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# CRUSTAL VELOCITY STRUCTURE BENEATH ASWAN AREA BY JOINT HYPOCENTER DETERMINATION (JHD) METHOD

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## تراكيب السرعة للقشرة الأرضية تحت منطقة أسوان بطريقه تحديد موقع الزلازل المترابط

**الخلاصة:** تناول البحث تراكيب سرعات القشرة الأ رضيه في منطقة أسوان بطريقه تحديد موقع الزلازل المترابط باستخدام حركة الموجات الابتدائية السيزمية لزلازل أسوان، وقد تم حساب السرعات لأربع طبقات أفقية مباشرة بطريقة التربيع الأدنى وذلك لاختيار أنسب نموذج بين الافتراضات المحسوبة والرصدات الحقيقية.

وتوصلنا إلى النتائج المقبولة لنموذج تراكيب سرعة الموجات الابتدائية فى كل طبقة وهى ٤,٢ ، ٦,٤، ٦,٨، ٧,٣ كيلومتر/ثانية وسمك كل طبقه ١، ٤ ، ١٠,٥ ، ١٦,٥ كيلومتراً تباعاً. وأن قيم تصحيح زمن رحلة الموجات الابتدائية للمحطات AHD, GAL, KSR, GRW, KUR, MAN هى قيم سالبة –٠,٠٤٨، –٠,٠٢٨ ، –٠,٠٢٨ ، –٠,١٨٧، –٠,٠١٦، –٠,٠١٧ أما المحطات الأخرى SKD, NMR, GMR, WKL, WAL, KRL, NAL فلها قيم موجبة ٠,٠٥٧ ، ٠,٠٢٥، ٠,٠٦٦ ، ٠,٠٤٠ ، ٠,٠٨٢ ، ٠,٠٤٩ و ٠,٠٠٥ على الترتيب.

**ABSTRACT**: *The crustal velocity structure in Aswan area, southern Egypt has been investigated by means of the joint hypocenter determination method (JHD), using initial P-wave motion from Aswan seismological data. The velocities of 4 horizontal layers model including a half space were directly determined by the least square method in order to select the best fitting model between calculated assumption and the real observations.*
*However, eventually the reasonable result due to this structure model come out, the velocity of P-wave in each layer is 4.2, 6.2, 6.8, and 7.3 km/s and its thicknesses are 1, 4, 10.5 and 16.5 km respectively. The stations AHD, GAL, KSR, GRW, KUR, MAN have minus signs in station P-wave travel time corrections and their values: - 0.017, -0.016, -0.187, -0.028, -0.028, -0.048 and other stations SKD, NMR, GMR, WKL, WAL, KRL, NAL have positive sign and their values: 0.005, 0.049, 0.082, 0.040, 0.066, 0.025 and 0.057 respectively.*

# INTRODUCTION:

Determination of velocity structure of the crust remains one of the important roles and major objective of seismology. Accurate velocity information is still necessary for a variety of purposes, including the location of hypocenters. Many methods have been introduced to obtain an accurate velocity in the source region, an example of those from Crosson (1976) the velocity structure model is calculated in the whole area where the ray paths penetrate. Similarly JHD is one of the powerful method to determine hypocenter location but it is more clearly understandable.

The joint hypocenter determination method in general, used merely initial P-wave arrival times and it has been known and developed since 1967 by Douglas ,and Freedman and modified by Hurukawa and Imoto (1987). The main idea for this method to earthquake implication is that it should reveal any regional bias in travel times from the same region and then from it is bias characteristic, the nature of velocity in that area could be more understood.

Aswan seismic network consists of 13 seismic stations distributed around the northern part of the Aswan High dam lake, (Kebeasy et al., 1982, 1987) as shown in Table (1).

## JOINT HYPOCENTER DETERMINATION (JHD) METHOD

Generally the calculation of the travel times by JHD for local earthquakes is based on an assumed crustal structure consisting of flat lying constant velocity. It is noticed that the ray path of first arriving P-wave from a hypocenter can follow one of two possible types of paths, either refract or direct. Furthermore, different ray paths for any given distance and depth are possible. Thus, all possible travel path would be exhaustively checked to obtain the minimum path for an arbitrary velocity thickness.

Consequently, if the rough epicenter location, depth, origin times of seismic events are known, the equation of condition for calculating the corrections to these approximate values are.

$$dTij = To - Tc = \frac{\partial \mathrm{Tij}}{\partial \mathrm{xi}} dxi + \frac{\partial \mathrm{Tij}}{\partial \mathrm{yi}} dyi + \frac{\partial \mathrm{Tij}}{\partial \mathrm{zi}} dzi + dti + dsj \quad (1)$$

I= 1........q , j= 1......p

where

$dTij = To - Tc$ = The travel time residual for the i-th event at j-th station

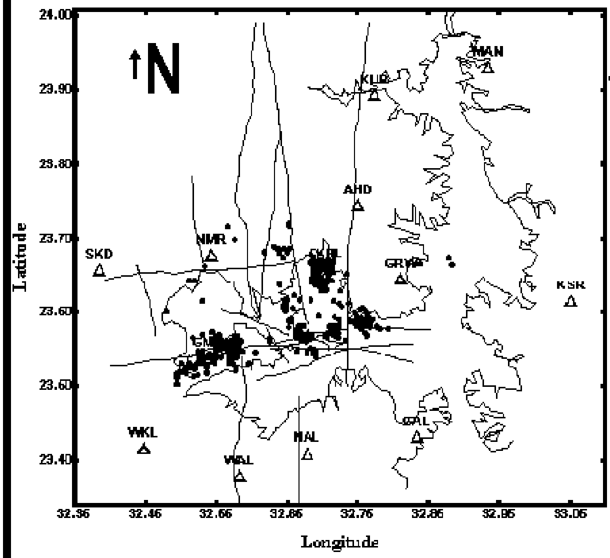
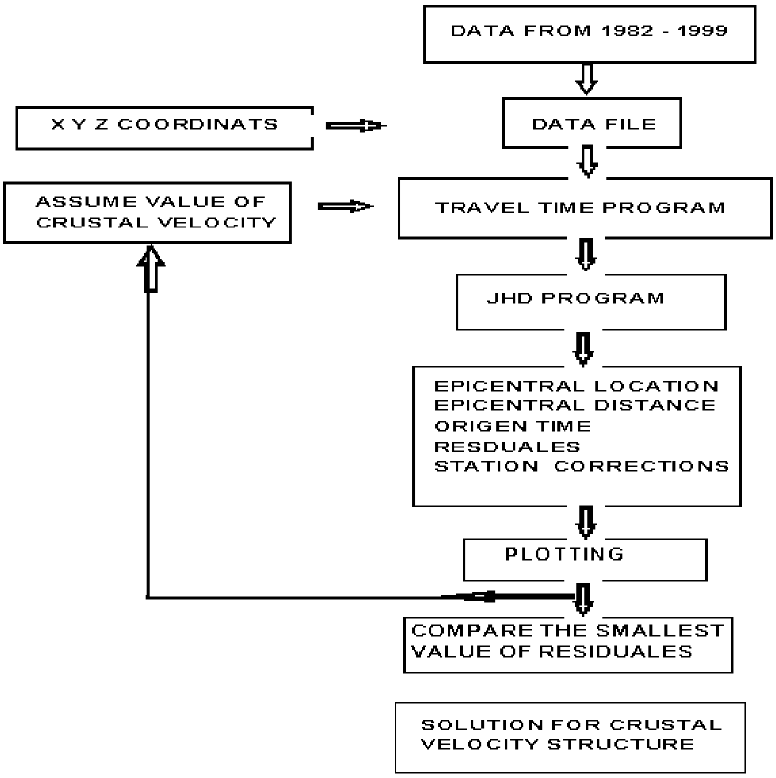



**Figure (1) local seismicity map**

| Number | Station | Latitude (deg) | Longitude (deg) | Elevation (meter) |
|---|---|---|---|---|
| 1 | KSR | 23.642 | 33.018 | 230 |
| 2 | KUR | 23.895 | 32.773 | 190 |
| 3 | MAN | 23.934 | 32.934 | 245 |
| 4 | WAL | 23.383 | 32.582 | 197 |
| 5 | AHD | 23.748 | 32.752 | 222 |
| 6 | SKD | 23.661 | 32.386 | 270 |
| 7 | NMR | 23.678 | 32.545 | 200 |
| 8 | GMR | 23.541 | 32.542 | 270 |
| 9 | WKL | 23.416 | 32.448 | 203 |
| 10 | GAL | 23.433 | 32.83 | 278 |
| 11 | KRL | 23.662 | 32.722 | 185 |
| 12 | NAL | 23.412 | 32.684 | 200 |
| 13 | GRW | 23.648 | 32.814 | 260 |

**Table (1) Aswan seismic network stations**

**Figure (2) The diagram of procedure for this study**



$\frac{\partial Tij}{\partial xi}, \frac{\partial Tij}{\partial yi}, \frac{\partial Tij}{\partial zi}$ = Coefficients obtained from travel time table

$dx, dy, dz$ = Corrections to the hypocenter in Cartesian coordinate x, y, z.

$dt_i$ = The correction to the initial origin time for the i-th event

$ds_i$ = The correction to the station travel

This equation can be written in a compact matrix as follows:

$$\Delta T = A\,\Delta X \qquad (2)$$

**ΔT** = the vector of observed- calculated (o-c) residuals based on approximate solution

**A** = coefficient matrix

**ΔX** = the solution vector containing the aggregate of hypocenters and station time correction.

$$\begin{bmatrix} \frac{\partial T11}{\partial x1}\frac{\partial T11}{\partial x1}\frac{\partial T11}{\partial x1}1 & & & 1 & & \\ \vdots & 0 & & & . & \\ \frac{\partial T11}{\partial x1}\frac{\partial T11}{\partial x1}\frac{\partial T11}{\partial x1}1 & & & & & 1 \\ & \frac{\partial T11}{\partial x1}\frac{\partial T11}{\partial x1}\frac{\partial T11}{\partial x1}1 & & 1 & & 1 \\ & \vdots & 0 & & . & \\ & \frac{\partial T11}{\partial x1}\frac{\partial T11}{\partial x1}\frac{\partial T11}{\partial x1}1 & & & & 1 \\ & & & 1 & & 1 \end{bmatrix} \begin{bmatrix} dx1 \\ dy1 \\ dz1 \\ dT1 \\ \vdots \\ dTq \\ ds1 \\ \vdots \end{bmatrix} = \begin{bmatrix} dT11 \\ \vdots \\ \vdots \\ dT1p \\ \vdots \\ \vdots \\ dTq1 \\ \vdots \end{bmatrix} \qquad (3)$$

All the solutions of the equations in this study are obtained by means of the iteration of the least squares method.

## DATA

Earthquake data routinely determined by Aswan seismic network in this period from January 1982 to December 1999 are included used in this analysis, using the initial P-wave reading observed at seven or more stations among 13 stations. The total number of earthquakes were 350. The distribution of the earthquakes in this study is shown in Figure 1.

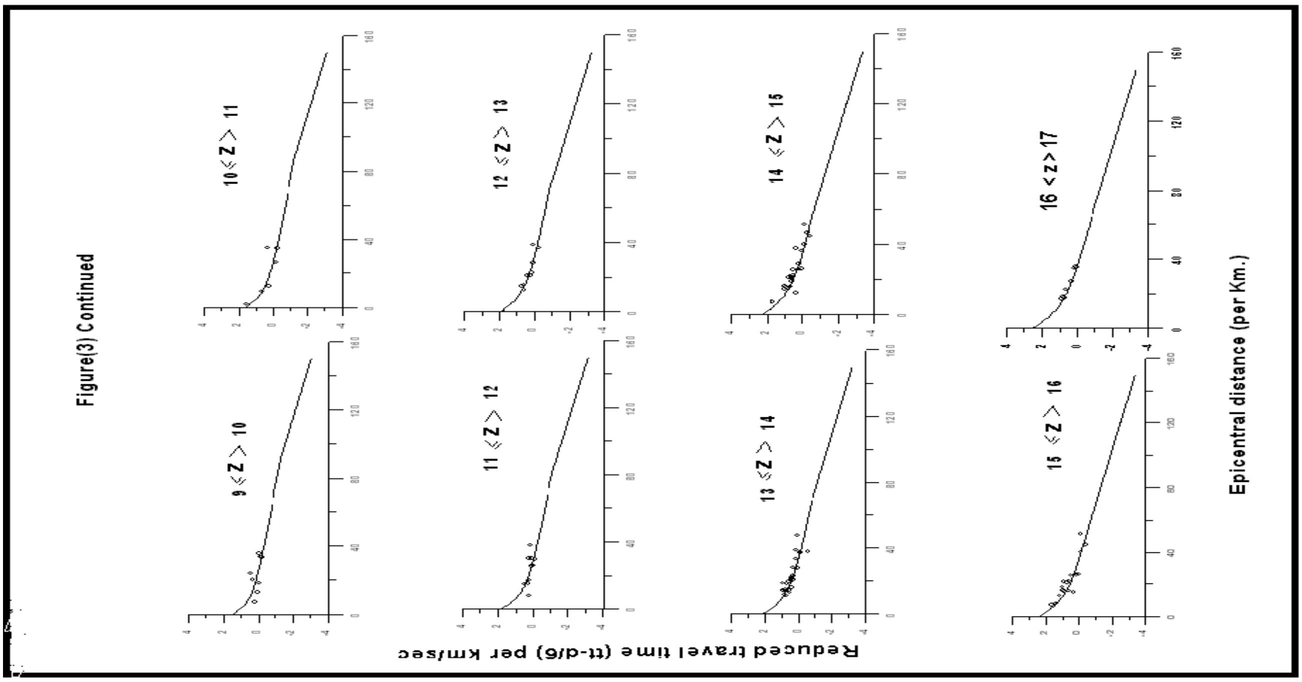
## PROCEDURE

According to the diagram in Figure 2, Firstly we collectrd and input all seismic data into the data file, then by assuming that there is a model with 4 constant crustal velocity layers in Aswan seismic network area and by trying the different values of velocity and thickness in each layer, the travel time table file will be instantly created and the computer chooses the most possible ray path from this structure. After the JHD Program is immediately executed to solve the mentioned equation. When the best solution for each execution which has the smallest value of residuals of individual event come out, again we create new travel time table by inputting different velocity layers and repeatedly use the JHD program. Next, after number of new results are available, they are compared with the previous ones. Certainly, the real observed and assumingly calculated travel times are instantly plotted with some different value of residuals for each depth and epicentral distances as shown in Figure 3. The reduced travel times on Y axis, in this case, are reduced by the velocity 6 km/sec and epicentral distances are on X axis. According to Hurukawa and Imoto (1987) this technique is borrowed to use for considering velocity in more detail. Lastly, the best fitting for the smallest value of residual is selected as a final result. It means that the assumed model well fit with real structure in the Aswan seismic network region. This model is applied for a variety of purposes.

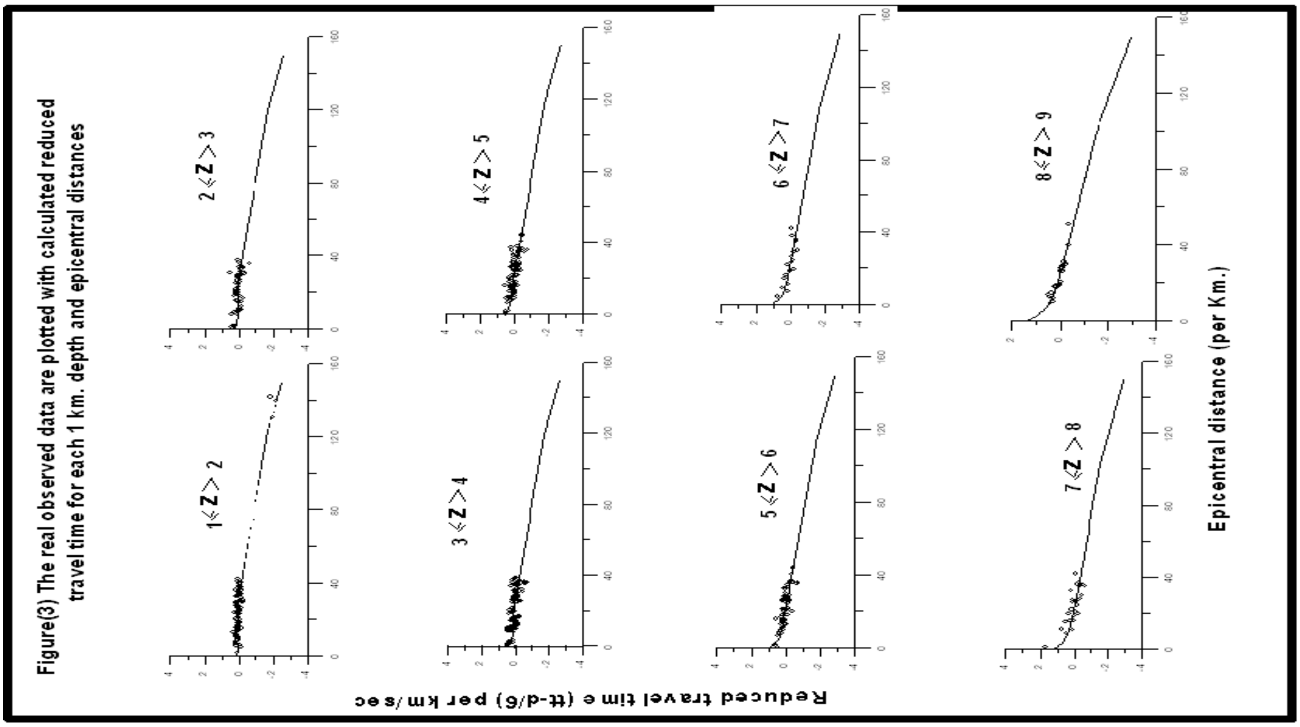
## RESULTS

After a number of trails, the best result for the 4 crustal P-wave velocity structure including a half space is that 4.2, 6.2, 6.8, and 7.3 km/s and its thickness are 1, 4, 10.5 and 16.5 km respectively.As a result, we can assume that the Mohorovicic discontinuity is at 31 km deep.

There are 13 seismic stations used in the calculation. Only 6 stations AHD, GAL, KSR, GRW, KUR, MAN have minus signs in station P-wave travel time corrections and their values - 0.017, -0.016, -0.187, -0.028, -0.028, -0.048 This means that seismic signal from hypocenter takes a bit short time to reach the station then to make correction in travel time, we should add this value before computation. It is possible to assume that the underground structure in the study area has a particular characteristic of high velocity structure and other stations SKD, NMR, GMR, WKL, WAL, , KRL, , NAL, have positive signs and their values 0.005, 0.049, 0.082, 0.040, 0.066, , 0.025, 0.057. This means that seismic signal from hypocenter takes a bit more time




Figure(3) Continued




Figure(3) The real observed data are plotted with calculated reduced travel time for each 1 km. depth and epicentral distances

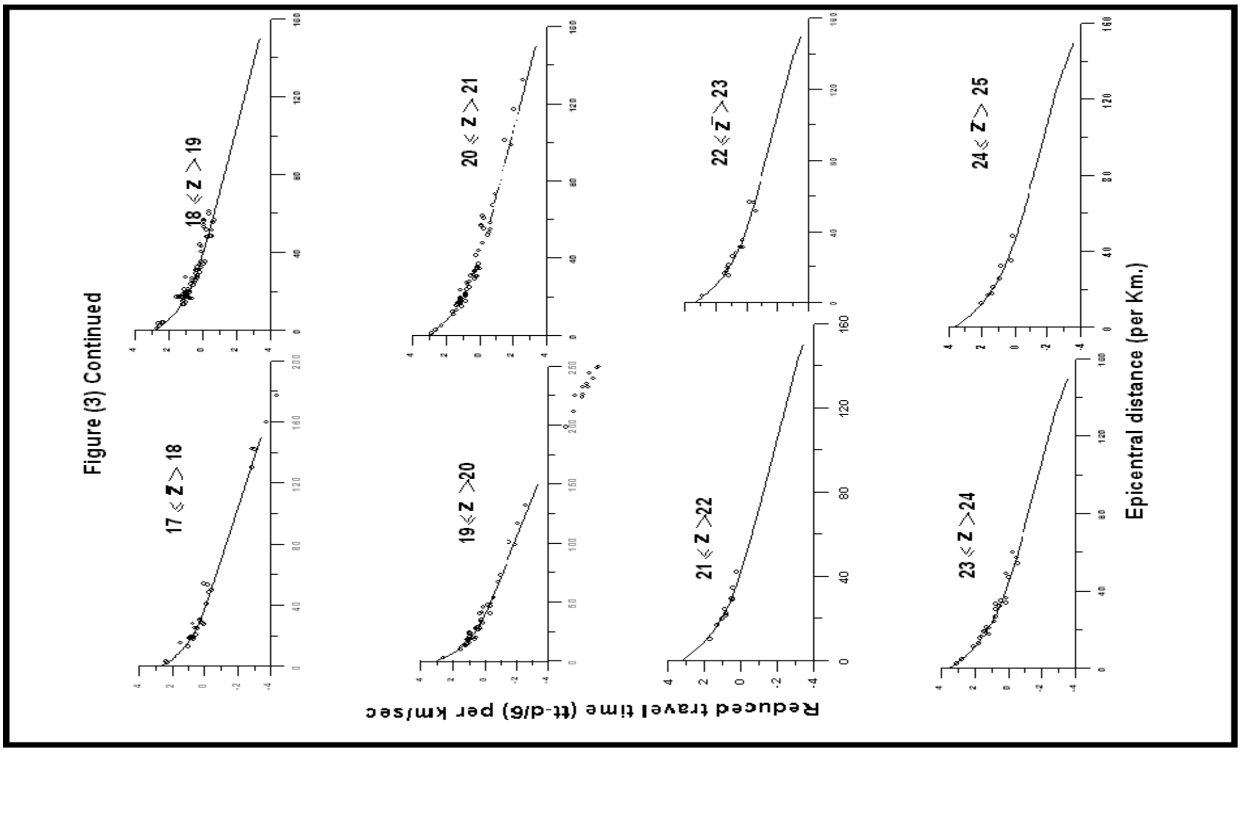



Figure (3) Continued

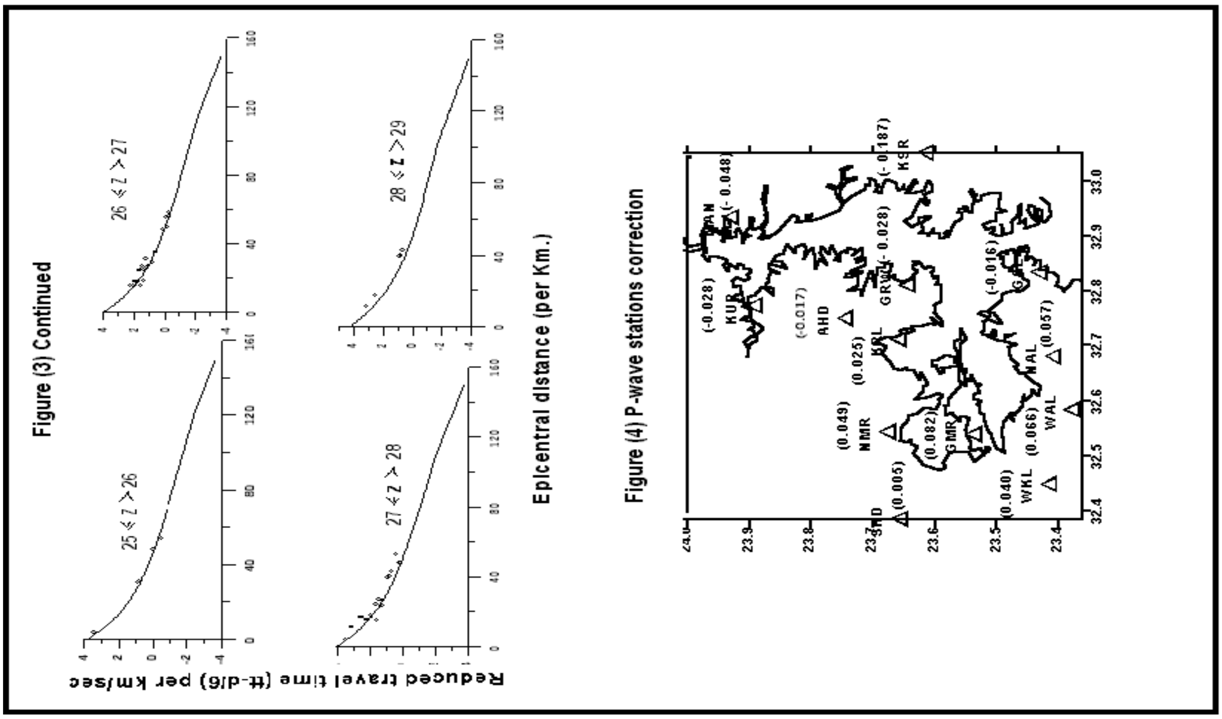



Figure (3) Continued

Figure (4) P-wave stations correction

to reach the station then to make correction in travel time, we should subtract these values before computation. It is possible to assume that underground structure in this area has particular characteristic of low velocity structure as shown in the Figure (4 ).

## CONCLUSION

The present paper aims to improve the crustal velocity structure under Aswan seismic network which consists of 13 seismic stations distributed around the northern part of the Aswan High dam lake. The P-wave velocities of 4 horizontal layers are 4.2, 6.2, 6.8, and 7.3 km/s and its thickness are 1, 4, 10.5 and 16.5 km respectively. The stations AHD, GAL, KSR, GRW, KUR, MAN have minus signs in station P-wave travel time corrections and their values - 0.017, -0.016, -0.187, -0.028, -0.028, -0.048 and other stations SKD, NMR, GMR, WKL, WAL, , KRL, , NAL, have positive signs and their values 0.005, 0.049, 0.082, 0.040, 0.066, 0.025 and 0.057 respectively.

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