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# An investigation of the seismicity applying the method of extremes values

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ABSTRACT: The method of extreme values based on Gumbel's theory of extremes and the Jenkinson's solution of the stability postulate, has been applied for the determination of the intensity of the expected macroseismic effect $I_{exp}$ in a certain return period T (in years). $I_{exp}$ has been taken as a parameter of the seismicity of the investigated area, the territory of Macedonia, Yugoslavia. There have been distinguished the isosurfaces, denoting certain high values of $I_{exp}$, that clearly contour the areas of high seismic activity.

## INTRODUCTION

The knowledge of the physics of the earthquakes still requires application of statistical models and methods in the research of "proposed future" seismic activity of the area under investigation.

If the concept of the "seismicity" indicates measure with which natural seismic activity is determined in a certain seismic active area, it is of great importance to determine the maximal magnitude or the value of the maximal expected intensity $I_{exp}$ of the earthquake in beforehand given return period T (in years).

Further investigations of the seismic hazard, as well as of the characteristics of the regional seismicity is enabled by taking $I_{exp}$ as one of the parameters with which the seismicity is described.

The results obtained by the application of the method of extremes in the investigation of the seismic activity on the territory of Macedonia and the bordering areas in the period 1901-1990, will be presented herewith.

## DATA

The territory of Macedonia is one of the most seismic active area on the Balkan Peninsula, where four disastrous earthquakes have occurred in the last 90 years (Tab.1).

Table 1. The strongest earthquakes occurred on the territory of Macedonia in the period 1901-1990.

| Date | Time | Epicentre | h(km) | M | I MCS |
|---|---|---|---|---|---|
| APR. 04. 1904 | 12h 25m | 41.72 N 23.08 E | 30 | 7.8 | 10 |
| MAR. 08. 1931 | 01h 50m | 41.28 N 22.50 E | 10 | 6.7 | 10 |
| JUL. 26. 1963 | 04h 17m | 41.02 N 21.42 E | 5 | 6.1 | 9 |
| NOV.20. 1967 | 07h 23m | 41.42 N 20.43 E | 20 | 6.5 | 9 |

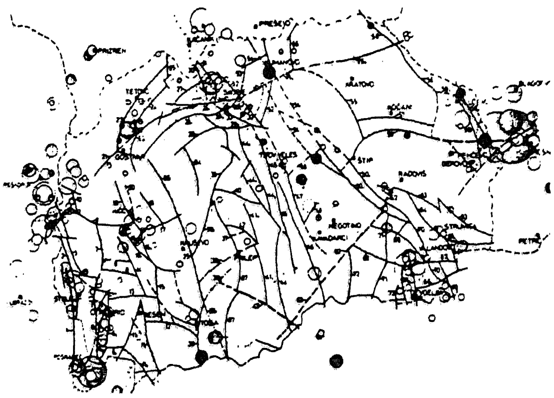

Fig.1 Seismotectonic map of Macedonia (Arsovski et al., 1976)

The neotectonic activity investigation indicates the existence of 19 separated morphostructural depressions on which edges there is strongly expressed seismic activity (Fig.1). By comparison of the distribution of the earthquake epicentres and the local tectonic structure, 42 local epicentral areas are separated (Pekevski, 1983).

It was found that the shape of the isoseismals of the earthquakes in these areas, and the attenuation of the intensity with epicentral distance, followed the local tectonic and geological structure.

## METHOD OF EXTREMES

The extreme values in a given distribution of a certain type of a geophysical element (magnitude or earthquake intensity, river water flow, air temperature, etc.) are

of a special importance. If such an extreme value was observed at least once or was never observed, it is possible to determine the probability that it will be observed at least once or once more for the selected sample of the given geophysical element.
This makes the theory of extreme values a matter of interest as it enables determination of the expected extreme values and the corresponding standard deviations via consideration of their distribution and frequency.

The wider application of the theory of extreme values was initiated by E. Gumbel (1958), who proposed three functional equations (known also as F-T types I, II and III) as solutions to the stability postulate published by M. Frechet in 1927. Today, the so called "Gumbel's distributions" corresponding to the F-T types I and III are widely used.

The solution of the stability postulate by A.F.Jenkinson (1965) which considerably simplifies the application of the theory of extreme values, includes all the three F-T types. This solution, which has little been applied in seismology, enables an easier determination of the parameters of the distribution of extreme values.

The Jenkinson's solution (1965), defining the size of the expected extreme value, applied on a given extreme value sample for return period T i.e., a mean interval expressed in years between two excesses of the extreme value $I_{exp}$, is of the following type:

$$I_{exp}=\sigma+\alpha*\{1-\exp[-k*\log(\log[T/(T-1)])]\}/k \quad (1)$$

where $k, \alpha, \sigma$ are the distribution parameters which have to be determined from the sample. For $k>0$, a solution which corresponds to the third Gumbel's distribution is obtained. In that case, the existence of a upper limit of the released energy is proposed.

Further it has been always taken that $k>0$.

The values of the extremes $I_{exp}$ for return period T is the principal parameter in addressing the problem of seismicity of the territory of Macedonia.

## RESULTS

Although the seismic activity of the territory of Macedonia has been instrumentaly followed since 1957, there is a great number of archive records with descriptions of the macroseismic effects of the occurred earthquakes from the beginning of this century. The homogeneity of the data was the main reason that macroseismic intensity was taken as input parameter, not the magnitude of the earthquakes (usually used in the seismic hazard and risk investigations). So the homogeneity of the data, is maintained by the earthquakes of which maximal intensity is 4 MCS and more.

For the earthquakes where the only data was their maximal observed intensity, maps of their theoretical isoseismals were drawn. For that purpose on the basis of 548 empirical maps of isoseismals (Hadzievski, 1976b; Hadzievski et al. 1985-1990) for 42 selected epicentral areas, the attenuation of the intensity $I_i$ with the epicentral distance $D_i$ was investigated, by the relation (Howell et al.,1975):

$$I_{max}-I_i=-a+b*\log(D_i^2+h^2)^{1/2} \quad (2)$$

where the values of a, b, h were calculated for two directions of extension of the isoseismals: across to the local tectonic structure and perpendicular to it.

The investigated territory was divided into 1620 cells (5x5 km). Each cell, in a certain year, has the extreme, maximal value of the observed or calculated intensity of the macroseismic effect of the earthquakes with epicentres on the territory of Macedonia and the bordering areas. In the years: 1901,1915,1941,1945 without any data, it was taken that the annual maximum "observed" intensity was zero. In that way there were formed 90 maps of annual maximal intensities (fig.2) according to which the samples for each cell were chosen.

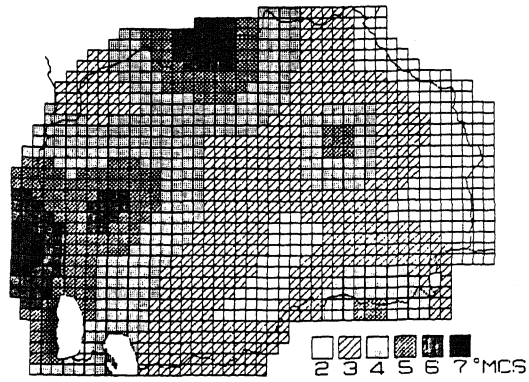


Figure 2. Isosurfaces with maximal, observed and calculated, values of macroseismic intensity from the occurred earthquakes in 1966.

The method of standard deviations (Makjanic, 1977) was used in the determination of the initial values of the parameters in Jenkinson's solution (1) and their final ML values were calculated by the maximum likelihood procedure. It was shown that the ML values of the coefficients in (1),could be calculated only for 705 samples. Using the linear regressions of the inital and the ML values of the coefficients (tab.2), the final values for all 1620 samples were calculated.

Table 2. Linear regressions of the initial and ML values of the coefficients in eq.1

$K_{ml}=0.0324+0.8674*K_o$ (corr. 0.8772)

$\alpha_{ml}=0.1070+0.9392*\alpha_o$ (corr. 0.9919)

$\sigma_{ml}==.0462+0.9810*\sigma_o$ (corr. 0.9965)

The maximal expected intensity $I_{exp}$ was calculated for return periods T=200 and 500 years, for each of the samples.

The surfaces with certain $I_{exp}$, intensity in MCS scale, are shown on fig. 3,4,5, whereas empty fields on fig.3,4 correspond to the samples on which ML procedure could not be applied.

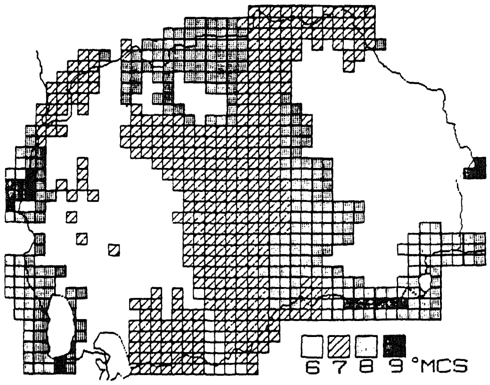


Figure 3. Isosurfaces with values of $I_{exp}$ calculated by ML coefficients for T=200 years ( probb. 63%).

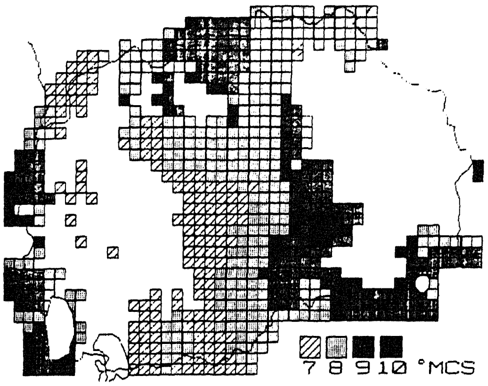


Figure 4. Isosurfaces with values of $I_{exp}$ calculated by ML coefficients for T=200 years ( probb. 95%).

## CONCLUSIONS

By apllying the method of extremes, by ML and correlated values of the coefficients of the Jenkinson's solution (1), there were calculated the values of the maximal intensity of the expected macroseismic effects of "future" earthquakes on the territory of Macedonia and the bordering areas.

It was shown that the longer the return period T, the bigger the standard deviation of $I_{exp}$, as well as the influence of "empty" (zero) annual extremes (years without data or with calculated $I_{exp}$=0), can lead to unreasonably high values of $I_{exp}$. Part of this could be seen on fig.3 and fig.4 where the occurrence probability for charted values $I_{exp}$ is 63% in the first case and 95% in the second one.

The seismogenic zones, which are characterised with high seismic activity are clearly pointed out by the surfaces with high $I_{exp}$ values (fig.5).

The presented procedure was used in the research of the seismicity in Macedonia for the period 1901-1980 (Pekevski, 1983) and the results were elaborated in the preparation of the seismogenic map of Yugoslavia i.e.

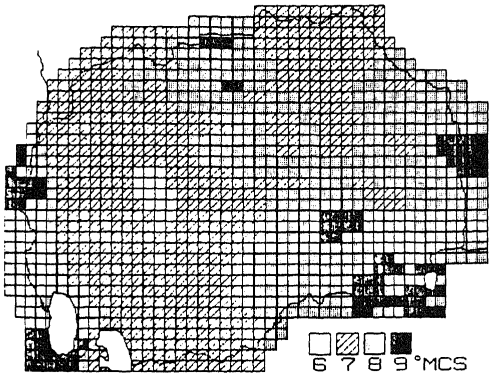


Figure 5. Isosurfaces with values of $I_{exp}$ calculated by correlated ML coefficients for T=500 years.

the part that concerns the territory of Macedonia (Ribaric et al.,1987).

In comparison with the earlier, the presented results show: increase of the number of the samples on which ML procedure could be applied (from 535 to 705), and decrease of standard deviations values of $I_{exp}$ calculated by ML procedure.

The problem of the determination of ML values of the coefficients in (1), should be overcomed by a thorough investigation of the nature and the parameters of the initial distributions of the chosen geophysical elements which include three F-T types (Makjanic, 1982).

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