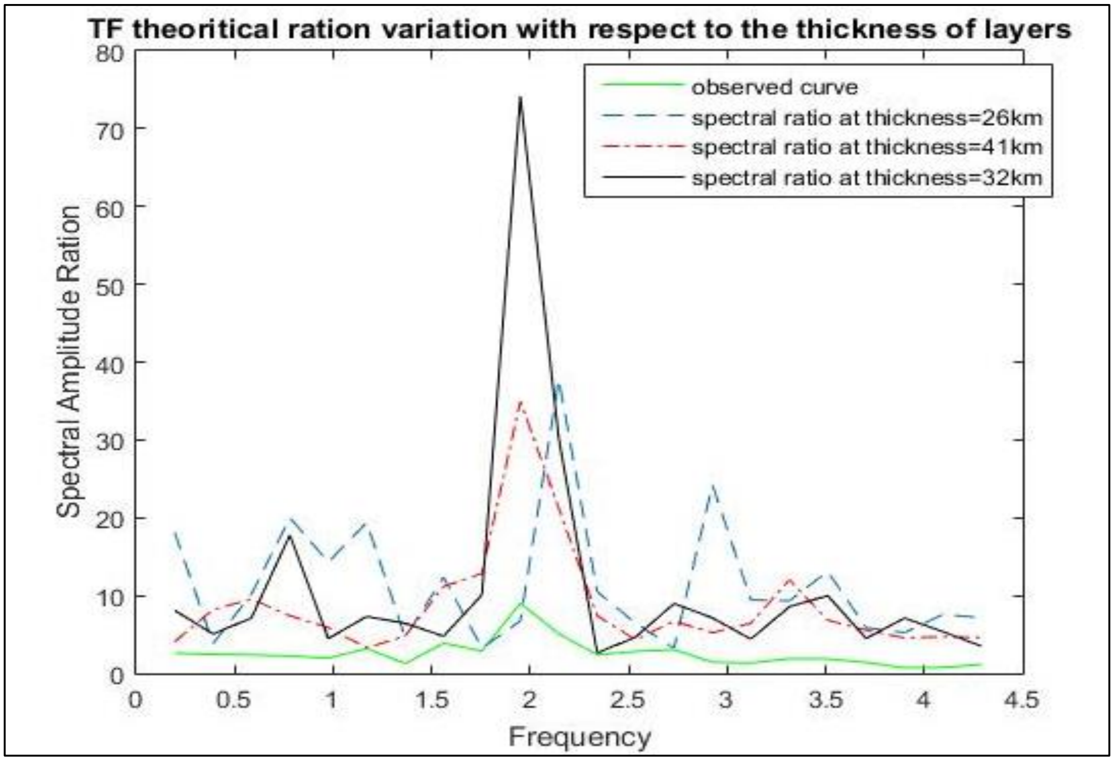

Figure 5: The theoretical transfer function ratio variation with respect to the thickness of layers

87 earthquakes recorded by the Nile Delta acceleration network In this study to estimate the crustal structure beneath the Nile Delta region our results for each station can be discussed as the following:

Alexandria station (RALX): This station is located in western north of the Nile Delta area and characterized by an accurate crustal thickness of ~ 30 km, the average P- wave velocity and S- wave velocity of the crustal beneath this station was 6.0 and 3.5 km/s respectively with an average density of 2.6 gm/cm3. **Table 2** describes details for crustal structure beneath this station.

Adfina station (RADF): This station is located in western north of the Nile Delta area and characterized by an accurate crustal thickness of ~ 32 km, the average P- wave velocity and S- wave velocity of the crustal beneath this station was 5.7 and 3.3 km/s respectively with an average density of 2.6 gm/cm3. **Table 3** describes details for crustal structure beneath this station.

Damanhur station (RDAM): This station is located in Middle West of the Nile Delta area and characterized by an accurate crustal thickness of ~ 32 km, the average P- wave velocity and S- wave velocity of the crustal beneath this station was 5.9 and 3.4 km/s respectively with an average density of 2.6 gm/cm3. **Table 4** describes details for crustal structure beneath this station.

Damietta station (RDOM): This station is located in eastern north of the Nile Delta area and characterized by an accurate crustal thickness of ~ 34 km, the average P- wave velocity and S- wave velocity of the crustal beneath this station was 5.7 and 2.5 km/s respectively with an average density of 2.6 gm/cm3**. Table 5** describes details for crustal structure beneath this station.

Mansoura station (RMAN): This station is located in Middle East of the Nile Delta area and characterized by an accurate crustal thickness of ~ 30 km, the average P-wave velocity and S- wave velocity of the crustal beneath this station was 5.8 and 3.4 km/s respectively with an average density of 2.6 gm/cm3. **Table 6** describes details for crustal structure beneath this station.

Tanta station (RTAN): This station is located in central of the Nile Delta area and characterized by an accurate crustal thickness of ~ 29 km, the average P-wave velocity and S- wave velocity of the crustal beneath this station was 5.8 and 3.4 km/s respectively with an average density of 2.6 gm/cm3**. Table 7** describes details for crustal structure beneath this station.

Zagazig station (RZAG): This station is located in Middle East of the Nile Delta area and characterized by an accurate crustal thickness of ~ 34 km, the average P-wave velocity and S- wave velocity of the crustal beneath this station was 5.9 and 3.5 km/s respectively with an average density of 2.6 gm/cm3. **Table 8** describes details for crustal structure beneath this station.

Ismailia station (TISM): This station is located in eastern south of the Nile Delta area and characterized by an accurate crustal thickness of ~ 34 km, the average P- wave velocity and S- wave velocity of the crustal beneath this station was 5.9 and 3.4 km/s respectively with an average density of 2.6 gm/cm3**.** **Table 9** describe details for crustal structure beneath this station.

Banha station (RBAN): This station is located in central of the Nile Delta area and characterized by an accurate crustal thickness of ~ 29 km, the average P- wave velocity and S- wave velocity of the crustal beneath this station was 6.6 and 2.7 km/s respectively with an average density of 2.6 gm/cm3. **Table 10** describe details for crustal structure beneath this station.

Helwan station (THLW): This station is located in south of the Nile Delta area and characterized by an accurate crustal thickness of ~ 34 km, the average P- wave velocity and S- wave velocity of the crustal beneath this station was 6.0 and 3.5 km/s respectively with an average density of 2.6 gm/cm3. **Table 11** describe details for crustal structure beneath this station.

Anshas station (RANS): This station is located in south of the Nile Delta area and characterized by an accurate crustal thickness of ~ 36 km, the average P- wave velocity and S- wave velocity of the crustal beneath this station was 6.0 and 3.5 km/s respectively with an average density of 2.6 gm/cm3. **Table 12** describes details for crustal structure beneath this station.

Table 1: crustal structure details beneath Alexandria station

	Thickness	VP	VS	Density
sedimentary cover	3.52	3.7	2.2	2.1
Upper crust	5.5	5.0	2.9	2.3
Medium crust	6.5	6.5	3.8	2.5
Lower crust	14.03	6.9	3.9	2.9
Upper mantel	∞	8.1	4.7	3.3

Table 2: crustal structure details beneath Adfina station

	Thickness	VP	VS	Density
sedimentary cover	**1.67**	**3.3**	**1.9**	**2.1**
Upper crust	**6.4**	**4.9**	**2.8**	**2.3**
Medium crust	**7.3**	**5.7**	**3.22**	**2.5**
Lower crust	**16.2**	**6.7**	**3.82**	**2.9**
Upper mantel	∞	**8.1**	**4.7**	**3.3**

Table 3: crustal structure details beneath Damanhur station

	Thickness	VP	VS	Density
sedimentary cover	1.6	2.6	1.5	2.1
Upper crust	5.0	5.1	2.9	2.3
Medium crust	7.5	5.9	3.4	2.5
Lower crust	17.5	6.9	3.9	2.9
Upper mantel	∞	8.1	4.7	3.3

Table 4: crustal structure details beneath Damietta station

	Thickness	VP	VS	Density
sedimentary cover	1.5	3.2	1.8	2.1
Upper crust	8.50	4.8	2.7	2.3
Medium crust	7.5	5.8	3.3	2.5
Lower crust	16.0	6.8	3.9	2.9
Upper mantel	∞	8.1	4.7	3.3

Table 5: crustal structure details beneath Damietta station

	Thickness	VP	VS	Density
sedimentary cover	1.5	3.2	1.8	2.1
Upper crust	8.50	4.8	2.7	2.3
Medium crust	7.5	5.8	3.3	2.5
Lower crust	16.0	6.8	3.9	2.9
Upper mantel	∞	8.1	4.7	3.3

Table 6: crustal structure details beneath Mansoura station

Mansoura	Thickness	VP	VS	Density
sedimentary cover	3.46	3.3	2.2	2.1
Upper crust	6.9	5.05	2.9	2.3
Medium crust	5.5	5.95	3.5	2.5
Lower crust	14.38	6.7	3.9	2.9
Upper mantel	∞	8.1	4.7	3.3

Table 7: crustal structure details beneath Tanta station

	Thickness	VP	VS	Density
sedimentary cover	2.22	3.5	2.1	2.1
Upper crust	7.0	5.0	3.0	2.3
Medium crust	6.44	6.0	3.6	2.5
Lower crust	12.89	6.5	3.8	2.9
Upper mantel	∞	8.1	4.7	3.3

Table 8: crustal structure details beneath Zagazig station

	Thickness	VP	VS	Density
sedimentary cover	3.46	4.4	2.2	2.1
Upper crust	6.9	4.9	2.9	2.3
Medium crust	5.6	5.3	3.5	2.5
Lower crust	18.0	6.8	3.9	2.9
Upper mantel	∞	8.1	4.7	3.3

Table 9: crustal structure details beneath Ismailia station

Ismailia	Thickness	VP	VS	Density
sedimentary cover	2.3	3.4	1.9	2.1
Upper crust	7.0	5.0	2.8	2.3
Medium crust	7.6	6.2	3.5	2.5
Lower crust	17.5	6.8	3.9	2.9
Upper mantel	∞	8.1	4.7	3.3

Table 10: crustal structure details beneath Helwan station

	Thickness	VP	VS	Density
sedimentary cover	3.52	3.8	2.2	2.1
Upper crust	6.0	5.0	2.9	2.3
Medium crust	7.0	6.0	3.5	2.5
Lower crust	17.0	6.7	3.9	2.9
Upper mantel	∞	8.1	4.7	3.3

Table 11: crustal structure details beneath Anshas station

	Thickness	VP	VS	Density
sedimentary cover	1.4	2.9	1.9	2.1
Upper crust	7.0	5.0	2.9	2.3
Medium crust	10.0	5.7	3.3	2.5
Lower crust	17.5	6.8	3.9	2.9
Upper mantel	∞	8.1	4.7	3.3

Discussions and conclusions

87 earthquakes recorded at the Nile Delta acceleration network were selected for spectral analysis. Spectral analysis calculations were based on comparing the observed spectral ratios with those computed from theoretical P-wave motion obtained using the Thomson-Haskell matrix formulation for horizontally layered crustal models. The effects of different model parameters on the theoretical spectra were tested by comparing the peak positions of the observed and theoretical spectral curves.

The derived model suggests that the average crust beneath the Nile Delta Region consist of five distinct layers, the sedimentary cover; the upper crust; the medium crust; the lower crust; and the uppermost Mantle. The average thickness of the sedimentary cover was 2.4 km; the average P-wave velocity was 3.4 km/s; the average shear wave velocity was 1.8 km/s; and the average density was 2.1 gm/cm3. For the upper crust, the average thickness was 7.4 km; the average P-wave velocity was 5.0 km/s; the average shear wave velocity was 2.6 km/s; and the average density was 2.3 gm/cm3. For the medium crust, the average thickness was 7.0 km; the average P-wave velocity was 6.0 km/s; the average shear wave velocity was 3.5 km/s; and the average density was 2.5 gm/cm3. For the lower crust, the average thickness was ~16.0 km; the average P-wave velocity was 6.8 km/s; the average shear wave velocity was 4.0 km/s; and the average density was 2.9 gm/cm3. While for the uppermost Mantle, the average P-wave velocity was 8.1 km/s; the average shear wave velocity was 4.6 km/s; and the average density was 3.3 gm/cm3. **Table 13** describes detailed average crustal structure beneath the Nile Delta region.

The average P- wave and S-wave velocity of this study area will be used for locating local and regional earthquakes occur in and around the Nile delta area. Therefore seismic Hazard assessment for the Nile Delta can be computed accurately.

Table 13: the average crustal structure beneath the Nile Delta region

	Average Thickness	Average VP	Average VS	Average Density
sedimentary cover	2.4	3.4	1.8	2.1
Upper crust	7.4	5.0	2.6	2.3
Medium crust	7.0	6.0	3.5	2.5
Lower crust	16.0	6.8	4.0	2.9
Upper mantel	∞	8.1	4.7	3.3

Acknowledgments

I would like to express my thanks and gratitude to Dr Ali. A Gharib, and Assoc. Dr Ahmad Hosni, Dr Khalid Omar. for their continuous support during this study. And all gratitude to my best college engineer Mona Mohamed for her patient with me during the processing of the data. Also. I would like to express my thanks and gratitude to the laboratory of general seismology staff, seismology department, NRIAG this work would not have been possible without providing me with data used in this study.

References

[1]. Abd El-Halim, M. (1992): Miocene sequence stratigraphic in the Nile Delta, Eleventh Petroleum Explore. And product. Conf. Vol., 2pp. 470-484.

[2]. Abdullah M. S. A1-Amri (1999). The crustal and upper-mantle structure of the interior Arabian platform, Geophys. J. Int 136,421–430.

[3]. Ghorab, M. A. and Marzouk, M. A. (1965): Oligocene rock stratigraphy of the Eastern Desert and Gulf of Suez regions, G.PC.

[4]. Hannon. W.J. 1964. An application of the Haskell- Thomson matrix method to the synthesis of the surface motion due to dilatational waves, Bull. Sei.vn. soc. Am. 54, 2067-2083.

[5]. Havskov, J., and Alguacil, G. (2004). Instrumentation in earthquake seismology. Modern approaches in Geophysics, Vol. 22, Springer, 358 pp.

[6]. Jens Havskov Lars Ottemöller.2010. Routine Data Processing in Earthquake Seismology, Springer.

[7]. Khaled Omar (2010): Characteristics of the Nile Delta basin structure and its implication on seismic effects, Egypt. Ph.D. thesis, Sohag Univ., Sohag, Egypt.

[8]. Luis M. Fernandez, S.J. 1965. The determination of crustal thickness from the spectrum of P wave. Saint Louis University. St. Louis. Missouri.

[9]. Narton, P. (1967): Rock stratigraphic nomenclature of the Western Desert, Pan American UAR Oil Company.

[10]. Omara S. and Ouda K. (1972): Lithostratigraphic revision of the Oligocene-Miocene succession in the northern Western Desert, Cairo.

[11]. Rizzini, A., Vessani, F., Cococetta, V. and Milad, G. (1976): Stratigraphy and sedimentation of Neogene-Quaternary section in the Nile Delta area. 5th. Explore. Seminar, EGPC, Cairo, Egypt. 42 pp.

[12]. Rizzini, A., Vezzani, F., cococetta, v. and Milad, G, (1978): stratigraphy and sedimentation of Neogene- Quaternary section in the Nile Delta area exploration seminar. I. E. C., Cairo.

[13]. Said, R. (1961): Tectonic framework of Egypt and its influence on distribution of Foraminifera, AAPG.Bull.,45.

[14]. Said, R. (1990): The geological evaluation of the River Nile. Springer-Verlag Pub., New York, Heidelberg, Berline, P. 151.

[15]. Scherbaum.F, and Johnson, J. (1992). Programmable Interactive Toolbox for Seismological Analysis (PITSA). IASPEI Software Library Volume 5.

[16]. Stein, S. and M. Wysession .2003. Introduction to seismology, earthquakes and earth structure. Blackwell Publishing, Oxford, 498 pp.

4/22/2024