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Seismic Activity and Essential Seismological Characteristics of the Kosovo Territory

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Abstract. In this scientific work presented are Seismic basic characteristics. Reliable seismic hazard assessment depends mainly on the level of consistency, quality and amount of data in earthquake catalogues. The lack of good seismic activity data may often affect the quality of the assessment.
This short review of the seismic activity affecting the territory of Kosovo throughout the time, points out that this region should be considered having high seismic hazard potential. Having in mind that in the last two decades, the region is undergoing very fast urbanization characterized with extensive infrastructure development and building modern high rise structures with different use: residential, administrative, commercial and buildings belonging to essential facilities such are schools and hospitals it is necessary to be aware of the seismic hazard to which the built environment can be exposed and all possible consequences of such event. In order to be able to assess the seismic hazard, it is necessary to integrate data from various field such as seismology, Seismotectonic, geology, tectonics, geophysics etc.

Keywords: Seismology, Seismic Activity, Earthquake

1. INTRODUCTION

The territory of Kosovo in terms of seismicity, represents a space, where a indigenous powerful earthquakes can be expected as well as an earthquake originating from the seismic sources in the bordering regions with the neighboring countries, such that might cause significant damage on the built environment yielding great material and human losses. Since the establishment of the Kosovo Seismological Network in 2008 in Kosovo, there have been over 1100 earthquakes with magnitudes of 1.5 to 5.2 on the Richter scale.
Seismic events show that within 15 years the territory of Kosovo has been hit by three medium-strong earthquakes of magnitude 4.8-5.2-5.7, with human victims (1 victim) and material damage.
The phenomena of autochthonous local seismicity and the seismicity caused by distant earthquakes, testify to the ranking of Kosovo in the ranks of territories with a high seismic activity.
The results of this study have a special importance, both in the scientific-professional aspect and in the practical aspect, because they give a clear picture of the seismic risk of Kosovo

2. SEISMICITY OF THE TERRITORY OF KOSOVO

For a well-founded seismic hazard study, we utilized in the first phase all the available information for the damaged earthquakes of the region, such as the earthquake catalogues of Albania, Montenegro, Croatia, Serbia, Macedonia, Greece (Thessaloniki), the earthquake bulletins of the International Seismological Centre (ISC), the southern and southern-eastern European earthquake catalogues.
Based on the above mentioned sources, a new catalogue expressed in for the territory Kosovo was prepared, including about 156 events with magnitude M≥3.5 for the period of time 1456 until 31/09/2020, utilizing all the available information.
The scale of seismic studies will never be of the right level, since it must be borne in mind that any new earthquake, which will hit the territory, will bring new data to supplement the existing ones.

From the seismological point of view, Kosovo is a region with high seismic activity, which has been hit in the past with 212 earthquakes, Magnitude > 3.5, period 1456-2019, and may be hit in the future by very strong autochthonous earthquakes, which have shallow foci, which are generated in the Earth's crust, maximum 15-25 km deep underground, tab.1, fig.1

Table 1. Earthquakes number by Magnitude submitted in the table, period 1456-2019, Mag .3.5

Nr. Earthq.	**112**	**60**	**22**	**11**	**3**	**3**
Magnitude	**3.5-3.9**	**4.0 - 4.4**	**4.5 - 4.9**	**5.0 - 5.4**	**5.5 - 5.9**	**6.0 - 6.2**
Intensity	**4.16-4.83**	**5.0 - 5.66**	**5.83 - 6.5**	**6.6 - 7.33**	**7.5 - 7.6**	**8.73 – 9.0**

2.1 Magnitude, frequency and distribution the earthquakes

Based on the catalog of earthquakes and seismicity of the territory of the Republic of Kosovo, the magnitude, frequency and distribution the earthquakes in years are presented in the graphs below, fig 1,2,3.

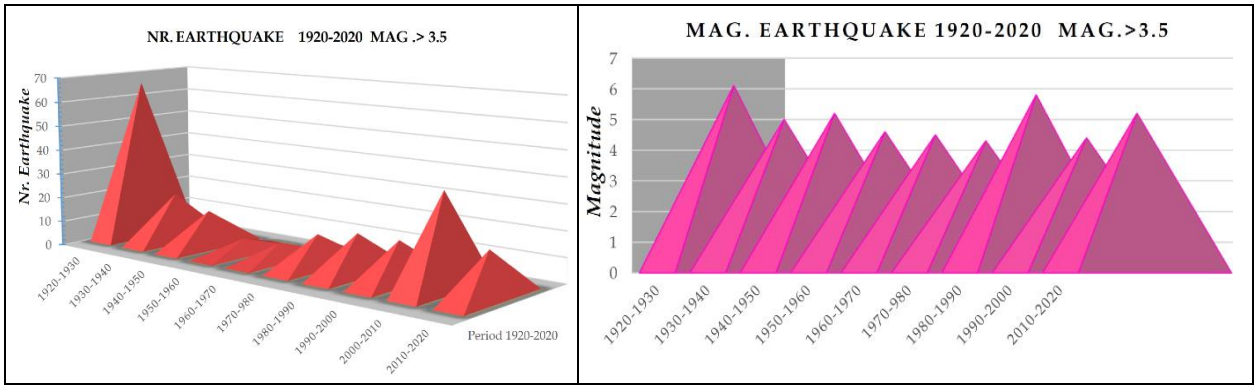

Fig. 1 Nr. of Earthquake and Magnitude for every decade

2.2 Focus of earthquakes in the Earth's crust

From the point of view and seismological study, Kosovo may be hit in the future by autochthonous earthquakes, which have shallow foci, which are generated in the Earth's crust, maximum 10-20 km deep underground, fig.2.

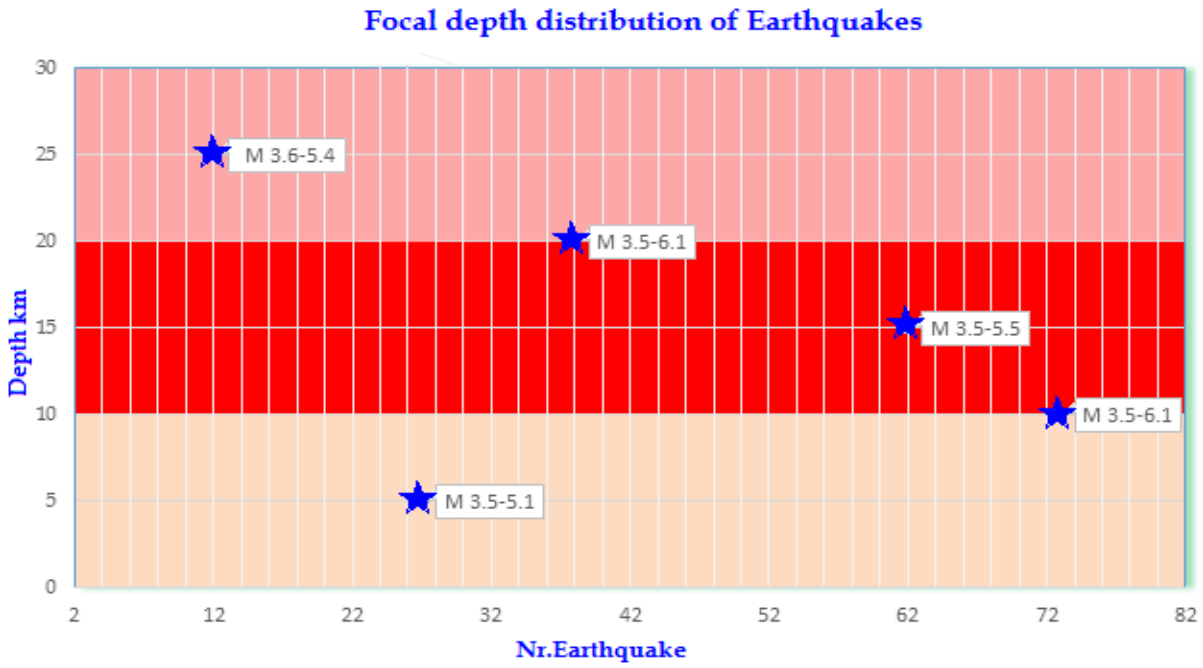

Fig.2 Focus of earthquakes in the Earth's crust of Kosovo territory maximum 10-20 km deep underground

The territory of Kosovo is characterized by a relatively high seismic activity. The most complete data on earthquakes that have occurred in the territory of Kosovo in the 20-th century can be found in the international seismological bulletins and as part of the data bases of the seismological observatories of the neighboring countries. Also, within the Balkan project that was carried out in the 70's of the 20th century, an attempt was made to synthesize data on historic and instrumental data on the Balkan earthquakes, fig 3.

Some of the strongest earthquakes that have affected the territory of Kosovo are listed below:

The Prizreni earthquake of June 16, 1456 (MS=6.1; 42.2 N, 20.7 E) epicentral intensity of $VIII_{1/2}$ degree (Sulstarova et al., 2005),
The Peja earthquake of November 11, 1662 (MW=6.0; 42.7 N; 20.3 E) epicentral intensity of $VIII_{1/2}$ degree (Sulstarova et al., 2005; Papazachos et al., 2000),
The Ferizaj-Viti earthquake of August 10, 1921 (ML=6.1; 42.3 N; 21.3 E) epicentral intensity of IX degree (SO Skopje, D. Hadzievski),
The Viti earthquake of august 15.1921 (Ml = 5.4; 42.3 N, 21.3 E) epicentral intensity of VIII degree (SO Skopje, D. Hadzievski).
The Gjilan earthquake of September 02.1921 (Ml = 5.0; 42 24 N, 21.3 E) epicentral intensity of VIII degree (SO Skopje, D. Hadzievski).
The Kaçanik-Viti earthquake of October 03.1921 (Ml = 5.6; 42.3 N, 21.3 E) epicentral intensity of VIII degree (SO Skopje, D. Hadzievski).
The Gjakova earthquake of September 03.1922 (Ml = 5.3; 42.401 N, 20.493 E) epicentral intensity of VII1/2 degree (SO Skopje, D. Hadzievski).
The Prizren earthquake of September 26.1945 (Ml = 5.0; 42.15 N, 20.7 E) epicentral intensity of VII degree (SO Skopje, D. Hadzievski).
The Klina earthquake of February 05.1947 (Ml = 5.2; 42.5 N, 20.8E) epicentral intensity of VIII degree (SO Skopje, D. Hadzievski).
The Kopaonik earthquake of May 18, 1980 (MW=5.7; 43.307N; 20.867E) epicentral intensity of VIII degree (Harvard University, 1980),
The Gjilani earthquake of April 24, 2002 (MW=5.7; 42.412N, 21.555E), epicentral intensity of VIII degree (ISC, 2002; Elezaj, 2002).

The Istog earthquake of march 10, 2010 (Ml = 5.2; 42.763440N, 20.628110E) epicentral intensity of VII degree (SIK Sh.Mustafa, N.Hasi, 2010).
The Vushtrri earthquake of November 18, 2013 (MI=4.8; 42.9 N; 21.014 E) epicentral intensity of VI degree (GSK, Sh, Mustafa, 2013)

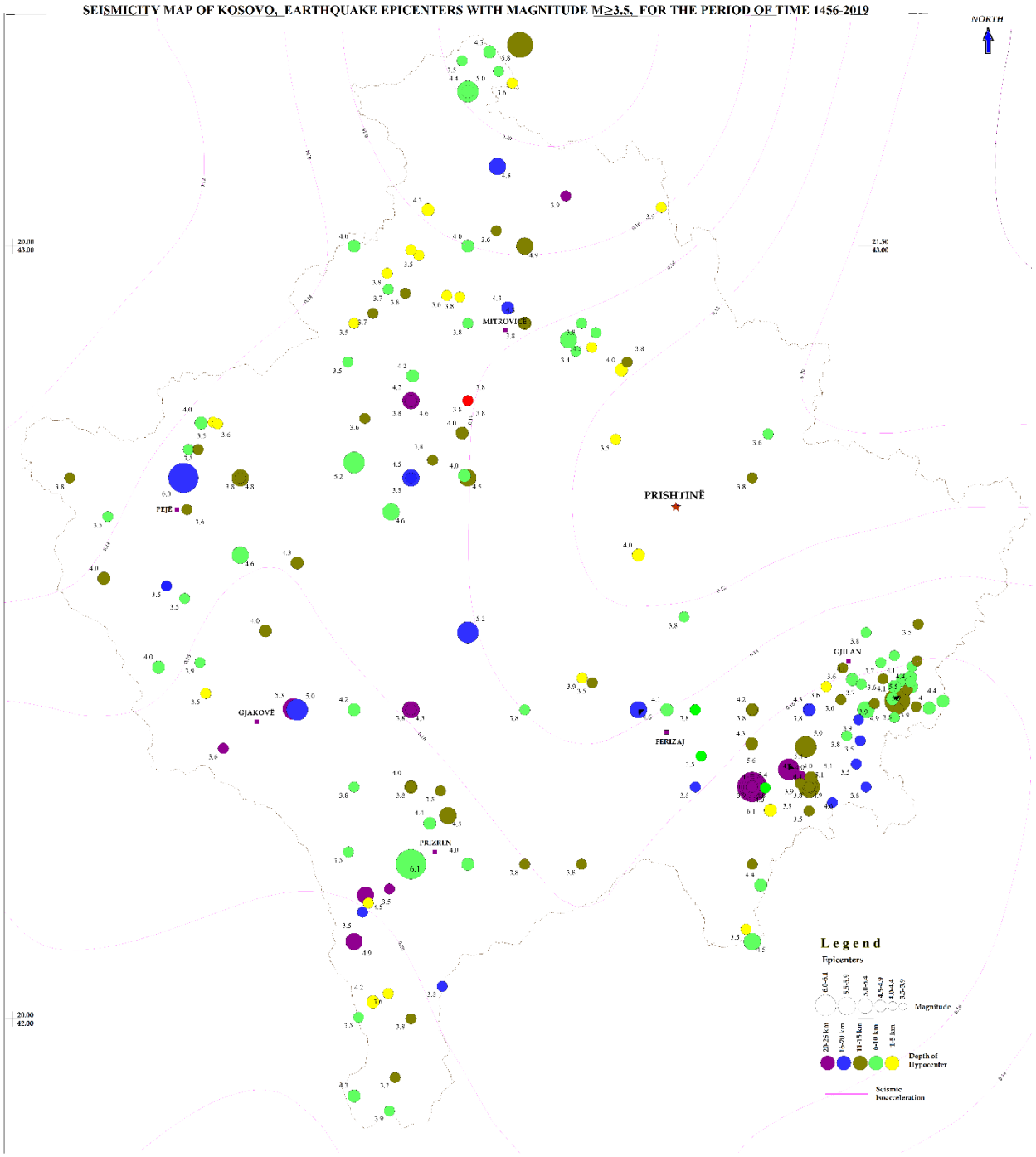

Fig. 3 Seismicity Map

2.3 Macroseismic intensity attenuation based Earthquakes catalog of Kosovo territory

Seismic attenuation describes the loss of energy in the experience from seismic waves when they propagate. For the territory of Kosovo we get for study three earthquakes with approximate magnitude but with different depths, 7km, 14km and 20 km, result in different extinction values, where at a distance of 100 km the 7 km depth quake has much higher attenuation values than the 20 km depth quake at a distance of 100 km,

Attenuation in 100 km within the territory of Kosovo, results with one intensity scale difference for two case 7 km and 20 km, tab.2 fig. 4.

$$I - I_o = -3.227 \log \sqrt{1 + \frac{\Delta^2}{h^2}} - 0.0033\left(\sqrt{\Delta^2 + h^2} - h\right)$$ Papazachos and Papaioannou (1997) **(1)**

$$I_{max} - I_i = 4.2 \log (R_i/h)$$ Hadzvieski and Pekevski (1975) **(2)**

Table 2. Analysis and study of Seismic attenuation of all earthquakes

I 10 = 7.21	I 20 =6.96	I 30=6.65	I 40 = 5.55	I 50 =6.10	I 60 =5.85	I 70 = 5.64	I 80 = 5.44	I 90 = 5.25	I 100 = 5.08
I 10 = 6.25	I 20 =5.53	I 30 = 5.00	I 40 = 4.59	I 50 =4.26	I 60 =3.98	I 70 = 3.74	I 80 = 3.52	I 90 = 3.32	I 100 = 3.14
I 10 = 7.06	I 20 =6.58	I 30 = 6.14	I 40 = 5.77	I 50 =5.45	I 60 =5.19	I 70 = 4.90	I 80 = 4.74	I 90 = 4.54	I 100 = 4.37
I 10 = 5.41	I 20 =4.49	I 30 = 3.90	I 40 = 3.47	I 50 =3.13	I 60 =2.84				
I 10 = 5.92	I 20 =5.16	I 30 = 4.67	I 40 = 4.20	I 50 =3.87	I 60 =3.59	I 70 = 3.34			
I 10 = 6.21	I 20 =5.63	I 30 =5.14	I 40 =4.75	I 50 =4.43	I 60 =4.15	I 70 = 3.91	I 80 = 3.69	I 90 = 3.50	I 100 = 3.32
I 10 = 6.98	I 20 =6.73	I 30 = 6.42	I 40 = 5.32	I 50 =5.87	I 60 =5.62	I 70 = 5.41	I 80 = 5.21	I 90 = 5.02	I 100 = 4.85
I 10 = 6.43	I 20 = .08	I 30 = 5.72	I 40 =5.39	I 50 =5.10	I 60 =4.84	I 70 = 4.61	I 80 = 4.40	I 90 = 4.22	I 100 = 4.04
I 10 = 6.83	I 20 =6.13	I 30 = 5.71	I 40 = 5.35	I 50 =5.04	I 60 =4.77	I 70 = 4.54	I 80 = 4.33	I 90 = 4.13	I 100 = 3.96
I 10 =5.80	I 20 =5.00	I 30 = 4.44	I 40 = 4.02	I 50 =3.68	I 60 =3.40	I 70 = 3.15	I 80 = 2.93	I 90 = 2.74	I 100 = 2.56
I 10 = 6.04	I 20 =5.20	I 30 = 4.63	I 40 = 4.21	I 50 =3.87	I 60 =3.58	I 70 = 3.33	I 80 = 3.12	I 90 = 2.92	I 100 = 2.74
I 10 = 6.80	I 20 =6.00	I 30 = 5.44	I 40 = 5.02	I 50 =4.68	I 60 =4.40	I 70 = 4.15	I 80 = 3.93	I 90 = 3.74	I 100 = 3.56
I 10 = 7.20	I 20 =6.68	I 30 = 6.23	I 40 = 5.85	I 50 =5.53	I 60 =5.26	I 70 = 5.02	I 80 = 4.81	I 90 = 4.62	I100 = 4.44
I 10 = 6.85	I 20 =5.96	I 30 = 5.38	I 40 = 4.95	I 50 =4.61	I 60 =4.33	I 80 = 4.08	I 80 = 3.86	I 90 = 3.66	I 100 = 3.48
I 10 = 8.00	**I 20 =7.33**	**I 30 =6.81**	**I 40 =6.41**	**I 50 =6.08**	**I 60 =5.80**	**I 70 = .55**	**I 80 =5.34**	**I 90 =5.14**	**I 100 = 4.96**
I 10 = 8.16	I 20 =7.81	I 30 = 7.45	I 40 = 7.12	I 50 =6.83	I 60 =6.57	I 70 = 6.34	I 80 = 6.13	I90 = 5.95	I 100 = 5.77
I 10 = 8.33	**I 20 =7.98**	**I 30 =7.62**	**I 40 =7.29**	**I 50 =7.00**	**I 60 =6.74**	**I 70 =6.51**	**I 80 =6.30**	**I 90 =6.12**	**I 100= 5.94**

2.3.1 **Results of macroseismic intensity attenuation, based Earthquakes catalog**

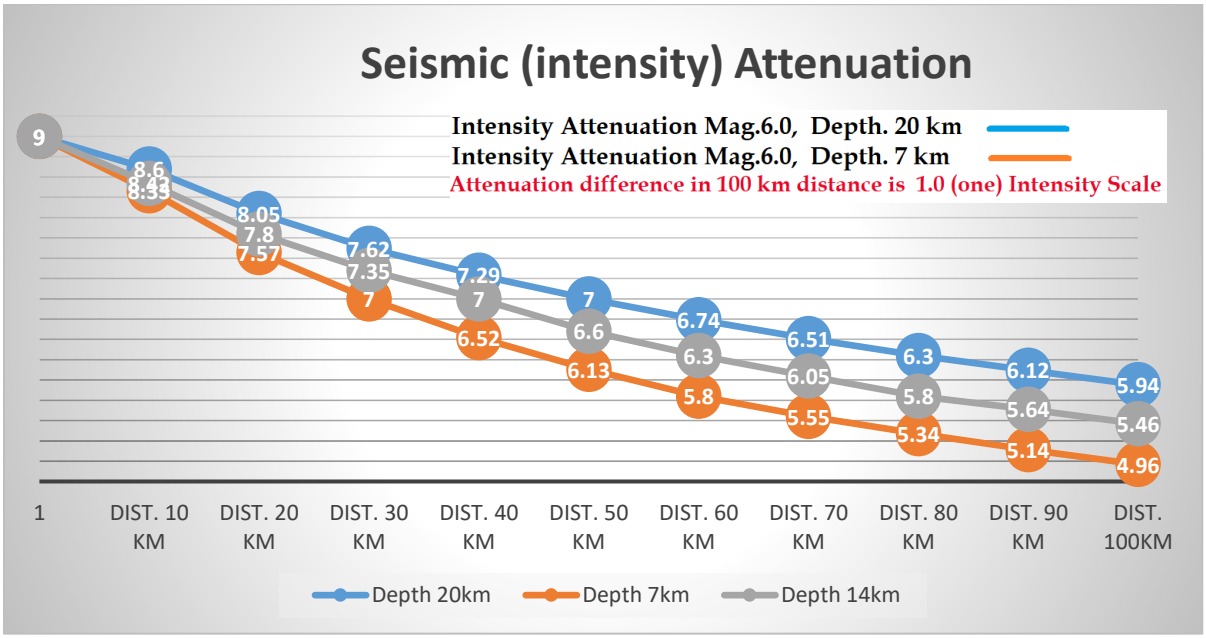

Fig 4. Graphical representation of Intensity attenuation at a distance of 100km

2.4 Seismotectonic characteristics

From the seismological point of view and study, Kosovo is a region with high seismic activity, which has been hit in the past and may be hit in the future by very strong autochthonous earthquakes, which have shallow foci, which are generated in the Earth's crust, maximum 10-20 km deep underground.
These two phenomena, the autochthonous local seismicity and the seismicity caused by distant earthquakes, testify to the ranking of Kosovo in the ranks of territories with a high seismic activity.
The results of this study have a special importance, both in the scientific-professional aspect and in the practical aspect, because they give a clear picture of the seismic risk of Kosovo.

Drenica Fault Max Depth (km) 10	Inferred from regional geological and seismological data.
Sitnica Fault Max Depth (km) 12	Inferred from regional geological and seismological data.
Prishtina Fault Max Depth (km) 10	Inferred from regional geological and seismological data.
Gjilan Fault Max Depth (km) 12	Inferred from regional geological and seismological data.
Prizren Fault Max Depth (km) 25	Inferred from regional geological and seismological data.
Dragash Fault Max Depth (km) 13	Inferred from regional geological and seismological data.
Peja Fault Max Depth (km) 12	Inferred from regional geological and seismological data.
Istog Fault Max Depth (km) 12	Inferred from regional geological and seismological data.

During the assessment of seismic activity, based on existing data and experience to date from research conducted, seismotectonic characteristics of Kosovo can be given in more detail than the data provided by seismological statistics. In the map below fig.5, are included all the seismic parameters, calculated and studied giving us a good overview or result in the Seismogenic aspect.

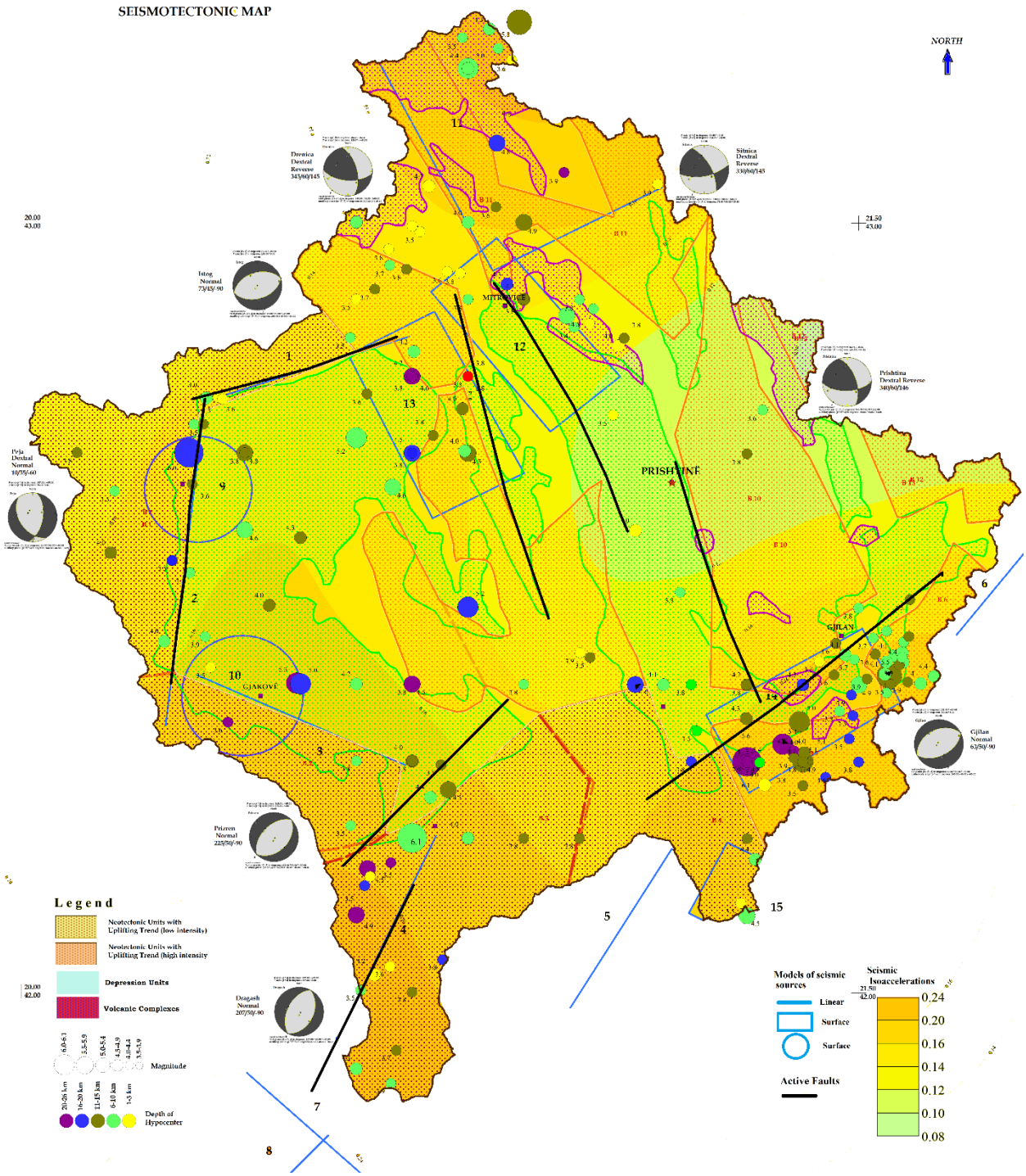

Fig.5 Seismotectonic Map

3. General recommendations before an earthquake

It is a normal practice in many countries that, in certain time intervals, the seismic hazard maps are updated continually, in order to include and reflect the latest achievements in seismology at local, regional and global level. We think that a study program is necessary to be undertaken in near future to include further review of the hypocenter parameters of the Kosovo earthquakes. Another problem would be re-evaluation of the magnitude of the historical earthquakes that have hit the Kosovo territory.

In conclusion, we think that this study represents an achievement in the philosophy of seismic hazard assessment for Kosovo. These results can be improved in the future if we'll have:

• Further improvement of the seismicity parameters through the updating of the earthquake data base for Kosovo and the surrounding areas

• A regional seismotectonic model that links seismicity with the active tectonic faults, their focal mechanism, etc.

• More accurate models for the prediction of ground motion parameters based on regional strong motion records in Kosovo and the surrounding areas.

Based on all these parameters and seismic values presented and studied, it turns out that the territory of Kosovo is a seismic zone, so for engineers and architects in their designs important design parameters should be taken into consideration, so design by capacity, accepted by all contemporary norms.

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