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ENGINEERING GEOLOGY MODELS AS APPLIED IN MICROZONATION MAPPING WITH A CASE HISTORY FOR THE TRIKALA AREA GREECE

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ABSTRACT

The geoseismic parameter usually used in the separation of geoseismic zones of a microzonation map is the seismic intensity (I). For a given area the seismic intensity depends on many factors the most important been a) the geologic stratigraphy b) the tectonics c) the ground water d) the epicentral distance. The first three factors can be incorporated in a geological model having definite geoseismic impedance. If Io the epicentral intensity and h the focal depth the intensity I in any area located in a distance Δ from the epicenter may be calculated by the Shebalin formula I=k log $\sqrt{1+\left(\frac{\Delta t}{h}\right)^2}$. In this min intensity a value of 1 to 4 MM units is added for each Eng. Geology model existing in the mapable area. Values of increase of the seismic intensity are given for about 15 Engineering Geology models.

Keywords: geoseismic parameter, seismic intensity, moment magnitude, microzonation mapping

INTRODUCTION

The pioneers in geoseismic microzonation mapping were Richter and Neumann for the U.S.A. and Medvedev and Popov for the former Soviet Union. Richter mapped the California area and the Russians areas of European Asian Russia. The purpose of these maps was to apply a microzonation distribution of the seismic hazard in the given area according to some geoseismic parameter. Even though different seismic parameters can be used in mapping, the geoseismic parameter of seismic intensity was used, which is determined by observing the seismic damages. In relation to the method used the following must be mentioned. Richter differentiates the zones according to observed damage. Medvedev divides the zones of intensity according to the velocity of the seismic waves and Popov according to general Engineering geology criteria. In Greece, a contribution to the microzonation mapping was made by the first author of this paper in a congress of Greek Geological Society on earthquakes in 1984. In this paper the design of the models of seismic hazard followed the Popov method whose classification of Engineering Geology models, modified for Greek conditions was presented by the first of the authors, in the 1984 Greek Geological Congress.

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DEFINITIONS

Microzonation map (microregional seismic maps)
The quantitative evaluation of the differences in seismic intensity in various types of soils allows the designing of geological maps with the seismic inputs. Data from these maps combined with data on the seismisity of the area are used to design microregional seismic maps that show the seismic hazard as a function of the maximum expected seismic intensity. Data on the seismisity of the area are usually taken from regional seismic maps that are small-scale maps showing data of the maximum expected seismic intensities on average soils in a wide area. Therefore, there is a division between regional and microregional microzonation seismic maps. Directions for the compilation of maps of these types are given by Richter (1959) and Medvedev (1960-65) and Popov (1959). The form of these curves is shaped according to technical and geological data and the analysis of seismic oscillations caused by powerful earthquakes and according to data from small earthquakes and measuring of the propagation velocity of the seismic waves. The mean differences in seismic intensity for various forms of rocks, achieve values that are analyzed later. These differences are added or decreased from the general value of seismic intensity pertaining to the area or added to the intensity of standard rock, that is, granite.

Method of seismic planning
The mapping of the seismic intensity according to the importance of the project in need of seismic protection can be combined with both the methods applicable to seismic design: The deterministic and the probabilistic. According to the first method the seismic focus that gives the highest magnitude or the focus nearest to the project will be taken into account. This magnitude is called maximum probable earthquake. The selection is based on a) historical or instrumental data b) on data on the active length of the seismic fault c) on palaeoseismic data and measurement. The maximum magnitude stemming from this data is increased by ½M and is used as the design magnitude. The probabilistic method of design is used in high value projects and takes into account all seismic focuses able to threat or hit the project with criteria for the seismic hazard the maximum expected seismic acceleration. According to this method it is assumed that a) no structure is totally safe, b) in a lengthy time frame no seismic acceleration or other form of seismic movement can be considered maximum and c) every fault, active or seismic, is considered to be of the same seismic hazard ness. Designing according to this method has as a basic criterion the maximum expected seismic acceleration every increase of which must respond to a given percentage of probabilistic seismic hazard.

GEOSEISMIC AND GEOLOGIC PARAMETERS

The meaning of some geoseismic parameters or terms used in this paper is analyzed as follows.
Fault: rupture taking place on a plane of weakness along which there has been displacement of the sides relative to one another. They are classified as normal, reverse and strike slip faults.

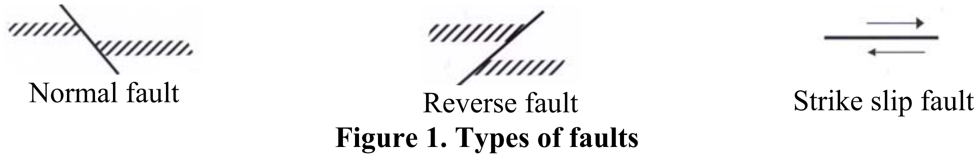


Figure 1. Types of faults

Active fault is a fault that has given a recorded or geologically deduced slip during the last 35000 years. Seismic fault is a fault that can give an earthquake and has the following characteristics a) it develops at a depth of 7-20km b) it intersects the geological bedrock c) it has a length of over 2,5km and d) has given microseismic activity with a magnitude of M>3,5 R. Focus of the earthquake is the starting point of a slip in an earthquake-producing fault. The epicenter of the earthquake is the projection of the focus connected to the earth centerline on the surface. Focal depth is the depth of focus h. Epicentral distance Δ or Δt is the distance of the area under investigation from the epicenter. Radius of perceptibility (r) is the average radius from the epicenter of the total area in which an earthquake is felt. Gutenberg and Richter (1956) gave the following relations between radius of perceptibility with epicentral intensity Io and unified magnitude M.

$$r=0{,}5Io^3-1{,}7 \text{ (Io seismic intensity in MM)} \quad (1)$$

$$\text{And } r=1{,}4(M - 0{,}614)^3 \text{ (M unified magnitude)} \quad (2)$$

The same authors (1942) determined the relation of (r) to focal depth (h) and epicenter intensity (Io).

$$Io = 1{,}5 + 3\log\left(\frac{r^2}{h^2}+1\right) \quad (3)$$

Seismic attenuation: is the decrease in average intensity of shaking with distance from the epicenter as in the following figure.

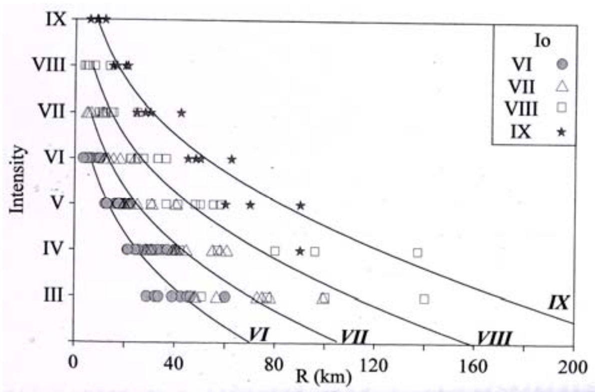


Figure 2. Attenuation as a function of Δ (after Udias 1999)

Seismicity of an area is the distribution of the foci and magnitude of earthquakes that these foci may produce. Seismic hazard is the distribution of the expected seismic accelerations in an area.
Seismic coefficient k:

$$k = a/g \quad (4)$$

Where a=earthquake acceleration and g=acceleration of gravity. Structure line direction is the strike of a fault or of the axis of a fold. Geologic structure is a term, which contains geologic stratigraphy and tectonics. Geologic substratum or bedrock is a geologic formation of an age greater than tertiary. Structure trend is the direction of an ore outcrop or a main folding or an orogenic zone. Isoseismic or isoseismal line or contour is a line-separating bands of predominantly one intensity rating in some scale intensity. Seismic impedance p_c is the product of the velocity of the longitudinal wave (V_p) and the density of the geologic formation ρ. This product influences the difference in intensity. Earthquake acceleration (a) in cm-sec^{-2} is related to the seismic intensity by the formula:

$$\text{Log } a=0{,}308I - 0{,}04I \text{ (Newman)} \quad (5)$$

$$\text{Or Log } a = \frac{I}{3} - \frac{1}{2} \text{ (Richter)} \quad (6)$$

$$\text{Or } a=0{,}45 * 10^{0{,}5Ij} \text{ (Kawasumi)} \tag{7}$$

$$\text{Or } \log a_{max}=-0{,}038+0{,}216(Mw-6)-0{,}777\log R+0{,}158G_3+0{,}254G_2 \tag{8}$$

Where Ij = Japanese seismic intensity scale, G3 G2=coefficients with values 0 to 1 depending of soil character and R:

$$R=\sqrt{d^2+r^2} \tag{9}$$

Where d= distance of area from seismic fault and r=focal depth. Velocity of shear wave calculated on the basic of N of the SPT (uncorrected) and the depth by the formulas (Sykora, 1987).

$$\text{Clay } Vs=195\ N^{0{,}17}\ D^{0{,}2} \tag{10}$$

$$\text{Sand } Vs=250\ N^{0{,}17}\ D^{0{,}2} \tag{11}$$

$$\text{Sand and gravel } Vs=275\ N^{0{,}11}\ D^{0{,}2} \tag{12}$$

Where Vs=shear wave velocity f/sec, D=depth in f below ground surface.

$$V_p=1{,}66\ Vs \text{ and } V_R=0{,}9Vs \tag{13}$$

Natural period of construction:

$$To=\frac{1}{N}=ch^{3/4} \tag{14}$$

Where h=height of structure in ft, c=0,03 for reinforced concrete and N=frequency.
Natural period of soil profile T:

$$T=\frac{4t}{Vs} \tag{15}$$

Where t= thickness in ft of loose sediment and Vs=shear velocity (ft/s).
Amplitude of surface (Rayleigh) wave: depending on rock formation as in following geologic section

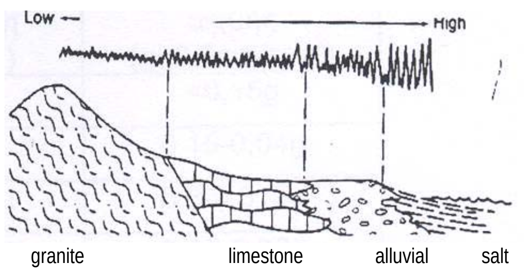


Figure 3. Seismic amplitude in different rocks

Earthquake frequency (annual):

$$\log N(M)=a-b\ Ms \text{ (Gunteberg – Richter, 1954)} \tag{16}$$

Where a=8 to 9, $b \cong 0{,}6-1{,}4$ and N=number of earthquakes larger than M.

SEISMIC MAGNITUDE

Richter (1935) defined the magnitude of a local earthquake as the logarithm to base 10 of the maximum seismic wave amplitude (in thousands of a millimeter) recorded on a standard seismograph located at a distance of 100 kilometers from the earthquake epicenter. Except the Richter local scale M_L, another four scales are currently is use: M unified magnitude Richter-Gutenberg, Ms scale based on the surface Rayleigh wave, Mb scale based on the mass waves P and S and Mw seismic moment scale. The Mw scale was introduced by Kanamori (1977) who defined it by the formula:

$$\text{Log Mo}=1{,}5M_w+16{,}1 \qquad (17)$$

Where M_o=seismic moment = $\mu \bar{u} A$, where μ= shear modulus $\cong 3{,}3*10^{-4}$Mpa, $\bar{u}$ = mean transverse slip of the fault and A= fault section. For calculating M_w use:

$$M_w=\log M_o(nt\text{-}w)+7/1{,}5-10{,}7 \qquad (18)$$

According to this formula the Chile earthquake had a magnitude of 9,5 and Alaska 9,1. The numerical relations between the various scales are given in the following table with maximum magnitude 9,5 in which the rocks may melt.

Table 1. Numerical relations among different magnitude scales (After Krynisky with modifications)

M Richter-Gutenberg Unified Magnitude	M_b Body Wave	M_L Local or Richter magnitude	Mo (dyne-cm) Seismic Moment	Mw Moment	Ms Surface Wave
5.4	5.0	5.4	$6.3x10^{23}$	5.4	5.0
5.9	5.5	5.9	$6.3x10^{24}$	6.0	5.8
6.7	6.0	6.4	$7.7x10^{25}$	6.7	6.7
7.5	6.5	6.9	$1.0x20^{27}$	7.5	7.5
8.3	7.0	7.5	$2.3x20^{28}$	8.4	8.3

The active length of a fault is related to the Ms by the formula:

$$M_S = a + b \log_{10} L \qquad (19)$$

Where A = 5,65 and b = 0,98L in Km or more recent form, given by Bonila (1985)

$$M_S = 6{,}10 \pm 0{,}25\ \% + (0{,}70 \pm 0{,}14)\ \text{Log}_{10} L \qquad (20)$$

L= active (slipping) length of the fault, Ms =surface wave magnitude. An empirical relation between L, Mw and I is given in the following table.

Table 2. Numerical relations among Mw, L and I (MM)

Fault length L (km)	Moment Magnitude	Richter Magnitude	Mercalli Intensity
	1,0-3,0	2	I
	3,0	2	II
	3,9	3	III
2,3	4,0		IV
	4,9	4	V

3,7	5,0	5	VI
6,1	5,5		
	5,9	5-6	VII
9,0	6,0	6	VIII
16,0	6,5		
45,0	6,9	7	IX
	7,0	7 & 8	X
169,0	7,5		
342,0		8,0	XI
954,0		8,5	XII
1800		>8,0	

SEISMIC INTENSITY I

Seismic intensity is the measurement of the level of damage occurring to man made structures the extent of the distortion of the ground and the reaction of people and animals to a given seismic vibration. The first scale for measuring the intensity of the earthquake, which is rarely used today, is the ten-units scale of Rossi-Forel 1880. In 1906 the Italian Seismologist and Volkanologist J. Mercalli introduced the 12units scale, which was modified by Wood and Newman by the adding of acceleration values and is used today in the U.S.A. The same 12units scale, modified by Sieberg and Kankani is used in Europe. In Japan the 7units Kawasumi scale I_j is used which relates to the MM scale by the relation:

$$I=0,5+1,5Ij \quad (21)$$

In the former Soviet Unions states two 12units scales are used the GEOFIAN of the Geophysical Institute of the former U.S.S.R. and the Medvedev, Sponheuer and Karnic MSK scale. Io and I as measured in the epicentre symbolize the seismic intensity in the area under investigation. The relations among the scales MM, M, GEOFIAN MSK & I_J are given in the following table No3. All scales of seismic intensity are based on the observations and it is not possible to be measured by an instrument.

Table 3. Relations among seismic intensities scales

MODIFIED MERCALLI MM USA	JAPANESE KAWASUMI	MERCALLI Europe	GEOFIAN F Soviet union	MEDVEDEV, SPONHEUER KARNIK
I	0	I	I	I
II	1	II	II	II
III	2	III	III	III
IV	2.3	IV	IV	IV
V	3	V	V	V
VI	4	VI	VI	VI
VII	4,5	VII	VII	VII
VIII	5	VIII	VIII	VIII
IX	5,6	IX	IX	IX
X	6	X	X	X
XI	7	XI	XI	XI
XII	7	XII	XII	XII

ENERGY (E) OF THE EARTHQUAKE

The relation between Energy of an earthquake and the surface wave magnitude scale (Ms) according Gutenberg is:

$$E=10^{5,24}*10^{1,44ms} \text{ (Gutenberg)} \quad (22)$$

Since $10^{1,44}$=27,54 one unit of increase of magnitude is equivalent to 27,54 fold increase in energy. As a function of M (unified magnitude):

$$Log_{10}E=9,4+2,14M-0,054M^2 \quad (23)$$

Relation between earthquake magnitude and nuclear explosion energy release
Romney (1959) and Riznichenko (1960) agreed to the formula:

$$M=3,65+nlogy \quad (24)$$

Where, n=0,5-1,0 and y=explosive yield expressed in kilotons of TNT equivalent.

The relation between M and Io
The relation between M and Io according Gutenberg and Richter (1956) is the following**:**

$$M=1+(2/3)\ I_o \quad (25)$$

expressed by the next nomograph.

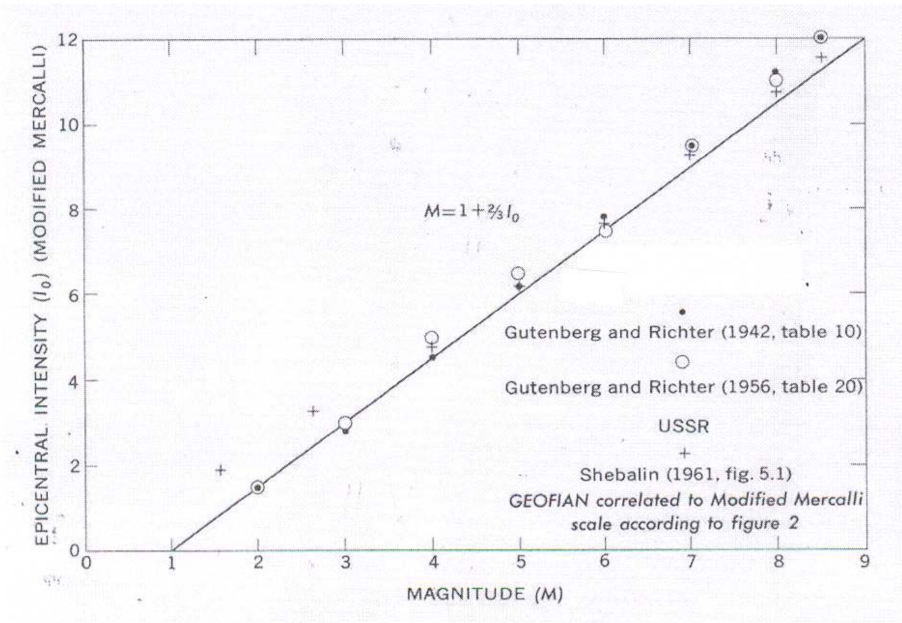


Figure 4. Relation of M and Io (After Barosh 1969)

From epicentral intensity Io determined by the above nomograph the intensity in a distance Δ from the epicenter may be calculated by the Shebalin (1959) formula.

$$\text{Io-I} = k \log \sqrt{1+\left(\frac{\Delta}{h}\right)^2} \quad (26)$$

Where h is the focal depth of the earthquake, k is a coefficient taking the value 2,8 to 4,5 for normal earthquakes with a mean value of 3,6, and 4,5 to 7,5 for deep earthquakes with mean value of 6. Most recent investigations have been resulted to the following formula.

$$I = Io - a \log\left\{\frac{1}{h}\left(\Delta^2 + h^2\right)^{1/2}\right\} - b\left\{\left(\Delta^2 + h^2\right)^{1/2} - h\right\} \text{ (after Udias)} \tag{27}$$

Where h = focal depth, Δ = epicentral distance, Io =epicentral intensity in MM, α =coefficient depends on geoseismic design and b =coefficient depends on the degree of attenuation.

SEISMIC INTENSITY DEPENDS ON MANY VARIABLES

The intensity of an earthquake at any specific point depends on many variables including earthquake magnitude epicentral distance, acceleration period, duration and amplitude of seismic waves, type of geologic formation, geologic structure, slope of the ground, depth of water level, type of construction, quality of workmanship and the natural period of structures and of soil profile and the specifications of static analysis. All intensity scales recognize the influence of the design of the structures and the quality of construction and the successive application of any scale, depend on uniformity of construction quality.

Relation of seismic intensity to the impedance

Medvedev (1961) used the impedance and the depth of ground water level as a basis for estimating the relative difference in intensity and determined that:

$$n = 1{,}67\ \left[\log\left(v_s P_s\right) - \log\left(u_n P_n\right)\right] + e^{-0{,}04h^2} \tag{28}$$

Where n=the increase intensity of the Geofian scale for geologic formations with characteristics u_n P_n with respect to standard ground with characteristics u_s, P_s and h equals depth of ground water level in kilometers. The increase n is given to 0,1 intensity unit to differentiate the various types of ground in seismic response as the intensity change in general is not particularly great. In practice the increase is rounded off to whole intensity units

Intensity variation as a function of focal depth

In some local areas most earthquakes are considered to originate at about the same depth thus the variation of intensity caused by different focal depths in such an area may be small. Information on the variation caused by different focal depths is important in attempting to compare the distribution of effects of earthquakes of different focal depths and to extrapolate earthquakes effects to the shallow depths in which unclear testing is conducted. According to Shepalin (1959) the epicentral intensity increases with decreasing focal depth. He proved the following relations:

$$Io = 1{,}5\ M - 3{,}5\ \log h + 3.0 \text{ for normal earthquake for } h<Hu=80km\ \alpha\text{nd,} \tag{29}$$

$$Io = 1{,}5\ M - 3.4\ \text{Log}\ h + 5{,}4 \text{ for deep earthquake} \tag{30}$$

Where Io in GEOFIAN units and 80km<h<640km. For the I_{max} Karnic (1969) give the following relation.

$$I_{max} = 1{,}5Ms\text{-}1{,}8\log_{10}h + 1{,}7 \tag{31}$$

Seismic intensity as a function of geology

The principal geologic parameters that affect the seismic intensity are the geological, stratigraphy, geologic structure, the physical and engineering properties of the subsurface material, the depth of ground water level, geomorphology, slope and thickness of loose surface sediments and probably the geologic form of focus area.

Seismic intensity as a function of geologic structure
Part of the variation in intensity could possibly be due to the trend of a linear source, which most likely parallels regional structure. The direction of the trend of basic geologic structures usually shows the direction of isoseismals. According to Newman (1954) the trend of regional structures and not the direction of a linear source are responsible for elongated isoseismals. Possibly the structural lines such as faults and folds are not as important in affecting seismic intensities as the resultant distribution of rock types caused by geologic structures. It was also verified that where tectonic stresses cause changes of rock formations by crushing and shearing it also affects the intensity (Popov, 1959). Experience from many regions of the world indicates that the distribution of isoseismals is partly dependent on the regional trends of the geologic structures. It was also propable that the effects of geologic structures on the shape of isoseismals are due to travel path of the earthquake waves or in differences of mechanism of earthquake origin. In the geoseismic mapping, a wide area must be divided in segments in relation to the epicenter distance as the seismic intensity depends on epicentral distance.

Intensity variation as a function of geologic stratigraphy
It has long been recognized that similar constructions in proximity and built on different geologic formations may suffer vastly different effects from earthquakes. This variation due to different responses of the underlying material is generally the principal factor causing the range of intensities at any epicentral distance. Various researchers (Newman, Popov, Medvedev) came to the conclusion that the minimum seismic intensity is noted on granite or granitic equivalents and the maximum on the loose water bearing formations. In general at a given epicentral distance the relative range in intensity given by these and other researchers is 4 units from granite outcrops to thick water saturated alluvium. According to Medvedev the mean increase of seismic intensity in relation to granite is a function of seismic velocity V_p. The following nomograph gives the intensity increase in relation to V_p.

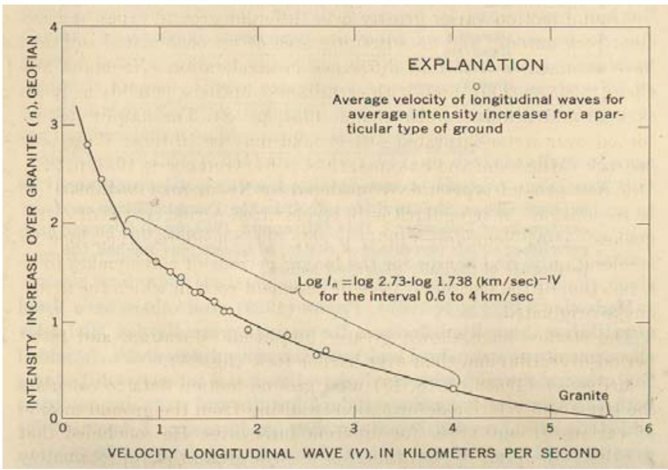


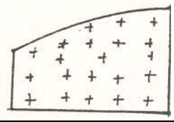
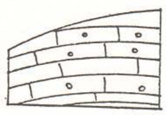
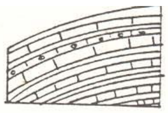
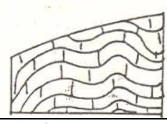
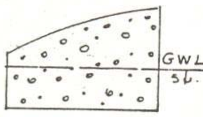
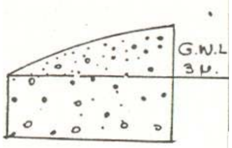
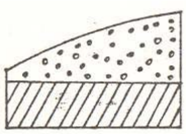
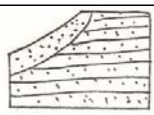
Figure 5. Relation of velocity longitudinal wave (km/sec) to intensity increase over granite (After Medvedev)

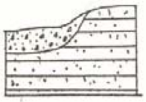
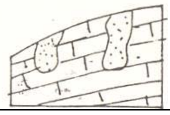
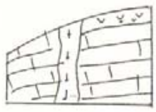
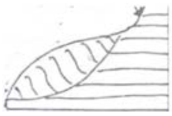
STEPS OF THE DESIGN OF A MICROZONATION MAPPING

In order to design a microzonation map the following steps must be followed.
1) An Engineering Geology map must be available on a scale depending on the extent of the under investigation area. 2) The design earthquake magnitude should be the max probable earthquake. 3) Epicentral intensity may be calculated by the formula M=1+2/3 Io (MM). 4) The focal depth may be known from seismologic stations of the area or may be calculated by the formulas 29, 30 or 31 in this paper. 5) Intensity on the area under investigation may be calculated by the Shebalin formula (25) and is considered to be the min referring to granite terrain and is called standard. 6) The increase of

intensity above the standard for each geologic unit of the available Eng. Geology map is taken from the following table No 5 after correction for ground water level.

Table 5. Eng. Geology models for correction of seismic intensity. Reference rock granite with increase 0

Model No	Representative Eng. Geology symbols	Geological description	Seismic Hazard		Increase for G.W.L.
			General classification	Increase of intensity	
1		Granite or equivalents without erosion and fracturing	Safe foundation without plastic deformation when I ≤ 10	0	0
2		Thick sedimentary rocks limestones, sand or metamorphic quartzite or gneiss	Safe foundation but less than in case 1 subject to plastic deformation or fracturing	0,2-0,8	0
3		Sedimentary rocks of layered structure medium thick, porous of acute dip or schist foliated, tuffs, sandstone, shale or mica schist Mesozoic marls or gypsum	Not dangerous if W.L.> 5m	0,7-1,1	0
4		Dry clay schist or sandstone Paleogene flysch	Safe without water bearing stratum. Dangerous with GWL	1,2-1,6	0,5-1
5		Alternate marls sandstone and shale in flysch formation of dip or slope up to 45^{o} in a dry state.	Not very great seismic hazard without GWL	1,0-2,0	0,5-1
6		Thick bedded alluvial sediments sands, clay gravels with water le-vel in depth below 5m	Not dangerous for water level >5m	2,0-2,5	1-1,2
7		Thick-bedded alluvial sediments, sand, clay, gravel with water table in depth less than 5m.	Clay more dangerous than silt and sand	1,6-2,4	1-1,2
8		Alluvial of less than 5m in thickness over solid bedrock	Hazards especially on slopes. The hazards increase as the difference in hardness of alluvium to bed rock increases	2,3-3,0	1-1,2
9		Wet marsh lands	Very dangerous on slope and horizontal ground	2,3-3,9	1-1,5

10		Natural fills with mining waste at over 3-10m thickness	Very dangerous especially when not compacted	2,3-3,9	1-1,5
11		Alluvial cones on sloping bedrock	Very dangerous especially on sloping bed rock	2,0-3,9	1-1,5
12		Karstic limestone terrain without lithification of the filling	Very dangerous on active karst due to differential settlement	2,0-4,0	0,5
13		Contact of volcanic intrusions in sedimentary or metamorphic rocks	Very dangerous especially when there is great difference in mechanical properties.	1,0-4,0	0,5
14		Old landslides, fills, marsh lands, sandy sediments prone to liquefaction a) with b) without GWL	Foundation on case (a) or case (b) need for soil improvement	1,0-4,0	1-1,5
15		Hard or semihard soil cover of active faults visible or not visible	Extremely dangerous due to vibration	3,0-4,0	1-1,5

A case history in microzonation mapping of Trikala area

The Trikala city is located in a plain of Thessalia county at a road distance of 330km NW from Athens. The microzonation map of wide city area was based on a Engineering Geology map prepared for the program of "Urban planning development" of the Greek Ministry of Public works. The planning geoseismic map was made according to the deterministic method for the seismic parameter of an earthquake of the April 30, 1954 of size 7 on the Richter scale induced a seismic intensity of VII MM for the geological bedrock and X MM for the alluvium covered Neogene's sediments of the Trikala plain. The map was planned to separate zones of different Eng. Geological Constitution for each of them the following three geoseismic parameters were defined (i) seismic intensity (ii) seismic acceleration (a) and (iii) seismic design coefficient (k). For the parameter (I) the values for each geologic formation were calculated on the basis (i) of the values of I of VII MM for geologic bedrock an X MM for the thin alluvium covered Neogene formations of the Trikala plain of earthquake of April 10, 1954 and (ii) according to the empirically recognized difference of seismic intensity of 4 MM units between the firmest rock (granite) and the weakest i.e. water bearing sand. The values of parameter (a) were calculated by the Richter formula

$$\log a=\frac{I}{3}-0,5 \tag{32}$$

in cm/sec^2 taken in account the values given in the modified Mercalli scale. The values of seismic design coefficient ere calculated according the Greek seismic regulations in force the period of mapping as product for four other coefficient a, b, c, d which are: a) Coefficient for seismic intensity with values of 1 for earthquake up to VIII MM and 2 for earthquake of I>VIII, b) coefficient of ground resistance = a/g, c) coefficient of height of the buildings calculated by the formula

$$c=\frac{2r}{2n+1} \tag{33}$$

where r is class of floor and n is number of floors taken as 4 d) ground foundation coefficient with a value of 0,8 for good ground quality and 1,3 for lower quality. According the above planning the next table of seismic parameters of the map was compiled.

Table 6. Seismic parameters for the microzonation map of the Trikala area

A/A	Geological or soil unit	Seismic intensity MM	Seismic acceleration mm/sec^2	Coefficient of seismic design according to Greek build code (G.S.C.)	Suitability for foundation	Symbol on map
1	Geological bedrock	VII	475	0,06	Suitable for any structure weight	VII MM
2	Neogene marls and sandstones	VIII	1000	0,12	Multistoried buildings, small constructions	VIII MM
3	Diluvia partially cemented	IX	2100	0,24	Light structures buildings of 4-5 floors	IX MM
4	Cohesionless alluvial, water bearing on neo-gene bedrock	X	4650	0,36	Suitable for light structures and small scale works	X MM
5	Marshes, dunes, bogs, talks water bearing sands	XI	6000	0,45	Unsuitable for any use	XI MM

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