United Nations Educational,
Scientific and Cultural Organization

Bulgarian Academy
of Sciences

23

International Project

" SEISMO-HYDROGEOLOGICAL VULNERABILITY OF THE ENVIRONMENT AND SOCIETY IN THE BALKAN REGION "

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Sofia, Bulgaria
2007

THERMAL AND THERMOMINERAL SPRINGS RELATED TO THE SEISMOTECTONIC ACTIVITY OF FAULTS IN THE REPUBLIC OF MACEDONIA

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Abstract

The aim of the paper is to present the correlation dependence of geothermal energy present as active thermal and geothermal springs and the seismicity in the territory of the Republic of Macedonia. In that regard, analysis has been carried out on existing data for geothermal occurrences and anticipated seismicity of fault structures (mostly geotectonic).

Keywords: termomineral springs, seismisity, faults

Introduction

According to available information in the territory of the Republic of Macedonia have been known over 150 springs of mineral, thermal and thermomineral water. Of this number, about 25 are of temperature higher than 20°C and have been distinguished as warm springs and more than 10 are hot springs with water temperature exceeding 35°C.

The paper will give an account of hot springs correlated to seismotectonic activity of fault dislocations on which they are located.

In terms of tectonics the hot thermal and themomineral springs in the territory of Republic of Macedonia are located mainly in the Vardar Zone and the Serbo-Macedonian massif. Occasionally such springs can be found in western Macedonia or in the Cukali - Krasta zone (close to the border with Albania (fig. 1).

Most of the Hot Springs and thermomineral springs are located in regional fault dislocations that are seismoactive with various degrees.

REGIONAL TECTONIC SETTING OF THE REPUBLIC OF MACEDONIA

The territory of the Republic of Macedonia is part of the Balkan Peninsula where several geotectonic units of the Alpine-Himalayan belt have been distinguished. The western and central parts of the territory belong to the Dinaride- Hellenides, and the eastern to the Serbo-Macedonian massif. The bordering part with Bulgaria is part of Carpatho-Blakanides.

Four geotectonic units have been distinguished within the Dinaride-Hellenides in the territory of the Republic of Macedonia which are characterized by specific tectonic elements and geological evolution.

From the west to the east several zones have been distinguished: the Cukali - Krasta, Western Macedonian and the Pelagonian horst - anticlinorum as well as the Vardar zone (Arsovski, 1997). The Serbo-Macedonian massif has been distinguished in Eastern Macedonia and the Kraishtide zone in the bordering part with Bulgaria as part of the Carpatho-Blakanides (fig. 1).

GEOTHERMAL OCCURRENCES IN THE TERRITORY OF THE REPUBLIC OF MACEDONIA

The geothermal occurrences in the territory of the Republic of Macedonia are related mostly to the Vardar zone. Their distribution in other geotectonic units is rare. Other units have been found in the Serbo-Macedonian massif and in the Cukali-Krasta zone. Geothermal occurrences are related to

paleogeothermal magmatic and volcanic rocks and hydrothermal occurrences. Hydrogeothermal occurrences can be Paleohydrothermal and present day (Georgieva, 1995).

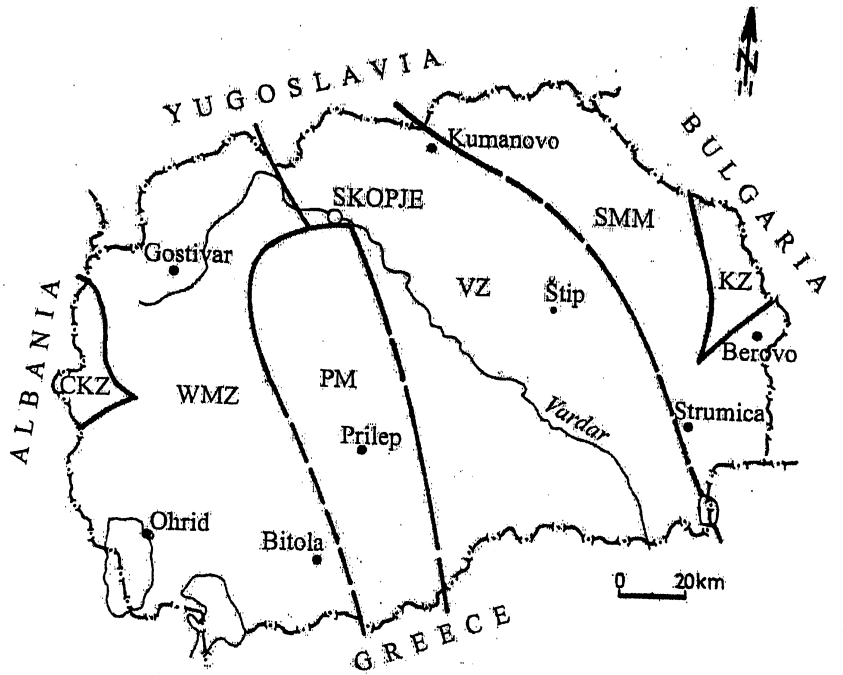

Fig. 1. Map of tectonic regional setting of the Republic of Macedonia (Arsovski, 1997). CKZ-Cukali-Krasta zone, WMZ- Western-Macedonian zone, PM-Pelagonian massiv, VZ-Vardar zone, SMM- Serbo-Macedonian massif, KZ- Kraishtide zone.

Present day hydrogeothermal occurrences are most common in the Vardar zone, which is fairly unstable geotectonic unit. Part of it is in the bordering belt between the Vardar zone and the Serbo-Macedonian massif. As it was said above, hydrogeothermal occurrences have also been found in the Cukali-Krasta zone and in the vicinity of Debar (fig. 2).

Active hydrogeothermal occurrences are most common in the lower parts (valleys), or in the contact zones between the flat land (representing morphostructures of subsidence) and the mountainous massifs (representing morphostructures of uplift).

In Macedonia more than ten important localities of active hydrogeothermal occurrences have been distinguished with over 50 springs etc. by explorations drill holes.

The temperature of thermal waters in the Republic of Macedonia varies from 20 to 80°C. Water temperature in most of the thermal occurrences amounts to 30°C.

The yield of present day hydrothermal springs varies with the period of the year. Most of them yield 5 l/s. Yields higher than 100 l/s are rare. (only two).

Chemical composition of thermal and geothermal waters in the Republic of Macedonia is different. Hydrocarbonate waters prevail owing to their anion composition, whereas those of chlorine are less common. The waters of mixed composition with almost equal Na, Ca and Mg contents are more abundant owing to their cation composition. Waters of Ca-Na and Ca-Mg are less abundant.

SEISMIC CHARACTERISTIC OF THE TERRITORY OF THE REPUBLIC OF MACEDONIA

The territory of the Republic of Macedonia is one of the seismically most active areas on the Balkans being part of the Mediterranean-Trans Asian seismic belt.

The high seismic activity in the territory of the Republic of Macedonia is due to the geological composition of the Earth's crust in the area and the high dynamics or instability.

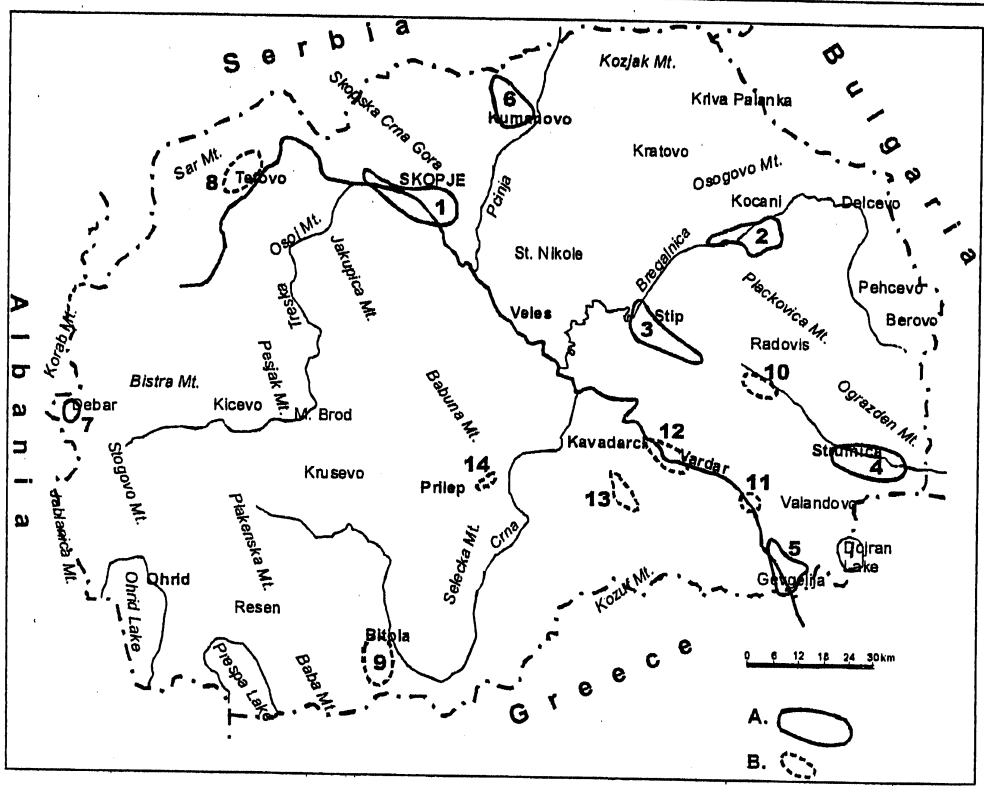

Fig. 2. Map of potential geothermal fields in the Republic of Macedonia (Mitrov, 1988).
A. I order geothermal fields, B. II order geothermal fields
1 - Skopje area, 2 - Kocani, 3 - Lakavica, 4 - Strumica, 5 - Geovgelija, 6 - Kumanovo, 7 - Debar, 8 - Tetovo, 9 - Bitola, 10 - Radovis, 11 - Valandovo, 12 - Demir Kapija, 13 - Kavadarci, 14 - Pletvar.

Seismologic analyses carried out on the territory were based on data obtained for earthquakes that have taken place and their macroseismic and instrumental analysis. The analyses helped create epicentral map with earthquakes that took place from 1990 to 1985 the magnitude being M≥4.5 (fig. 3).

The map shows that three seismic zones can be distinguished in the territory of the Republic of Macedonia: the Strumica, Vardar and Drim zones. Seismically most active parts are regarded to be the places of intersection of faults or tectonic knots. The places are located in the depressions (valleys) which are also epicentral areas. Based on this, the following epicentral areas have been determined: Skopje, Valandovo, Pehcevo, Debar, Ohrid, Tetovo, Bitola and Tikves.

CORRELATION BETWEEN GEOTHERMAL OCCURRENCES AND SEISMIC ACTIVITY

It is known that earthquakes are closely related to the stage of the geological development. In other words, earthquakes are related to the parts of the earth's crust characterized by increased instability and more intense tectonic movements.

The orientation, the system of strain, mechanism and manifestation of tectonic processes and seismic activity have been taken as criteria for the classification of seismic active faults. Based on these, seismically active fault structures have been classified as gravitational, seldom reverse or horizontal block compression.

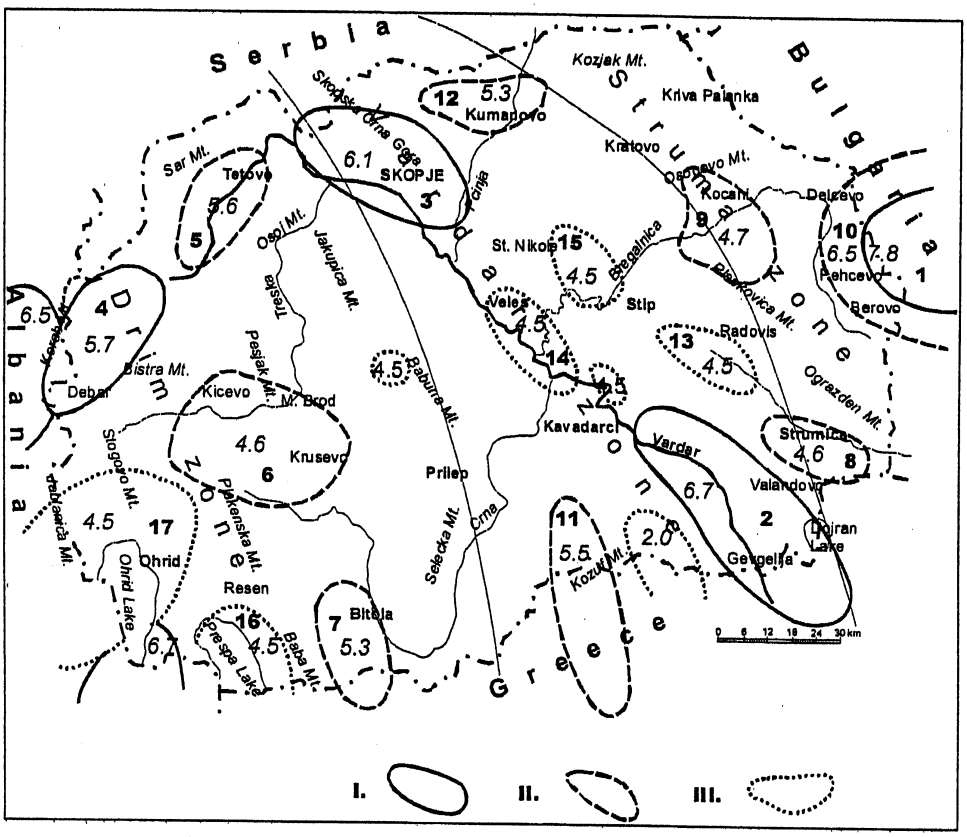

Fig. 3. Map of earthquakes that took place in the territory of the R. of Macedonia (Hadzievski, 1986). I. First order seismogenic sources: 1 - Berovo-Pehcevo, 2 - Valandovo, 3 - Skopje, 4 - Drim; II - Second order seismogenic sources: 5 - Polog, 6 . Kicevo, 7 - Bitola, 8 - Strumica, 9 - Kocani, 10 - Delcevo, 11 - Tikves, 12 - Kumanovo: II. Third order seismogenic sources: 13 - Radovis, 14 - Veles, 15 - Sveti Nikole, 16 - Prespa, 17 - Debarca.

Based on the analysis for the spatial distribution of seismically active faults, several seismogenic sources or zones of anticipated seismicity haye been separated.

The seismogenic sources in the map are I order sources with M≥ 8.0, II order seismogenic sources with M ≥ 6.0, III order seismogenic sources M ≥5.0.

The I order seismogenic sources are Pehcevo-Berovo, Valandovo, Skopje and Drim areas. The II order sesimogenic sources are Polog, Kicevo, Bitola, Strumica, Kocani, Delcevo, Tikves and Kumanovo. The III order seismogenic area includes Radovis, Veles, Sveti Nikole, Prespa and Debarca.

The analysis of the spatial distribution of thermal and geothermal sources in the Republic of Macedonia indicates that they are related to the fault structures or tectonic knots. The sources studied are used as spas or for green houses warming. They are often located in seismically active fault structures such as:

The Debar thermomineral spa in the Drim seismogenic zone is located in a tectonic knot on a potential (M=5.0) and low potential (M=4.0) active faults. The Kosovrasti spa is located in a strong seismoactive fault the anticipated seismisity being M=6.1 - 6.5.

In the Skopje - Kumanovo seismogenic area, the Katlanoska spa is located in a tectonic knot of potential (M=4.5) and low potential (M=4.0) active faults.

In the Kocani seismic area the Banja, Polog and Istibanja thermal sources are located along low potential active fault an anticipated magnitude of M-4.0.

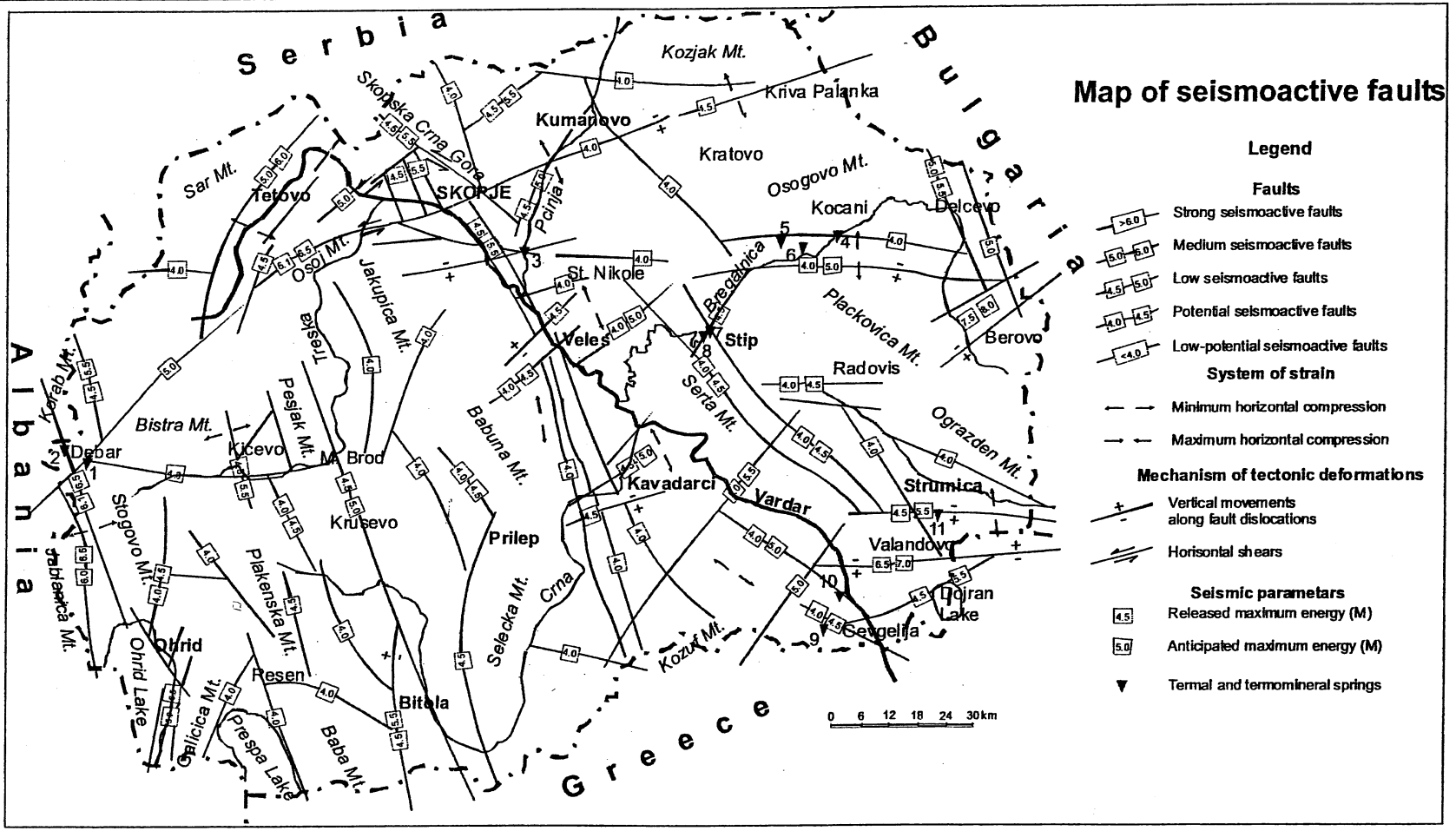

Fig. 4. Map of seismoactive faults in the territory of the Republic of Macedonia, (Jancevski, 1987).
1. the Debar spa, 2. Kosovrasti, 3. Katlanovo spa, 4. Istibanja, 5. Banja, 6. Polog, 7. Ladzi, 8. Kezovica, 9. Smokvica, 10. Negorski spa, 11. Bansko.

In the Lakavica seismic area the Kezovica spa and the Ladzi spring are located in a potentially seismoactive fault the anticipated seismicity being M=4.5.

In the Strumica seismoactive area, the Bansko spa is located in a medium seismoactive fault with anticipated seismicity of M=4.5 - 5.5.

In the Gevgelija seismic area, the Negorska spa and Smokvica are located in a low seismoactive faults of anticipated seismicity of M=4.0 - 5.0.

SEISMO-HYDROGEOLOGICAL PHENOMENA RELATED TO SOME EARTHQUAKES IN THE TERRITORY OF THE REPUBLIC OF MACEDONIA

The Drim Seismogenic zone:

Hot water appeared in a well in the village of Gradec near Gostivar and Tetovo after the earthquake the magnitude 5.6 and intensity 7 - MSK-64 that took place on 12 December 1960.
During an earthquake at Debar on 30 November 1967, the magnitude of 6.5 and the intensity of 9 - MSK-64 water emerged in several places.
During an earthquake in the area of Struga on 9 December 1964, the magnitude of 4.6 and the intensity of 7.5 - MSK-64 water mudding was noticed in the lake. The water in some springs at the foot of Mt. Galicica also got muddy.
During an earthquake that took place in the area of Bitola, near the village of Kukurecani on 1 September 1994, the magnitude of 5.2 and the intensity of 7.5 - MSK-64, fissures filled with water could be seen in the soil. At the same time the amount of water in the fountains reduced. Water also appeared in Capari, Trnovo, Duhovo etc. Water level in springs, the river, wells and fountains increased and mudding water mudding was noticed in Bitola and the villages mentioned.
During an earthquake that took place on 18 February 1911, the magnitude 5.9 and intensity 8 - MSK, a decrease of half a meter of Lake Ohrid water level was noticed. A fairly yielding spring disappeared close to St. Naum monastery.

The Vardar seismogenic zone:

During the Skopje earthquake that took place on 27 July 1963 mudding and change of water level was noticed in wells. In Katlanovska Banja in 3 out of 9 springs the water level was lower. However, in one spring there was increase in water level with temperature rise by 5°C.
During an earthquake in the area of Demir Kapija on 28 September 1985, the magnitude of 5.3 and the intensity of 7.5 - MSK-64 water emerged from the earth with increase of water in fountains, wells and springs accompanied with mudding.
During an earthquake in the area of Valandovo on 7 March 1931, the magnitude of 5.5 and the intensity of 8 - MSK-64, and change of water level was noticed in the spring in Bogdanci. Wells at Josifovo were filled with muddy water. At Gradec a lot of mineral water springs with increased sulphur content appeared. In Negorski Banji the occurrence of new springs was noticed. In Stojakovo, Bogorodica, Mirvaci etc. increased amount of water was noticed in fountains and wells.

The Struma seimogenic zone

During the earthquake that took place on 4 April 1904, the magnitude of 7.8 and the intensity of 10 - MSK-64 in the area of Pehcevo - Kresna (in Bulgaria) in the wider epicentral area both hot and cold water appeared. In the vicinity of Kocani hot water springs also appeared which disappeared after a short period of time. In the vicinity of Stip, cracks appeared in the ground from which self-potential water and geysers of up to 10 meters appeared.

In the Lakavica seismic area the Kezovica spa and the Ladzi spring are located in a potentially seismoactive fault the anticipated seismicity being M=4.5.

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DISCUSSION AND CONCLUSION

Based on the analysis for the spatial distribution of thermal and thermomineral occurrences and earthquake areas in the territory of the Republic of Macedonia, it can be inferred that there is high correlative dependence between these phenomena. Notably, it can be inferred that geothermal fields are related to earthquake areas. By all means, correlation is not 1000 per cent. There are earthquake areas such as the Pehcevo, which is characterized by high seismicity, but no mineral water sources are related to it.

The correlation between thermal sources and seismic activity of fault structures makes it possible to conclude that thermal sources are located in seismoactive faults, or seldom close to the faults. With regard to seismic activity and the intensity of faults on which they are located, it can be inferred that thermal sources are often located in low potential to potential faults with anticipated magnitude of M=4.0 - 5.0. This conclusion also indicates that the heat source of thermal and thermo mineral waters in the territory of the Republic of Macedonia should not be looked for only in the energy that is released by seismic activity of fault structures.

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