# STRATEGIES TO EXPAND EARTHQUAKE MITIGATION IN MACEDONIA

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## SUMMARY

We can mark the limits of earthquake-hazards mitigation from the very broad, which include any type of action takin prior to an earthqauke to decrease its effects, to the very narrow, which contain specific actions to design, build, and retrofit structures to minimize earthquake damage, Nevertheless, to define smaller used and more effective mitigation activities and to encourage their application, this report defines earthquake mitigation as those actions that smaller impacts of earthquakes through controlling the quality and location of buildings and other structures. These are strategies that lessen the expected losses. They would be applicable through land-use regulations, building codes, building and design practiecs, siting structures, retrofitting buildings, and securing objects within buildings. Activities that support and continue the above mitigation measures are: estimating, monitoring and mapping hazards; listing the number or distribution of people and buildings, appraising their vulnerability and expected losses; developing improved seimic construction critera and practices; educating and training design professionals, emergency managers of public institutions and private industry; and researching new methods and impacts of policy. These activities are essential to the implementation of mitigation measures.

Earthquakes cannot be prevented but their effects can be mitigated. The paper is divided into sections:understanding the problem of earthquakes in Macedonia; impact of earthquakes on Macedonia economy; measures undertaken to mitigate the effects and what can be done to reduce damage in future.


## INTRODUCTION

Activities that support and continue the above mitigation measures are: estimating monitoring and mapping hazards; listing the number or distribution of people and buildings, appraising their vulnerability and expected losses; developing improved seismic construction criteria and practices; educating and training design professionals, emergency managers of public institutions and private industry; and researching new methods and impact of policy. These activities are essential to the implementation of mitigation measures. Earthquakes can not be prevented but their effects can be mitigated. The paper is divided into sections: understanding the problem of earthquakes in Macedonia; impact of earthquakes on Macedonia economy; measures undertaken to mitigate the effects and what can be done to reduce damage in future.

## ASSESSMENT OF SEISMIC HAZARD

The seismic hazard in Macedonia is evaluated by seismic zoning and microzoning study at industrial centers and evaluated of seismic oscillations in great construction sites. Seismic zonation map is applied in the planning, in the collecting of the projects documentation and the intensity determination of anti-seismic design.

The following maps must be obtained in the seismic zoning:

- map of source zones (seismogenic zone maps),

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- map of maximum seismic intensities $I_{max}$ which indicates the source generating these earthquakes,
- map of depending of intensities from ground conditions

Several moderate to large earthquakes (M > 4.5) have affected various parts of Macedonia in its 100 year history (Table 1). Many have caused significant damage (Seismic Intensity > VIII).

**Table 1 Some significant Macedonian earthquakes**

| YEAR | DATE | TIME | LAT. | LONG | M | I0 | DEPTH |
|---|---|---|---|---|---|---|---|
| 1905 | 24 Oct | 04 37 | 42.10 | 21.80 | 5.0 | 6.5 | 19.00 |
| 1906 | 28 Sep | 02 30 | 40 90 | 20 70 | 6.0 | 8.0 | 20.00 |
| 1906 | 8 Oct | 07 27 | 41 80 | 23 10 | 6.4 | 8.0 | 19.00 |
| 1907 | 17 Aug | 11 51 | 41 30 | 22 50 | 4.9 | 7.0 | 6.00 |
| 1910 | 22 Mar. | 02 06 | 41 20 | 22 00 | 5.0 | 8.0 | 10.00 |
| 1911 | 18 Feb | 21 35 | 40 90 | 20 80 | 6.7 | 9.0 | 15.00 |
| 1914 | 22 Mar. | 12 51 | 41 80 | 22 00 | 4.7 | 5.0 | 30.00 |
| 1921 | 30 Mar. | 15 05 | 41 70 | 20 50 | 5.8 | 8.0 | 13.00 |
| 1922 | 7 Dec | 16 22 | 41 80 | 20 50 | 5.7 | 7.0 | 17.00 |
| 1927 | 23 Jan | 19 14 | 41 70 | 22 70 | 4.9 | 6.0 | 21.00 |
| 1931 | 8 Mar | 01 55 | 41 30 | 22 50 | 6.7 | 10.0 | 16.00 |
| 1931 | 8 Mar | 01 55 | 41 30 | 22 50 | 6.7 | 10.0 | 16.00 |
| 1931 | 8 Mar | 05 03 | 41 30 | 22 50 | 4.6 | 7.0 | 6.00 |
| 1942 | 27 Aug | 06 14 | 41 60 | 22 50 | 6.0 | 8.5 | 12.00 |
| 1953 | 7 Jan | 01 18 | 41 30 | 20 60 | 5.6 | 6.5 | 19.00 |
| 1958 | 15 Mar | 06 27 | 40.50 | 20.20 | 5.3 | 7.0 | 16.00 |
| 1960 | 12 Mar | 11 54 | 41 90 | 20 90 | 5.7 | 8.0 | 6.00 |
| 1962 | 17 Sep | 19 44 | 41 10 | 20 80 | 4.4 | 6.0 | 9.00 |
| 1963 | 26 July | 05 26 | 41 80 | 21 30 | 6.0 | 9.0 | 15.00 |
| 1964 | 9 Dec | 18 28 | 41 10 | 20 70 | 4.5 | 7.0 | 11.00 |
| 1965 | 19 Mar | 4 35 | 41 30 | 22 80 | 4.5 | 6.0 | 4.00 |
| 1966 | 29 June | 0 49 | 41 40 | 20 40 | 4.6 | 7.0 | 7.00 |
| 1967 | 2 Dec | 12 44 | 41 30 | 20 30 | 5.3 | 8.0 | 14.00 |
| 1967 | 21 Dec | 0 9 | 42 00 | 21 00 | 4.6 | 6.0 | 9.00 |
| 1970 | 17 Mar | 7 0 | 41 40 | 20 90 | 4.5 | 6.0 | 16.00 |
| 1972 | 12 Aug | 11 47 | 41 10 | 22 80 | 4.8 | 7.0 | 5.00 |
| 1973 | 19 Aug | 16 33 | 40 80 | 20 70 | 4.5 | 6.0 | 20.00 |
| 1974 | 21 June | 1 9 | 41 20 | 22 80 | 4.7 | 6.0 | 25.00 |
| 1978 | 18 Aug. | 20 53 | 41 70 | 20 30 | 5.0 | 7.0 | 20.00 |
| 1979 | 26 Feb | 22 9 | 41 60 | 20 60 | 4.5 | 6.0 | 18.00 |
| 1980 | 19 July | 0 37 | 41 40 | 20 50 | 4.8 | 6.0 | 27.00 |
| 1985 | 28 Sep. | 14 50 | 41 50 | 22 30 | 5.1 | 7.0 | 21.00 |
| 1990 | 21 Dec | 6 57 | 41 00 | 22 30 | 5.8 | 7.0 | 13.00 |
| 1992 | 30 Mar | 19 32 | 41 10 | 20 90 | 4.9 | 7.0 | 23.00 |
| 1992 | 31 Mar | 22 1 | 41 10 | 20 90 | 4.7 | 6.0 | 15.00 |
| 1992 | 15 Apr | 21 51 | 41 00 | 20 90 | 4.5 | 5.5 | 18.00 |

On the Fig 1 is shown correlation between source of occurred earthquakes, neotectonic zoning and the distribution of maximum intensity. Based on the previous investigation, Timiovska L.(1996), a seismic zoning

map has been elaborated. Illustrated in Fig.2 are four zones of expected damages. Attenuation curves specifying how values of intensity level decreases with epicentral distance are essential for construction this zoning map. The boundaries zones are found from distribution of seismic activity and configuration of geological profile for each point. The map of source zones is composed by following the tectonical and seismological data, on the basis of a study on the correlation between great earthquake focus with tectonic structure and activity. Map of maximum seismic intensity is compiled on the basis of source zone map and correlation between seismic intensity with source characteristics and distance from the source: I = f(M,h,D).

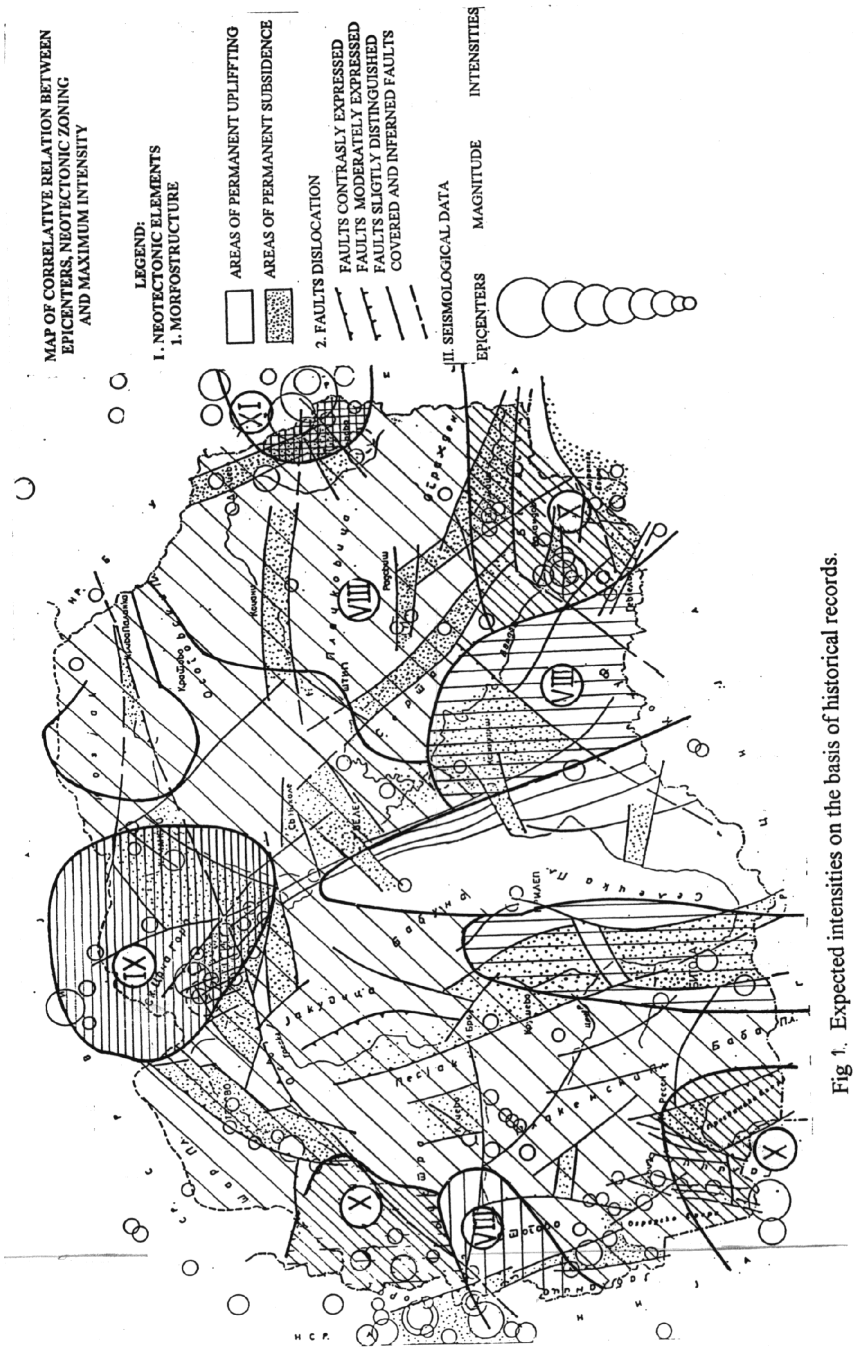


Fig 1. Expected intensities on the basis of historical records.

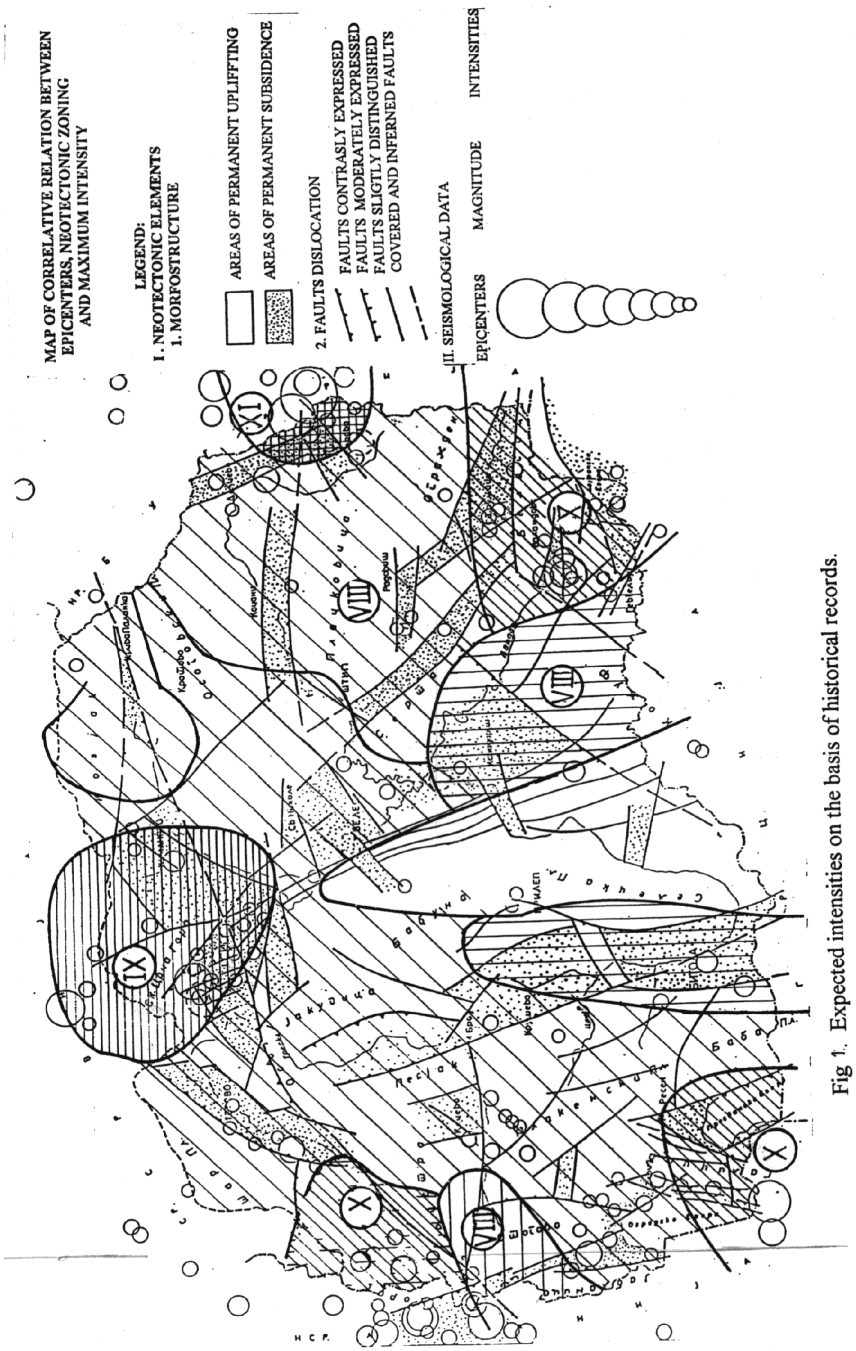


Fig 1. Expected intensities on the basis of historical records.

This macroseismic field equation is established following macroseismic data about large and perceptible earthquakes. As to the seismic microzoning that is seismic zoning in great scale, which takes into account the influence of ground conditions on seismic intensity. Maps of seismic zoning were compiled for Skopje city and industrial construction sites. The parameters on seismic microzoning maps were applied in the planning and design of construction, with using the function I = f(M,h,D,s).

## EARTHQUAKE DISASTER MITIGATION IN MACEDONIA

During the past years, analysis of earthquakes have been done by use of a number of approaches. Macedonia did not do much in this field due to the economic situation of the country. However, the situation changed with the earthquakes in Bitola and Gevgelija, in the last decade, which initiated activities for elaboration of a program for earthquake mitigation. Also , there lately have been efforts, for taking active part in different programs of United Nations as is the participation of Skopje city in the 'RADIUS' program under the initiative of IDNDR. The objective of these activities has been to prepare the world for seismic hazard and response to possible catastrophic effects, both from the aspect of protection of population and the economic aspect. The scenario for mitigation of earthquake consequences could include:

- assessment of earthquake risk, occurrence of earthquakes; estimation of hazards, hazard maps are essential and understanding vulnerability;

- for seismically prone areas to be done: long - term hazard prediction, planning land development and human site occupancy, load codes revisions, insurance and government response in a rational manner.

- the importance of training leading engineers in emergency management in my country is under-developed.

## CONCLUSIONS

For Macedonia as the central area of Balkan Peninsula, it is very important not to forget the consequences of the Skopje earthquake of 1963, and plan corresponding protective measures even in the case that such a catastrophic earthquake never occurs again. There must be a coordination between disciplines whose results express the nature of mitigation of seismic hazard as well as the benefits for the society. There is a need for getting an insight into the geology of Macedonia, in order to compare deferent approaches of analysis used in adjacent countries. This refers to investigation of structural geology for obtaining an information on potential earthquake focus and urban geology(application of geology in planned construction of towns) with including geophysical analysis for understanding and reduction of possible damages.

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