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DURATION MAGNITUDE (M_D) ESTIMATION OF THE KUWAIT NATIONAL SEISMIC NETWORK, NORTHEASTERN ARABIAN PENINSULA

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حساب القوة الزلزالية الزمنية لشبكة الرصد الزلزالى الكويتية لشمال شرق شبه الجزيرة العربية

الخلاصــة: تم تطوير معادلة خاصة بالقدر الزلزالي لشبكة الرصد الزلزالي الوطنية الكويتية (KNSN) من معلومات الزلازل التي تم إنشاء هذه الشبكة لغرض مراقبة النشاط الخاص بها. بواسطة هذه المعادلة الخاصة بالقدر الزلزالي (الخاص بالاستمرارية) و التي تم استخلاصها بواسطة الاستنتاج كما في المعادلة التالية:

MD= 2.66 log (τ) + 0.036Δ -1.97 + Ci

تم استخراج معادلة القدر الزلزالي كنتيجة لتقنية الانحسار الخطي الهندسي المتعدد للمعلومات الخاصة باستمرارية الإشارة الزلزالية (τ) و المتوفرة من ست محطات رصد زلزالي ضمن الشبكة الوطنية الكويتية لرصد الهزات الأرضية (KNSN).

لضمان إمكانية تطبيق هذه المعادلة (القدر الزلزالي الخاص بالاستمرارية للإشارة الزلزالية) على الشبكة تم حساب التصحيح الخاص بكل محطة رصد زلزالي ضمن المعادلة(Ci). تم تقييم التصحيح الخاص بكل محطة رصد زلزالي من خلال الفوارق بالقيم بين المحسوبة بواسطة المعادلة و التي تم الحصول عليها من كل محطة رصد زلزالي.

ABSTRACT : *One type of magnitude formula are preliminarily developed from Kuwait National Seismic Network (KNSN) data which is proposed and intended for application by the network in its seismic monitoring activities. This is the duration magnitude scale of measurement which are empirically determined and expressed as:*

$M_D = 2.66 \log(\tau) + 0.036\Delta - 1.97 + Ci.$

The magnitude formula is the result from applying multiple regression techniques to the data which have the seismic signal duration, τ, that are availed from 6 stations of the network. To ensure applicability of the magnitude equation for the network, stations corrections were determined which are indicated by the Ci for the ith station. The station corrections are evaluated from the average of the difference values between the proposed magnitude formulas to respective magnitude equations obtained from each seismic station.

INTRODUCTION

Magnitude is a measure of an earthquake size. It is one of the contributing factors that are reckoned with when it is considering the degree of destructiveness of a seismic event. A reliable and standardized measure of the size of an earthquake is an essential and important need for consideration in the concept of seismic disaster mitigation and minimization of earthquake losses. Hence, it becomes imperative for a seismic network to develop and established its own formulas and methods in determining and defining the seismic parameters of local earthquake events that are related to the level of destructiveness. It is advisable and desirable that a seismic network can react immediately and promptly provides information regarding the occurrence of an earthquake of concern independently from other seismological agencies. An appropriate timely reaction to an earthquake emergency may mitigate disaster and minimize seismic losses. Time delay in responding to an earthquake emergency may contribute further disaster from potential contributory secondary effects such as fire and strong aftershocks generated by the main seismic event. A seismic network needs to be prepared and ready to meet satisfactorily the national and local demands and requirements in seismic disaster preparedness.

The concept of a magnitude scale for an earthquake is introduced by Richter (1935) for earthquake in California, U. S. A. This is known as the local magnitude scale developed in terms of the records of Wood-Anderson torsion seismograph. The amplitude- distance relation was derived for California and is not applicable to other regions. Although the definition of the local magnitude is quite arbitrary, this became a basis for further development of the magnitude concept. Gutenberg (1945) introduced the body-wave magnitude (Mb) based on P-waves depth phases from shallow earthquakes, and later developed it further to include earthquakes of any focal depth. The amplitude-distance correction was determined by combination of theory and observation and included effects due to geometrical spreading and anelastic absorption.

In 1958, Bisztricsany found a linear relation between magnitude of teleseismic events and the logarithm of the surface-wave trace duration. This concept was applied to local earthquakes with the seismic signal trace duration defined as the total length of the trace instead of the surface-wave (Solov'ev, 1965; Tsumura, 1967; Crosson, 1972; Lee et al, 1972; Real & Teng, 1973; and Bakun & Lindh, 1977).

Regional and local peculiarities require that each local seismic network should fundamentally developed their own methods, tools, and formulas for classifying and defining seismic events within their area of responsibility and region of concern. Particularly, a seismic parameter of interest in this paper is the measurement of the magnitude of an earthquake event. This parameter is related to the release seismic energy in an earthquake occurrence and therefore an important number characteristic in the evaluation of earthquake hazards that are generated. It is apparent that to develop a system of reliable magnitude measurement becomes one of the fundamental contributions to earthquake disaster mitigation. The system paves the way for immediate assessment of the level of destruction when other physical factors such as soil properties, focal depth, and elements at risk are as well taken into consideration.

Substantially, the empirical magnitude formulas that are developed from regional and local considerations are more appropriately applicable and reliable for a local seismic network. These are based on data that reflect the regional and local characteristics of geometric spreading and anelastic absorption that influence and affect the behavior of calibrating functions. Hence, it is for this purpose that an attempt to develop preliminary magnitude formula from the Kuwait National Seismic Network (KNSN). KNSN stations data is undertaken, for contribution and proposed application in the determination of the strength of recorded local and regional seismic events. This study may also encompass the intention of promoting and cultivating regional cooperation among neighboring seismological networks.

DATA SOURCE

There are two main sources of seismic data that are referred in this study of magnitude formula development. These are the seismic bulletins from the KNSN in the period from 1998 to 2003 and the preliminary determination of epicenters (PDE) of the United States Geological Survey (USGS) corresponding to these years. The seismic data that were taken from KNSN earthquake bulletins are the duration values from its short period seismic stations: QRN, RDF, NAY, RST, MIB, and UMR. The location of these seismic stations and the study area is shown in figure (1).

The corresponding body-wave magnitude (Mb) values and epicenters are availed from the PDE of USGS. The values of these seismic parameters were referred to and assumed as standard measurements in reference to the preliminary development of the magnitude formulas.

The numbers of duration and amplitude values utilized in each seismic station are tabulated as follow:

Station code	QRN	RDF	NAY	RST	MIB	UMR
No. of Duration	21	30	43	29	38	40

The data from the KNSN and USGS are used as initial hypotheses in the fulfillment of the objectives of this paper.

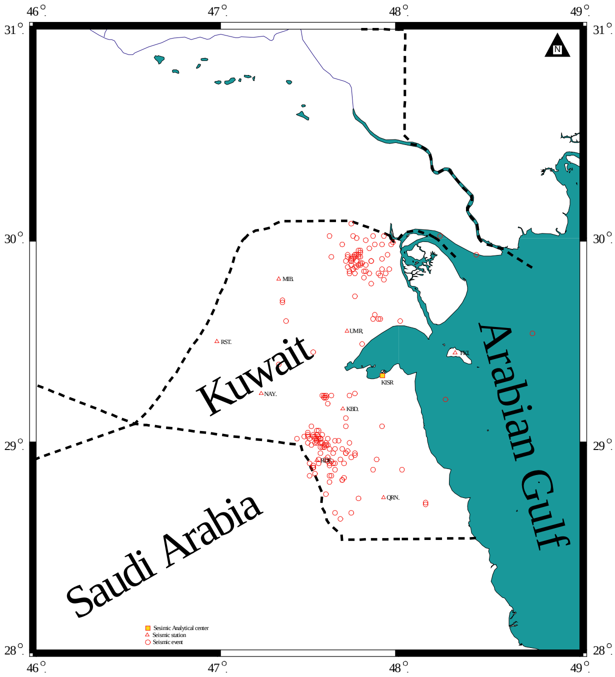


Fig. (1): Location map of the Kuwait National Seismic Network stations and the analytical center.

METHODOLOGY

One type of magnitude formula was envisioned to be developed from the KNSN data. This is the magnitude based on the duration of seismic signal. The generally applied method in the preliminary development of the magnitude formulas when sufficient data is available is by means of statistical procedures. The amplitude and duration with the associated epicentral distance data are regressed against corresponding values of a standard and internationally accepted magnitude scale to determine the calibrating function.

Duration Magnitude

Two procedural steps are conducted in the preliminary development of this type of magnitude based from the collected and compiled data. These are the calibration of the duration magnitude scale for each seismic station and the other is the development of a single formula for all the considered stations. Comparative analysis of the two approaches will generate correction for each seismic station, thereby facilitating the application of a single formula for the whole network for this type of magnitude.

The relation of the magnitude of an earthquake to seismic trace duration is known (Lee et al 1972, Real & Teng 1973, Tsumura 1967, Bakun & Lindh 1977) to be expressed by the equation

$$M_D = a\log\tau + b\Delta + c \qquad (1)$$

where M_D is the duration magnitude that is referred from the body-wave magnitude which is taken as the standard magnitude value in this paper, $\log\tau$ is the decadic logarithm of the seismic signal trace duration (τ) in seconds which is measured from the initial onset of the seismic signal up to the time when the signal is twice the normal trace as defined by KNSN, Δ is the epicentral distance in degrees, a, b, c are constants. The determination of equation (1) can be performed in two steps. The first step is conducted without considering the distance, that is,

$$M_D = a\log\tau + k \qquad (2)$$

Where k is a constant and the other variables are as defined previously. The second step is to consider the contribution or correction due to the influence of the distance to equation (2) which is

$$M_D - a\log\tau = b\Delta + c \qquad (3)$$

for each seismic station for equations (2 & 3). Another approach is a direct consideration of equation (1) which is applied in preference in this paper since the distances are relatively larger compared to local events. Then by applying the usual method of least square approximation, the regression constants a, b, c can be determined for each seismic station. The graphical presentation of the steps for the six stations of KNSN is shown in figures (2a, b, and c).

The determination of the single formula from the seismic data of the network follows the same procedures and regression of equations (2 & 3) or (1) by considering all the utilized data from each seismic station. The development of the single formula is represented as

$$M_D - d\log\tau = e\Delta + f \qquad (4)$$

or

$$\mathrm{M_D = dlog\tau + e\Delta + f} \qquad (4a)$$

for purposes of discussion. The parameters M_D, τ, and Δ are as defined in equation (1), and d, e, f are regression constants to be determined by multiple regression analysis from the total data of the considered seismic stations. The graphical presentation for this type is shown in figure (3).

Station corrections for equation (4a) are determined as follows. Equation (4a) is applied separately to each considered seismic station data to evaluate the magnitude values. Likewise, the representative magnitude equation (1) for each seismic station is also applied to respective data for evaluation. The average of the corresponding magnitude differences is then determined and this is taken and assumed as the station correction. The procedure can be expressed as

$$M_{corr.} = [(d-ai)\log\tau + (e-bi)\Delta + (f-ci)]/Ni \qquad (5)$$

where $M_{corr.}$ is the magnitude correction, Ni is the number of data considered for the ith seismic station, with the coefficients and constants as defined previously. Eventually, equation (4) becomes

$$M_Di = di\log\tau i + ei\Delta i + fi\, M_{corr.}i \qquad (6)$$

for the ith seismic station when reckoned.

The results of the statistical analyses are shown in table 1. The table is composed of five columns. The first column is for the seismic stations. The second is for the regression constants. The third is for respective station correction.

DISCUSSION AND CONCLUSION

The KNSN seismic stations are distributed in strategic locations, but relatively near each other. However, it is possible that each seismic station can respond differently to seismic signals due to the influence of some physical factors. These factors could be due to geological and environmental conditions at each station site that could affect the response of the seismic instruments. These possibilities prompted separate analysis of the seismic data which are the seismic trace duration that are gathered and compiled at each KNSN station. The assumptions seemed to be supported and validated by the results as shown in table (1).

The results for the preliminary determination of the duration magnitude formula for the KNSN show close values for the coefficient of *log*τ as shown in Table 1. However, this conformity is not shown in the consideration and correction due to distance. Two seismic stations which are RDF and RST behave differently from the other seismic stations QRN, NAY, MIB, and UMR. The duration magnitude formula for each of the two seismic stations (RDF and RST) seems to indicate increasing seismic signal trace duration with distance. Initially, the characteristics of the respective equations reflect that the station sites are suitable for the generation and recordings of surface waves and possibly some signal noise. However, the initial guess for the explanation of the different behavior need further study and investigation for validation. Nevertheless, when the seismic data from the other stations (QRN, NAY, MIB, and UMR) are included with RDF and RST data for the determination of the single duration magnitude formula gives an appropriate result as indicated by the station corrections. The treatment for the whole data seemed to be appropriate since the results from equation (2) give relatively close values for each seismic station. These considerations including the nearness of the seismic stations reflect that the single duration magnitude is recommendable and advisable to apply for the KNSN with the inclusion of respective station correction.

The result of the validity test in table 1 indicates that five seismic stations using the single duration magnitude formula can be used. These are QRN, NAY, RST, MIB, and UMR. Station NAY seems to be fitted better for duration magnitude determination.

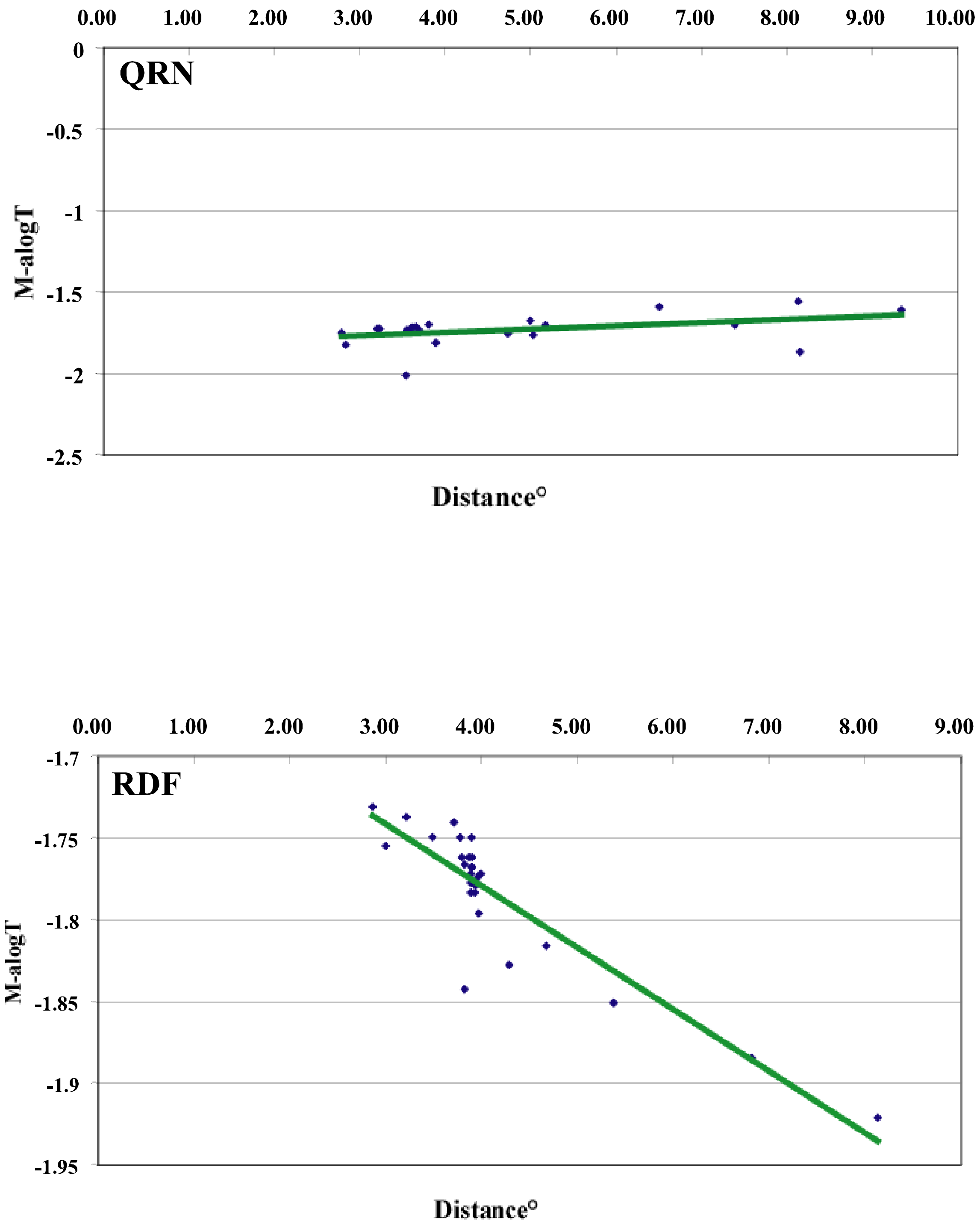
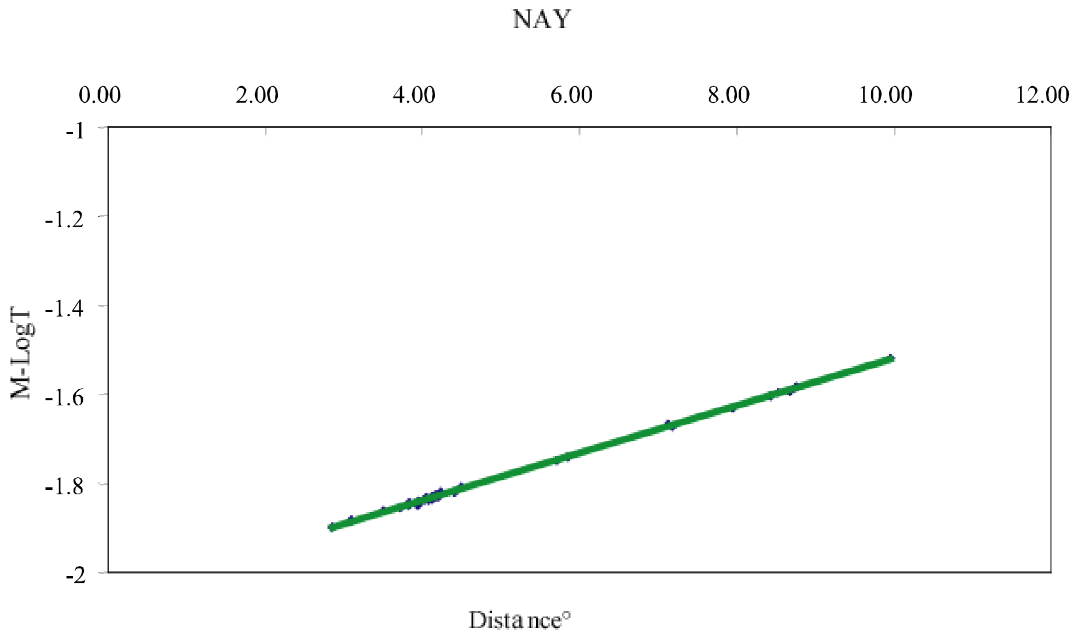


Fig. (2a): Plots of the data points between the difference of magnitude (M) and product of the coefficient (a) and logarithm of the seismic signal duration (T) against distance for the QRN and RDF seismic stations of RNSN.



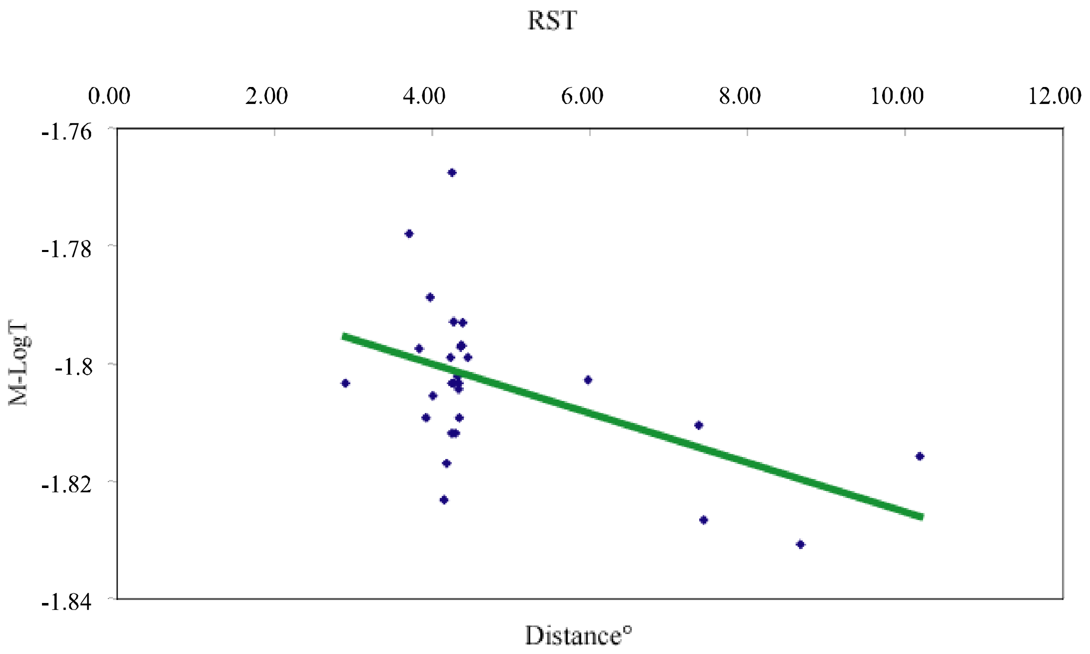
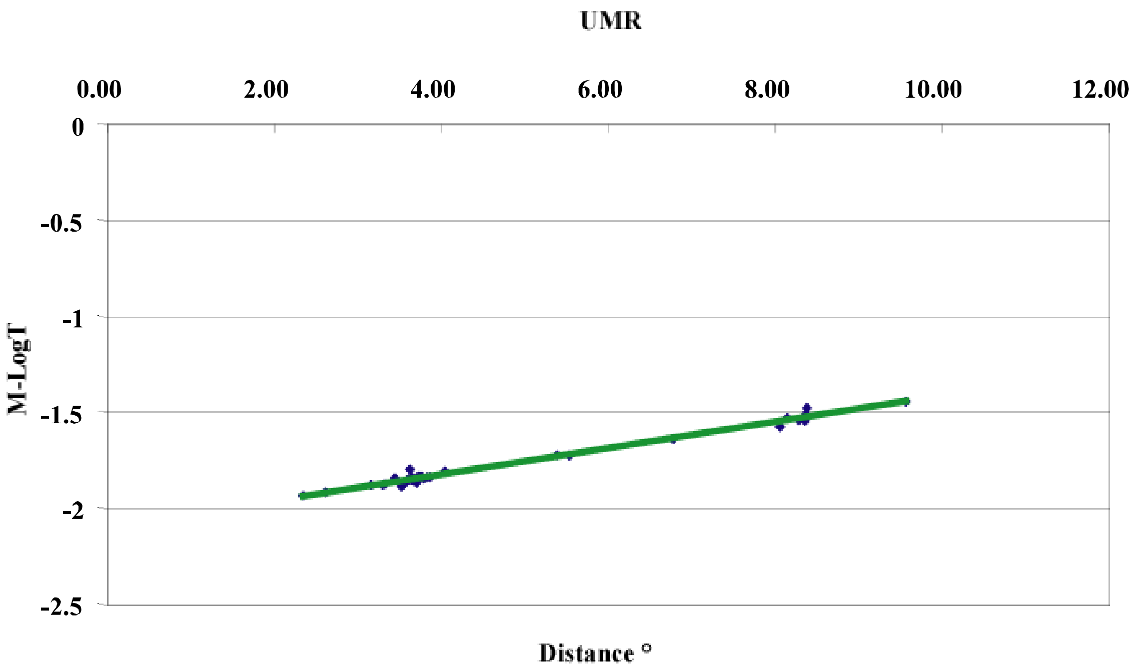


Fig. (2b): Plots of the data points between the difference of magnitude (M)

Figure (2b) Plots of the data points between the difference of magnitude (M) and product of the coefficient (a) and logarithm of the seismic signal duration (T) against distance° for the NAY and RST seismic stations **of KNSN.**



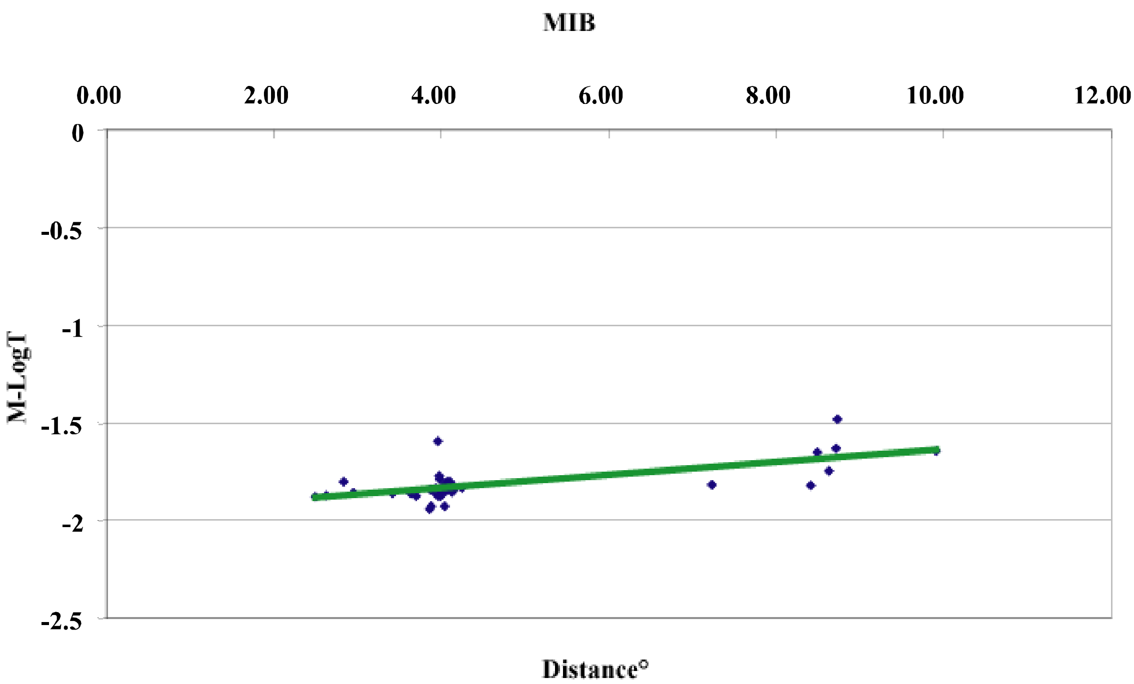


Fig. (2c): Plots of the data points between the difference of magnitude (M) and product of the coefficient (a) and logarithm of the seismic signal duration (T) against distance for the UMR and MIB seismic stations of KNSN.

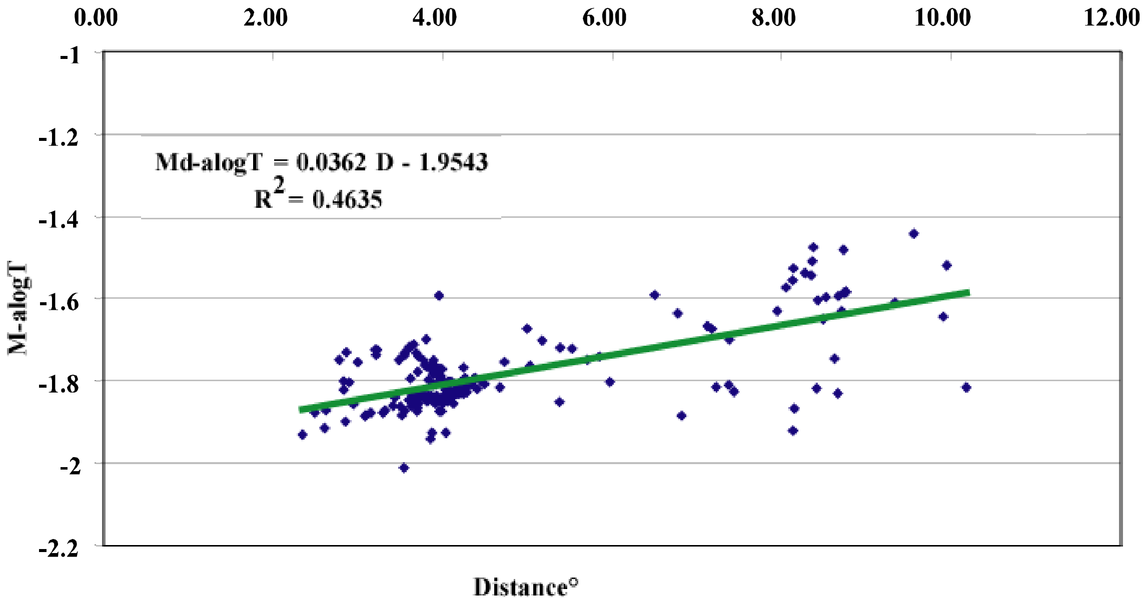


Fig. (3): Plots of the single magnitude formulas for duration magnitude scale that are proposed for application by the KNSN in its seismic monitoring activities.

Table (1): Duration magnitude formula for each KNSN seismic station as indicated and for a single representative equation for the considered stations of the network. Each seismic station correction is evaluated from the single formula (total).

Station Code	Regression Constants			Station Correction
	a/d	b/e	c/f	
QRN	2.25	0.036	-0.91	-0.026
RDF	2.54	- 0.035	-1.36	0.35
NAY	2.66	0.053	-2.06	-0.069
RST	2.73	-0.0053	-1.94	0.18
MIB	3.2	0.015	-3.14	0.00
UMR	2.76	0.067	-2.3	-0.017
Total	2.66	0.036	-1.97	

The development of the empirical formula for the duration magnitude scale is mainly based within the hypothesis of the initial seismic data taken from the KNSN seismic stations. Hence, the magnitude equations are affected by the reliability and accuracy of the utilized seismic data. Comparison of preliminary determination of seismic parameters such as location and magnitude of seismic events from KNSN and USGS indicates some discrepancies. In case of discrepancies, preference is given to the USGS determinations, for the reason that this agency relies from more seismic stations and application of statistical procedures to the utilized seismic reports. It is also observable from the KNSN seismic data some unintentional errors of recordings for the duration values when based from the corresponding magnitude and distance of earthquake events. The occurring errors could be due to malfunctioning in the system of response of the instruments.

These errors were considered for correction in relation to the general trend of the graphs and corresponding values from the other seismic stations. It is therefore advisable that automated evaluation of the required data be counter-checked for the realistic assessment of magnitude.

Hence, magnitude estimates from the preliminarily developed equations can be considered as conservative values due to encountered constraining factors. The level of accuracy is within the limits of the utilized seismic data and assumptions that were taken regarding similarities in the calibrating functions. Although the station corrections imply the significance and relative accuracy of the proposed formulas, the level of validity can be improved from application for further verification.

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