B. MUÇO and P. MINGA

# MAGNITUDE DETERMINATION OF NEAR EARTHQUAKES FOR THE ALBANIAN NETWORK

**Abstract.** Analysing about 500 earthquakes recorded by the Albanian Seismological Network during 1984-1988, new relations for the determination of near earthquake magnitudes are found, based on a more accurate correction factor Ao of Richter's magnitude formula. The seismological station Tirana was the first to be provided with this a new relationship. Accepting this as the principal formula, others were obtained for different stations of the Albanian network. According to total event signal duration, equivalent relations for the magnitudes were also produced.

## INTRODUCTION

Magnitude still remains in practice the main parameter in earthquake information. Knowing it, one can give a preliminary and approximate judgement about the intensity and damage potential of an earthquake.

Many special magnitude scales for various continental regions have been developed since the original magnitude concept was introduced by Richter (1935). They use different types of seismic wave and are classified for different epicentral distances and focal depths.

It is well known that for near earthquakes, the geological setting of the seismological station influences the magnitude determination, that is, some discrepancies in magnitude determination result from not using the appropriate correction factor Ao, the amplitude that would be produced by the "standard" calibration earthquake (Richter, 1935) which is not the same for different areas of the world. In order to improve the accuracy of magnitude determination by taking into account the above mentioned factors, a new set of formulas are here derived.

## MAGNITUDE DETERMINATION IN THE ALBANIAN NETWORK

Since the installation of the Tirana seismological station in 1968, the number of stations has increased and the present Albanian Seismological Network (ASN) consists of 13 stations and is mostly equipped with short period type seismographs (DDJ-1) (Fig. 1). Up to now, according to recommendations from the World Data Center A (Willmore, 1979), in the ASN we use in routine practice a magnitude scale derived by converting the record traces of our DDJ-1 short period seismographs into values compatible with the Wood Anderson instrument. This formula is:

$$ML = \log Y - \log (V/Vw) - \log Ao \ , \quad (1)$$



Manuscript received, September 5, 1990; accepted March 20, 1991.

Seismological Observatory, Tirana, Albania.

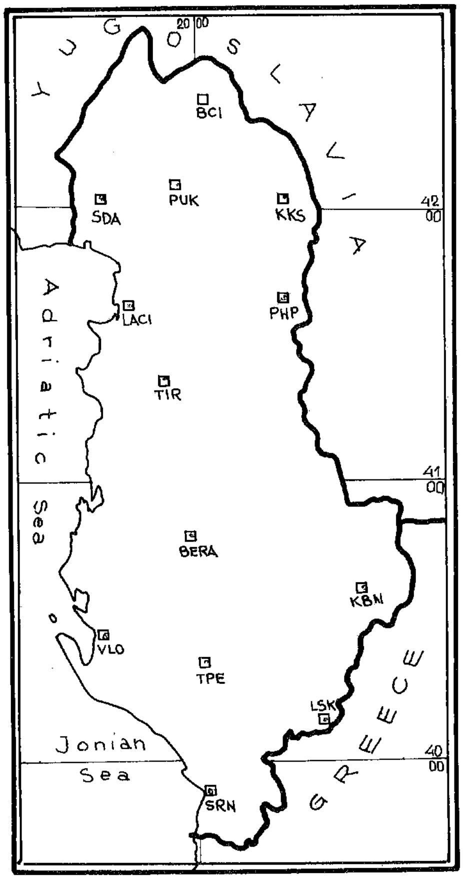


Fig. 1 — The seismological Network of Albania.

where $Y$ is the maximum amplitude of surface waves in mm, measured on horizontal components, $V/Vw$ is the ratio of magnification of the DDJ-1 instrument versus that of Wood Anderson for the period corresponding to the given amplitude; $log\ Ao$ is a distance factor calculated by Richter (1958) for California, in the original formula

$$ML = log\ A - log\ Ao\ . \tag{2}$$

In recent years, magnitude scales based on the recorded signal length have been frequently applied in various parts of the world (Baker, 1970; Bakun and Lindh, 1977; Huangceng et al., 1987; Wahlstrom, 1979). Such a scale already exists for near earthquakes recorded at Tirana (TIR) station (Muço, 1978):

$$MD = 2.03\ log\ \tau + 0.002D - 1.15\ , \tag{3}$$

where $\tau$ is the event total signal duration on horizontal components in sec., and $D$ is the epicentral distance in km. Another similar formula is used for the northern stations of the ASN - Bajram Curri (BCI), Kukes (KKS), Puke (PUK) and Shkodra (SDA) - for epicentral distances up to 100 km (Muço, 1982):

$$MD = 2.5\ log\ \tau - 2.28\ . \tag{4}$$

In the above formulas, the geological characteristics of the Albanian crust are not taken into consideration. As said above, the values of correction factors Ao in Richter's formula for magnitude determination are the same as those used in California.

## THE NEW MAGNITUDE RELATION FOR TIRANA

To deal with this problem, we started correcting Ao values in the magnitude formula given by Richter. Determining the value of anelastic attenuation coefficient $\gamma$ for Albania, according to techiques given by Nuttli (1973) and Bollinger (1979), we found the new values of correction factors Ao (Muco and Minga, 1990) following Ebel (1982). These values influence magnitude determinations, carried out with the previous formula, by 0.1 unit for earthquakes 80 km from the station and 0.5 for those up to 600 km.

The analysed earthquakes were chosen from the records of Tirana station during 1984-1988, and there were about 450 which occurred within 10 - 600 km of this station.

The amplitude measurement is made on the horizontal components. The periods are calculated by counting the number of zero crossings of the seismic trace within a given time interval and dividing the window with twice that number. The epicentral distances are taken either from the monthly bulletins of the Albanian Seismological Network or from those of the International Seismological Center.

With these amplitudes, periods, distances, and the new corrections of Ao-values resulting from the anelastic attenuation coefficient for Albania, the magnitude values were determined with the existing formula (1). These values are in the range of 1.6 to 5.5. We tried to satisfy the relation:

$$ML = log\ (A/T) + a\ D + b, \tag{5}$$

which is used world-wide (Nuttli, 1973; Prochazkova et al., 1985). In this formula, the amplitudes are expressed in nanometers, and the distances in km. The constants for the above relation were found using the least square method: a=0.0035, and b=—0.4691 with a correlation coefficient 0.73. As one can see from Fig. 2, the straight line, the analytical expression of which is the relation given above, does not cover all the points of the data set. If we want to use such a relation, we should separate it into two parts, finding different coefficients for the earthquakes up to 100 km from the station and for those within 100-600 km. The trend of the points expressing the dependance of *(ML—log (A/T))* on distance, as can be seen, resembles a logarithmic function. After some trials, the following relation was found to be more plausible:

$$ML = log\ (A/T) + a\ log\ D + b\ D + C\ , \tag{6}$$

which after the multiple regression analysis has the form:

$$ML = log\ (A/T) + 1.6627\ log\ D + 0.0008\ D - 3.433\ , \tag{7}$$

with coefficient of correlation 0.97, and a satisfactory Fisher test (Fig. 2). Making use of this new relation for the seismological station of Tirana (TIR), we can determine the magnitudes of the earthquakes from 10 to 600 km.

## THE FORMULAS FOR THE OTHER STATIONS OF THE ASN

The new relations for the other stations in the network were found assuming as reference magnitude that of the Tirana master stations. Thus, the amplitudes and periods of the events recorded in the seismological stations of Shkodra (SDA), Kukesi (KKS), Peshkopia (PHP), Korca (KBN), Berati (BERA) and Vlora (VLO) were estimated, and their epicentral distances determined. The earthquakes considered are the ones recorded by Tirana station, which were used to find the above formula (7). In addition to these earthquakes, some new ones (about 60), recorded

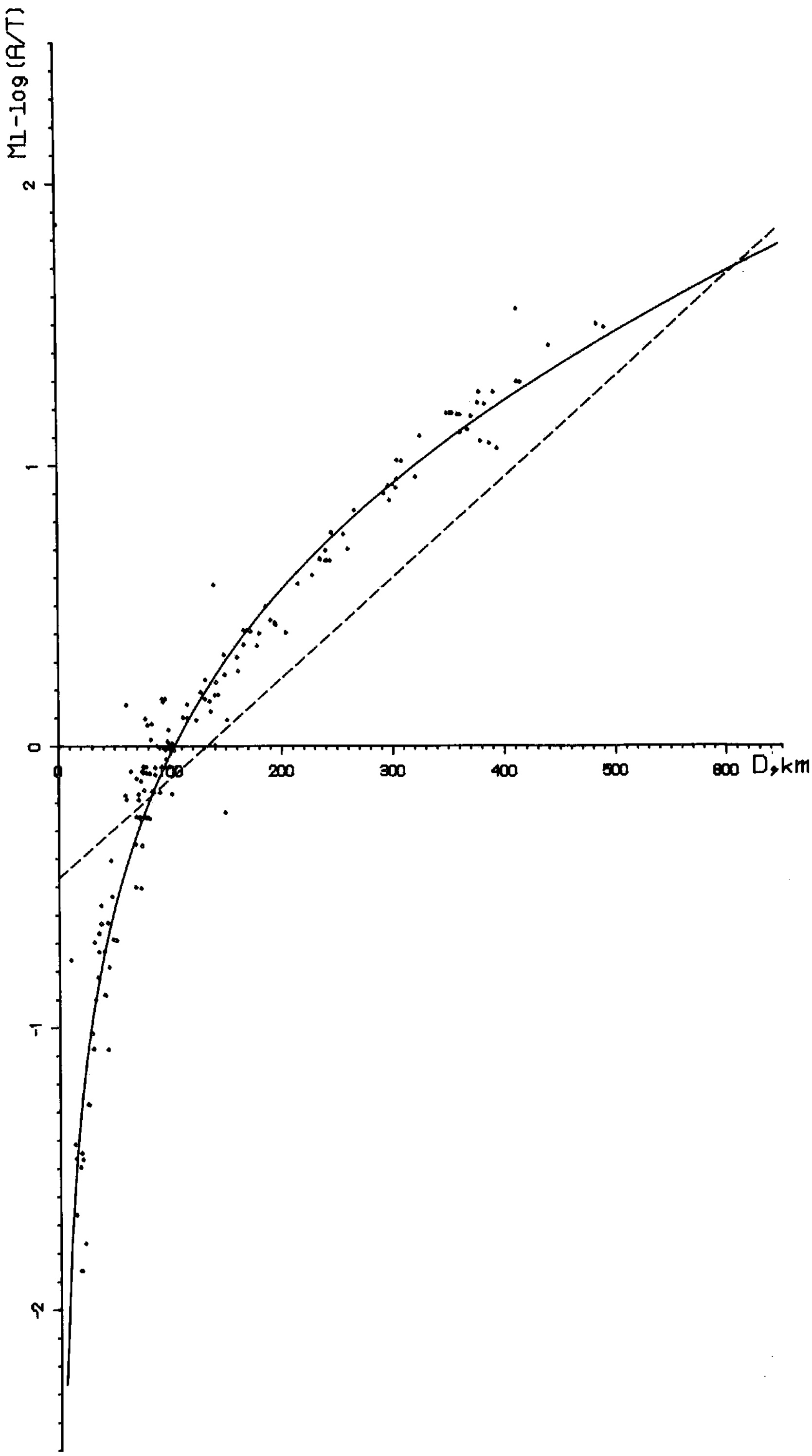


Fig. 2 — The dependance of *[ML—log (A/T)]* on distance expressed by eq. (7) (for Tirana station).

by both TIR and another of six stations were also treated. Assuming that of Tirana as reference magnitude, as expressed by the relation (7), a relationship of type (6) was sought for each of the six stations. Using about 1500 data for these stations, we obtained the following formulas:

$$SDA:\ ML = \log (A/T) + 1.6361 \log D + 0.0012\ D - 3.114 \quad (8)$$

$$KKS:\ ML = \log (A/T) + 1.804 \log D + 0.0009\ D - 3.581 \quad (9)$$

$$PHP:\ ML = \log (A/T) + 1.8324 \log D + 0.0003\ D - 3.553 \quad (10)$$

$$KBN:\ ML = \log (A/T) + 1.579 \log D + 0.001\ D - 3.206 \quad (11)$$

$$BER:\ ML = \log (A/T) + 1.4023 \log D + 0.001\ D - 2.757 \quad (12)$$

$$VLO:\ ML = \log (A/T) + 1.9986 \log D + 0.001\ D - 4.178 \quad (13)$$

The correlation coefficient of the above equations varies from 0.86 to 0.98.

## THE RELATIONSHIPS OBTAINED FROM SEISMIC SIGNAL DURATION

The event signal duration was estimated on the vertical component for each station mentioned here from the first onset until its disappearance into the microseismic background.

The estimations were carried out for all the earthquakes we analysed above; that is the ML values obtained from eqns. (7) to (13) were used to calibrate MD.

Initially, for Tirana station, two kinds of formula were sought (Real and Teng, 1973; Wahlstrom, 1979):

$$MD = a \log \tau + b\ D + c\ , \quad (14)$$

$$MD + a\ (\log \tau)^2 + b\ D + c\ . \quad (15)$$

Working out the data set by multiple regression analysis, the coefficients of the above formulas come out to be:

$$MD = 2.326 \log \tau + 0.00067\ D - 1.842 \quad (16)$$

$$MD = 0.5642\ (\log \tau)^2 + 0.0006\ D + 0.521 \quad (17)$$

The relationship correlation coefficients are respectively 0.817 and 0.821. As we can see, these relationships have almost the same correlation coefficient. We accepted the first one, relation (16), for it is easier to use.

The same procedure was also used for the relationships of the other six stations starting from the magnitudes according to formulas (8)-(13), and from the measurements of durations on their records. The formulas obtained are as follows:

$$SDA:\ MD = 2.1206 \log \tau + 0.001\ D - 1.3866 \quad (18)$$

$$KKS:\ MD = 2.2358 \log \tau + 0.001\ D - 1.8327 \quad (19)$$

$$PHP:\ MD = 2.3002 \log \tau + 0.001\ D - 1.9190 \quad (20)$$

$$KBN:\ MD = 2.4338 \log \tau + 0.001\ D - 2.3560 \quad (21)$$

$$BER:\ MD = 2.5338 \log \tau + 0.001\ D - 2.4774 \quad (22)$$

$$VLO:\ MD = 2.6318 \log \tau + 0.0006\ D - 2.3110. \quad (23)$$

## SOME RELATIONSHIPS OF MAGNITUDE FORMULA BETWEEN NEIGHBOURING STATIONS

We also tried to find relationships of the magnitude formula obtained for Tirana station with neighbouring seismological stations outside Albania. The stations taken into consideration are Trieste (TRI), Titograd (TTG), Athens (ATH) and Valsamata (VLS). We used the earthquakes of the same period 1984-1988, and the magnitude values of TRI, TTG, ATH, VLS were selected from CSEM monthly bulletins. These relationships are shown in Fig. 3, and their respective matematical expressions are as follows:

$$ML\ (TIR) = 0.73 + 0.82\ ML\ (TRI) \tag{24}$$

$$ML\ (TIR) = 0.12 + 0.96\ ML\ (TTG) \tag{25}$$

$$ML\ (TIR) = 0.61 + 0.80\ ML\ (ATH) \tag{26}$$

$$ML\ (TIR) = -0.89 + 1.21\ ML\ (VLS). \tag{27}$$

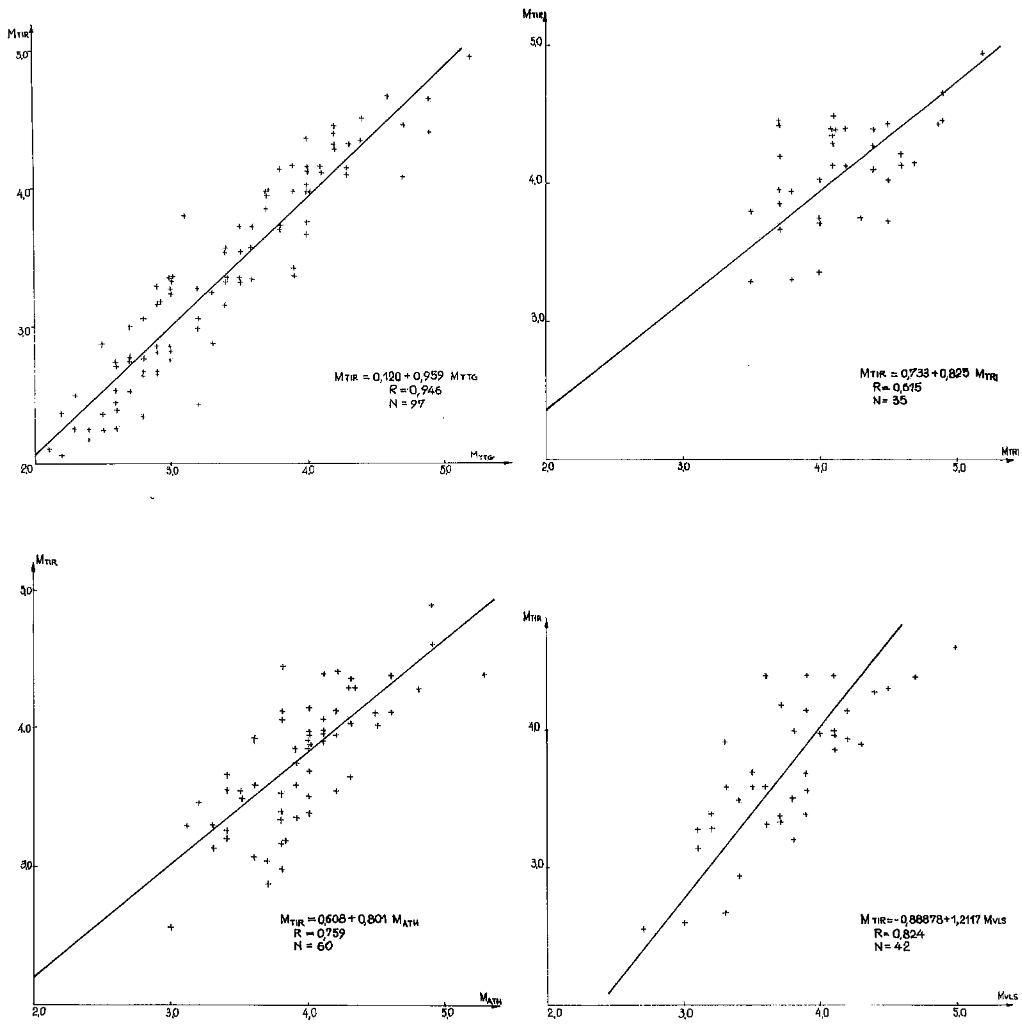


Fig. 3 — The relationships of TIR local magnitude with the magnitudes of some neighbouring stations.

The correlation coefficients and the number of data used are respectively: 0.61 and 35 for the pair TIR-TRI; 0.95 and 97 for the pair TIR-TTG; 0.76 and 60 for the pair TIR-ATH; and 0.82 and 42 for the pair TIR-VLS.

## CONCLUSIONS

Analysing about 500 earthquakes from the four year time interval, 1984-1988, with about 2000 data on amplitudes and periods, new relationships for magnitude determination of ASN records were determined. According to these formulas, we can estimate the magnitude making use of surface wave amplitude or the total signal duration. Some relationships between the magnitudes at Tirana station and neighbouring ones allowed us to convert the magnitude values of one station to another.

The new formulas have some advantages over the previous ones used in routine practice by the ASN:

1. based on the derived value of the Albanian anelastic crust attenuation coefficient, more realistic values of Ao - in the Richter magnitude formula - are obtained;

2. accepting as reference magnitude that of Tirana station, the magnitude relations for other stations of the ASN contain the relative corrections with respect to the master station: consequently, we have for the same earthquake less scatter of magnitude values for the stations;

3. they are more suitable for processing.

**Acknowledgements.** The authors with to thank K. Collaku for his help in the routine calculations. The data processing was done at the Institute of Informatics and Applied Mathematics of Tirana. We are grateful to M. Konomi and K. Gjoka for unsparing and valuable help. Some improvements were made in this paper during the stay of one of the authors (B.M.) at the Earthquake Research Institute, Tokyo. He would like to express his gratitude to all the staff of this institute.

## REFERENCES

Baker R.G.; 1970: *Determining magnitude from Lg*. Bull. Seism. Soc. Am., **60**, 1907-1919.

Bakun W.H. and Lindh A.G.; 1977: *Local magnitude, seismic moments and coda duration for earthquakes near Oroville, California*. Bull. Seism. Soc. Am., **67**, 615-629.

Bollinger G.A.; 1979: *Attenuation of Lg-phase and the determination of mb in southeastern United States*. Bull. Seis. Soc. Am., **69**, 45-63.

Ebel J.E.; 1982: *ML measurements for Northeastern United States earthquakes*. Bull. Seism. Soc. Am., **72**, 1367-1378.

Huangcheng G., Caizhong H., Peiyan Y. and Zhenfei L.; 1987: *Lg magnitude determination for the Eastern six provinces of China, (1)*. Acta Seism. Sin., **1**, 42-61.

Muço B.; 1978: *On magnitude determination of near earthquakes according to signal time duration*. Permbl. Stud., 14, **3-4**, 137-142 (in Albanian with English abstract).

Muço B.; 1982: *The Fierza lake and its influence on the seismicity of the zone around*. M. Thesis. Seismological Center (in Albanian).

Muço B. and Minga P.; 1991: *Anelastic-attenuation coefficient and the corrections of Ao-values of Richter magnitude formula for Albania*. Tecnophysics, submitted.

Nuttli O.W.; 1973: *Seismic wave attenuation and magnitude relations for Eastern North America*. J. Geophys. Res., **78**, 876-895.

Prochazkova D., Tobyas V. and Knaislova D.; 1985: *Magnitude relations for short epicentral distances at seismic stations PRU and KHC*. Travaux Geophysiques, **33**, 35-46.

Real C. and Teng T.; 1973: *Local Richter magnitude and total signal duration in Southern California*. Bull. Seism. Soc. Am., **63**, 1809-1827.

Richter C.F.; 1935: *An instrumental earthquake magnitude scale*. Bul. Seism. Soc. Am., **25**, 1-32.

Richter C.F.; 1958: *Elementary seismology*. Feeman and Co., San Francisco, 768 pp.

Wahlstrom R.; 1979: *Duration magnitudes for Swedish earthquakes*. Seismological Inst., Report No 5, Uppsala, pp. 1-47.

Wahlstrom R. and Ahjos T.; 1984: *Magnitude determination of earthquakes in the Baltic Shield*. Ann. Geoph., **2**, 553-558.

Willmore P.L.; 1979: *Manual of Seismological Observatory Practice*. World Data Center A for Solid Earth Geophysics, Rep. SE-20, pp. 1-141