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# Neotectonic and seismotectonic features of the Pelagonian, Kičevo and Poreč depressions and the surrounding block structures

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*Зл. Илиовски, В. Мирчовски, Г. Петров, О. Спасовски, Ст. Николов. Неотектоническая и сейсмотектоническая характеристика Пелагонийской, Кичевской и Поречкой депрессий и окружающих блоковых структур.* В работе приведена характеристика нескольких неотектонических депрессий (Пелагонийской, Кичевской и Поречкой), а также — окружающих блоковых структур.

Исследованный район принадлежит к двум геотектоническим регионам — к Пелагонийскому массиву и к Западной Македонской зоне. Оба региона прошли сложное полифазовое геотектоническое развитие.

Во время неотектонического периода в результате интенсивных тектонических движений по реактивированным и новообразованным неотектоническим разломам оформились морфоструктуры воздымания (блоки — горсты) и структуры проседания (депрессии — грабены). Неотектонические разломы различаются по степени сейсмической активности. На основании анализа данных по землетрясениям выявлены две сейсмические зоны — зона Кучево и зона Битоля. В связи с ними можно ожидать землетрясения с магнитудом до 5.5 степени.

*Abstract.* The paper presents the lithostratigraphic, neotectonic and seismotectonic characteristics of the Pelagonian, Poreč and Kičevo depressions and the surrounding horsts.

The area under consideration belongs to two geotectonic regions — the Pelagonian massif and the Western Macedonian zone which have had a complex multiphase geotectonic evolution.

During the Neotectonic stage, owing to the intense tectonic development, morphostructures of uplift (block-horsts) and subsidence (depressions-grabens) were formed along reactivated older and newly-developed neotectonic fault structures. The neotectonic fault structures are of various degree of seismic activity. The analysis of data from earthquakes makes possible to distinguish two seismic zones — Kičevo and Bitola, — in which earthquakes with a magnitude of up to 5.5 could be anticipated.

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***Key words:*** seismicity; neotectonic structure.

## Pre-Neogene tectonic evolution

The area of the Pelagonian, Kičevo and Poreč depressions and surrounding horsts occupies parts of the Pelagonian massif and the Western-Macedonian zone (Fig. 1).

The Pelagonian massif is a relict of the Precambrian, Pre-Baikalian earth's crust in this part of the Dinarides. The horst is separated from adjacent tectonic units from all sides by deep faults of NNW to submeridional strike. In the east it borders the Vardar zone and in the west the Western-Macedonian zone. A study of the evolution of the Pelagonian massif during the Phanerozoic gives grounds to assume that it was, and still is, a stable block

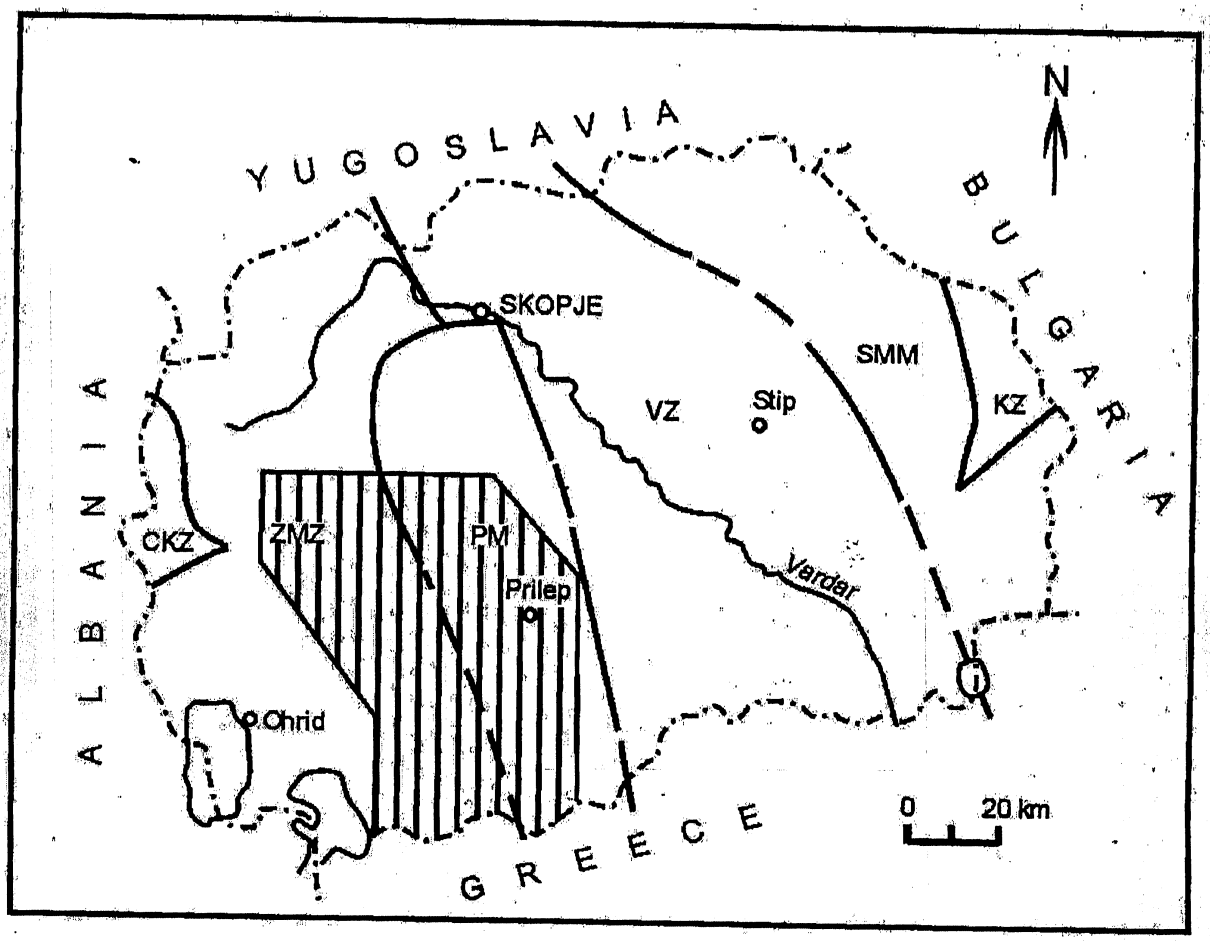


Fig. 1. Tectonic setting of the territory of Macedonia (after Arsovski, 1997).
CKZ — Cukali-Krasta zone, ZMZ — Western-Macedonian zone, PM — Pelagonian massif, VZ — Vardar zone, SMM — Serbo-Macedonian massif, KZ — Kraistide zone

(microcontinent) in which vertical oscillation movements have played a major role. During the Alpine tectonogenesis the Pelagonian massif was an internal massif with tendency of permanent uplift.

The Western-Macedonian zone represents an inner massif situated in the northeastern part of the Dinaride-Helenides. In the west it borders the Mirdita zone (in the territory of Albania). It borders also partially the Cukali zone (in the area of Debar). Its eastern border, towards the Pelagonian massif, represents a regional fault zone.

The initial stage of the development of the zone is associated with the break up of the primary Grenvillian crust during Riphean — Cambrian times. During the Hercynian orogeny intrusion of granite magma resulted in the development of large batholite bodies such as the Pelister and Kruševo granitoids.

## Neotectonic evolution

The territory of the Republic of Macedonia is part of the Mediterranean orogenic area where basinal conditions terminated by the end of the Paleogene and the beginning of Neogene. This was followed by continental development. During the first phase or the Lower Miocene intense peneplenization and nivelation of the structures of the Pyrenean to Savian orogenic phase took place.

During the Middle Miocene a period of extension and evolution of neotectonic movements took place, as well. Intense vertical movements resulted in the development of numerous morphostructures of uplift (horsts) and subsidence (grabens). The process of differentiation displacements between depressions and horst massifs was intensified with time which resulted in the activation of earlier

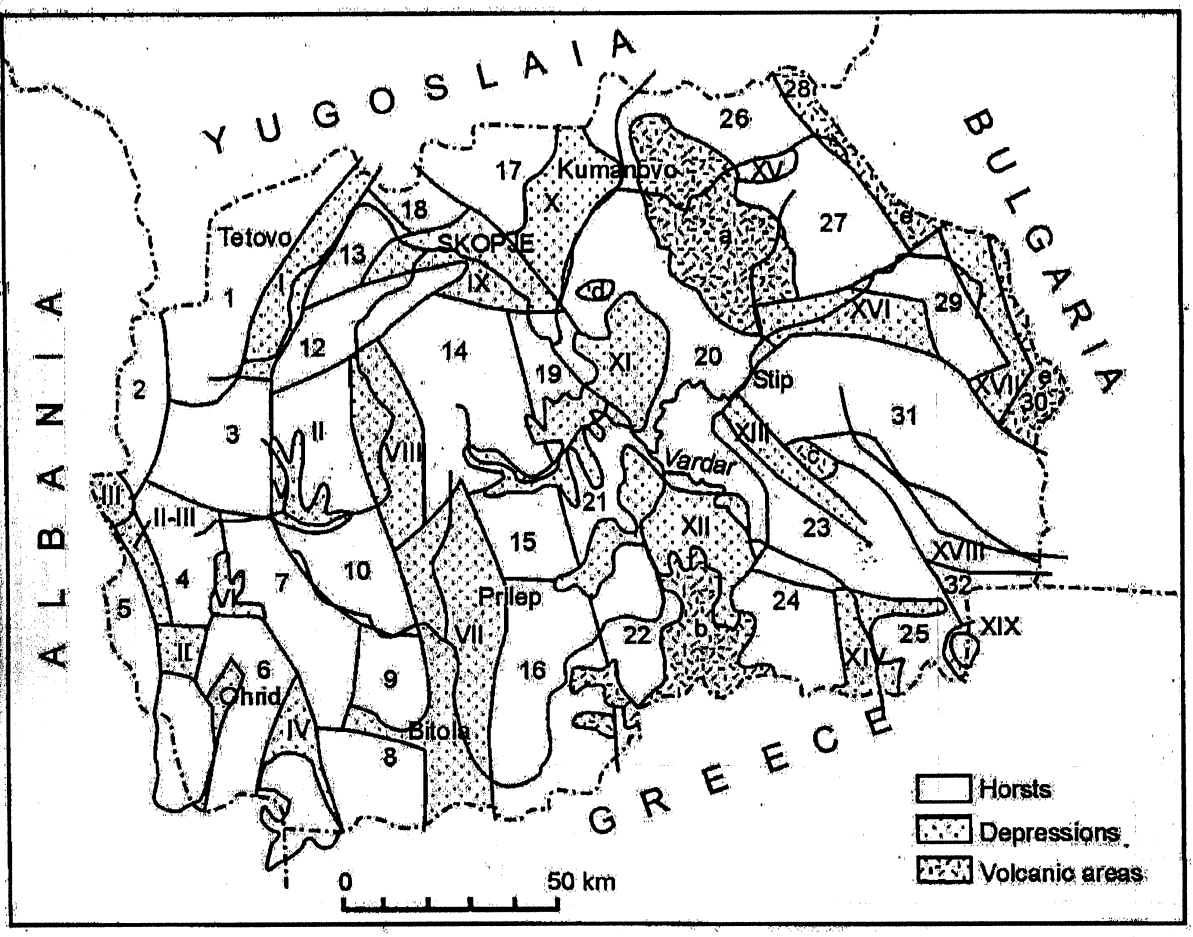


Fig. 2. Neotectonic setting of the territory of Macedonia (after Arsovski, 1997).
Horst morphostructures: 1. Šar Planina, 2. Korab, 3. Bistra, 4. Stogovo, 5. Jablanica, 6. Galičica, 7. Ilin, 8. Pelister, 9. Semnik, 10. Ljuben, 11. Pesjak, 12. Suvogor, 13. Zeden, 14. Jakupica, 15. Babuna, 16. Seleč, 17. Srpsko-Crnogorski, 18. Raduca, 19. Kadina, 20. Bregalnica, 21. Klepa, 22. Marlovo, 23. Plauš, 24. Kožuf, 25. Furka, 26. Kozjak, 27. Osogovo, 28. Ruen, 29. Golak, 30. Maleš, 31. Plačkovica, 32. Belasica.
Subsidence morphostructures (depressions): I. Polog, II. Ohrid, III. Debar, II-III, Drim graben; IV. Prespa, V. Kičevo, VI Belčiska, VII. Pelagonian, VIII. Poreč, IX. Skopje, X. Kumanovo, XI. Ovče Pole, XII. Tikveš, XIII. Lakavica, XIV. Valandovo, XV. Slavica, XVI. Kočani, XVII. Pehčevo, XVIII. Strumica, XIX. Dojran.
Volcanic areas: a. Zletovo, b. Vitačevo, c. Sopur, d. Venac, e. Pehčevo — Zeravina

and development of new border faults which represent natural borderlines between these morphostructural units. The orientation of extensive system of the development of neotectonic morphostructures of subsidence made it possible (Jančevski, 1987) to distinguish the Western-Macedonian province with predominant graben orientation of N — S and the province of Central and eastern Macedonia with graben orientation of E — W strike.

The Pelagonian, Kičevo and Poreč depressions belong to the Western-Macedonian province. They represent grabens located between horst morphostructures (Fig. 2).

The **Kičevo depression** is associated with subsidence of the terrain in the zone of cross-cutting faults of meridional and equatorial strikes. It is a neotectonic depression that subsided several hundred meters during the Neogene, and was filled in by Pliocene limnic sediments and Quaternary layers. The valley is fairly reduced since the Pliocene layers were affected by processes of uplift in the marginal parts whereas the central parts (particularly to the south) were affected by continuing subsidence.

The fault zone in which the River Treska flows from west to east is regarded as the major fault zone (Jamski fault). It represents the tectonic boundary of the depression in the south bordering the Ilin and Ljuben blocks (Fig. 2). The second important fault has a N — S strike,

Table 1
*Neotectonic faults in the area of Pelagonia, Kičevo and Poreč depressions (after Jančevski, 1987)*

| No. | Structure | Genetic type | Angle | Pronouncement in the relief | Length (km) | Amplitude of vertical displacement | Regional importance | Orientation | Reactivated or newly formed |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Porečko - Kruševski | gravitational | 80° | contrast | 85 | 800 | first order | longitudinal | reactivated |
| 2 | Dautički | gravitational | 80° | medium pronounced | 7 | 600 | third order | diagonal | reactivated |
| 3 | Topolčanski | gravitational | 55° | medium pronounced | 15 | 250 | third order | diagonal | reactivated |
| 4 | Jamski | gravitational | 85° | medium pronounced | 55 | 200 | third order | transverse | reactivated |
| 5 | Djavatski | gravitational | 80° | medium pronounced | 7 | 200 | third order | transverse | reactivated |
| 6 | Bitolski | gravitational | 75° | contrast | 30 | 2600 | first order | longitudinal | newly formed |
| 7 | Selečki | gravitational | 50° | medium pronounced | 50 | 800 | third order | longitudinal | newly formed |
| 7A | Brod-Negotino | gravitational | – | poorly pronounced | – | 70 | third order | longitudinal | newly formed |
| 8 | Nebregovski | gravitational | 65° | poorly pronounced | 16 | 200 | third order | longitudinal | newly formed |
| 9 | Prilepski | gravitational | 58° | medium pronounced | 35 | 700 | third order | longitudinal | newly formed |
| 10 | Barbaraski | gravitational | 65° | poorly pronounced | 16 | 200 | third order | longitudinal | newly formed |
| 11 | Jakupicki | gravitational | 85° | contrast | 38 | 900 | third order | longitudinal | newly formed |
| 12 | Cerski | gravitational | – | poorly pronounced | 23 | 150 | third order | longitudinal | cwly formed |
| 13 | Zajaški | gravitational | 60° | medium pronounced | 18 | 500 | third order | longitudinal | newly formed |
| 14 | Kičevski | gravitational | – | poorly pronounced | 8 | 200 | third order | diagonal | newly formed |
| 15 | Pesjacki | gravitational | 65° | contrast | 17 | 800 | third order | longitudinal | newly formed |
| 16 | Smilevski | gravitational | 90° | poorly pronounced | 20 | 300 | third order | longitudinal | newly formed |
| 17 | Demirhisarski | gravitational | – | poorly pronounced | 28 | 100 | third order | longitudinal | newly formed |

and is traced from the village of Kolibari, along the River Zajaška, through Kičevo where it directs towards SE near the villages of Bigor and Dolenci, and subsides into a depression in the foot of Mt. Baba.

The Pelagonian depression is the largest depression in the Republic of Macedonia. It developed in Late Miocene times through differential tectonic movements. It occupies an area of about 1500 km$^2$, and is situated at altitudes of 580 to 650 m above sea level. The southern part extends further south to the territory of Greece. It is delineated by mountain massifs from all sides — the Pelister, Semnik and Ljuben block in the west and Babuna and Selečki, in the east. The blocks are built up of Precambrian and Early Paleozoic rocks covered by Lower Neogene — Quaternary sediments (Fig. 2.). The basement of the Neogene sediments in the Prilep part has been reached at a depth of 400 m, and in the Bitola part of the depression is estimated to be at a depth of about 1000 m. Comparing the highest point of the basement of Neogene sediments (400 m) to those along the margin (1100 m in some places), a height difference of 1500 m is obtained. This is the estimate of the possible neotectonic amplitude between the surround-

ing horst mountain uplift and Pelagonia subsidence.

Such movements have been taking place along young marginal fault dislocations along the periphery of Pelagonia. In the vicinity of the old Zivojno colliery cross-sections have been discovered in which tectonic distortions of Neogene layers and coal are clearly pronounced. Based on the morphology of the terrain and the distribution of coal layers found during drillings in the Suvodol open pit and in the Brod — Gneotino district it can be said that the area was affected by young tectonic movements of high intensity.

The **Poreč depression** is situated between the Pesjak block in the west and Jakupica block in the east (Fig. 2) It is of meridional orientation and 30 km in length. The border faults are well expressed in the relief. Displacements have continued to the present time resulting in the more intense uplift of surrounding blocks than the depression itself. Several fault structures have been found in the depression, most of them being neotectonic. Parts of them are earlier faults reactivated during the neotectonic stage. Their characteristics are shown in Table 1.

## Faults and seismicity

Fault structures determined in the area belong to several groups (Fig. 3). The Pelister faults include the Gavato (5) fault, which represents a seismogenic dislocation. The earthquake in Bitola (M=5.2) on 1 September 1994 could be associated with it. Other earthquakes that took place in the past are also associated with this fault. The Smilevo (16) and Demirhisar (17) faults northwest of Bitola were activated during the neotectonic phase when the Ilin and Semicki block were dislocated. The earthquake on 31 July 1966 (M=4.6) as well as that in Bitola on 1 September 1966 are associated with the Demirhisar fault.

The **Kičevo group** includes the Cer (12), Pesjak (15), Zajas (13), Kičevo (14) and Jamski (4) faults. They comprise a tectonic intersection since part of them are of meridional strike and parts are of E — W strikes. The formation of the Kičevo depression is related to this intersection. Present day activity can be seen in the immediate proximity of the tectonic intersection and a large number of earthquakes with magnitude of 5.1 are related to it.

The **Pelagonian group** is associated with the formation of the Pelagonian (VII) and the Poreč (IX) depressions. The most striking is the fault along their periphery — the Jakupica fault (11). It is postulated that this fault is the source of sesmisity with magnitude of 4-5.5. However, no earthquake has been registered in the area so far.

The Poreč — Kruševo fault (1) is an earlier regional dislocation that can be observed today in the western periphery of the Poreč and Pelagonian depressions at a length of about 70 km. The present morphology of both sides indicate that its activities did not occur along the entire length. Earthquakes of M= 4-5 can be anticipated in individual parts (Jančevski, 1987).

The Dautica (2) and Prilep (9) faults are distinguished in the north of the Pelagonian depression. They exhibit a low seismisity (M about 4). No earthquake has been associated over the past one hundred years. The Bitola fault (6) with a uplifted western wall (Pelister) and subsided eastern wall is the best expressed in the southwesternmost periphery of the Pelagonian. The activity of the Bitola fault has continued to the present time creating the prerequisites for its seismisity. The earthquakes anticipated are with magnitude of up to 5.5.

The **Babuna-Selečka group** of faults is related to the periphery parts of Mts. Babuna and Selečka near the Pelagonian depression. These are the Selečki (7) and Nebregovski fault (8). No earthquake has been associated with the Selečki fault for the last 100 years, whereas a recent earthquake of M=4.3 is associated with the Babuna fault.

## Assessment of the seismicity

Generally speaking, these fault structures are not characterized by a strong seismicity. The seismotectonic map (Fig. 3) shows the maximum energy released and the maximum energy anticipated (Jančevski, 1987), modified with new data. The map shows the epicentres of earthquakes that have taken place from 1902 to 1996 based on the data of the seismologic observatory of the Faculty of Mathematics and Natural Sciences in Skopje (ISIIS Skopje) (Table 2). The analysis of data obtained about the earthquakes and their distribution in the terrain and the neotectonic fault structures related with these earthquakes made possible the seismic zoning of the terrain.

The seismic centres are grouped in two regions: Kičevo and Bitola, that define two seismogenic zones.

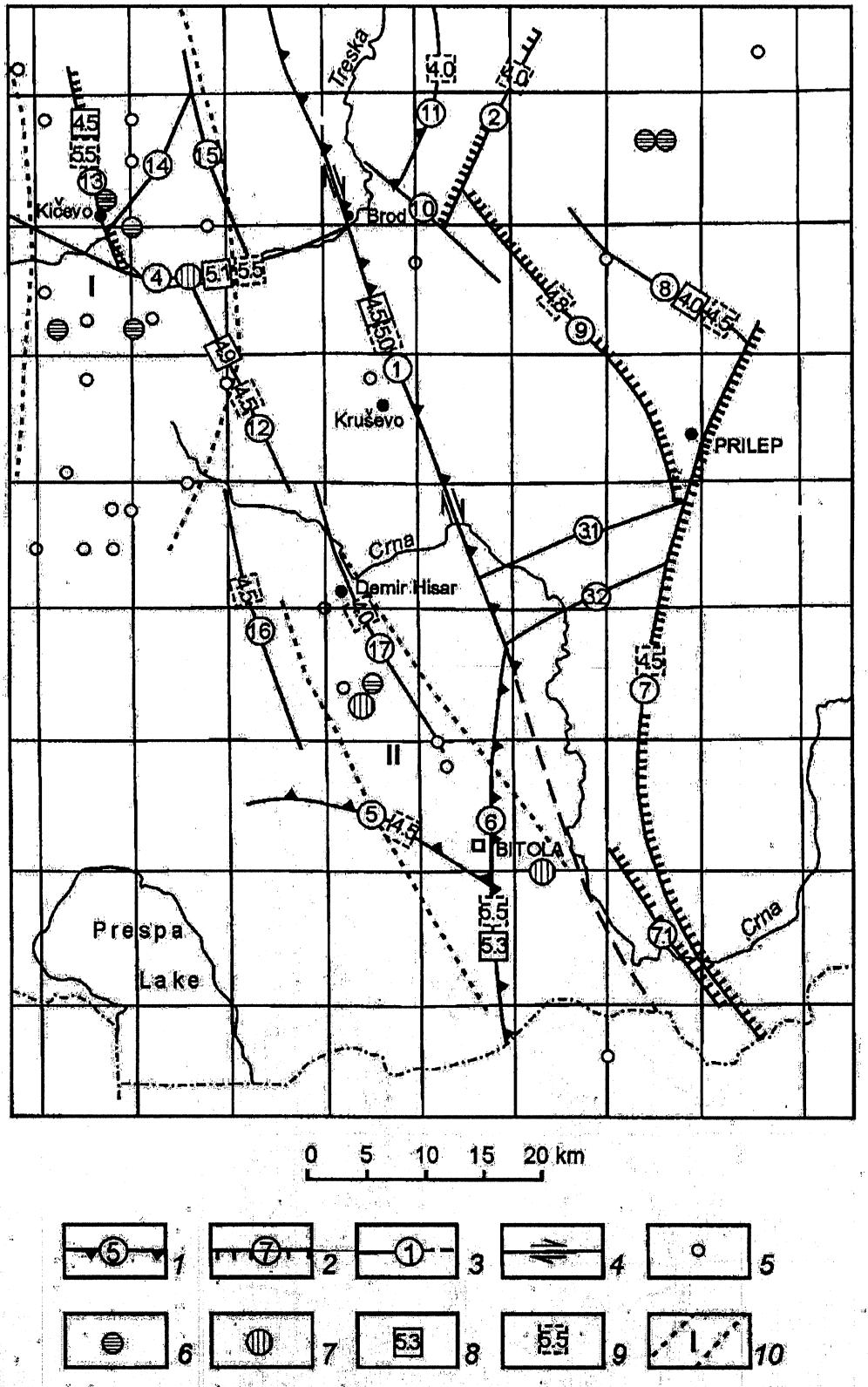


Fig. 3. Seismotectonic map of the Pelagonian and Kičevo valley and the Poreč area
1 — faults with contrast relief expression; 2 — faults of medium expression in the relief; 3 — poorly expressed or postulated faults; 4 — strike-slip faults; epicentres of earthquakes with magnitude: 5 — M=4-4.5; 6 — M=4.5-5; 7 — M=5-5.5; 8 — maximum energy released; 9 — anticipated maximum energy; 10 — seismogenic zones: I — Kičevo, II — Bitola

Table 2
*Catalogue of earthquakes in the Pelagonian, Poreč and Kičevo depressions and the surrounding block structures*

| No. | Earthquake occurred | | Geographic location | | Depth h [km] | Magnitude M | Intensity | Seismogenic zone |
|---|---|---|---|---|---|---|---|---|
| | date | time | φ | λ | | | | |
| 1 | 25.06.1906 | 15:00 | 41.56 | 21.55 | 15 | 4.5 | 6 | / |
| 2 | 02.08.1911 | 09:00 | 41.50 | 21.00 | 15 | 4.5 | 6 | Kičevska |
| 3 | 17.02.1920 | 08:30 | 41.45 | 20.91 | 15 | 4.2 | 6 | Kičevska |
| 4 | 10.07.1920 | 07:00 | 41.56 | 21.56 | 15 | 4.5 | 6.0 | / |
| 5 | 23.07.1920 | 18:40 | 41.63 | 21.66 | 20 | 4.5 | 6.0 | / |
| 6 | 05.09.1920 | 01:20 | 40.86 | 21.50 | 20 | 4.1 | 5.0 | Bitolska |
| 7 | 14.09.1920 | 02:08 | 41.00 | 21.43 | 20 | 5.3 | 7.0 | Bitolska |
| 8 | 04.10.1920 | 01:17 | 41.38 | 21.25 | 25 | 4.2 | 5.0 | / |
| 9 | 15.03.1921 | 01:40 | 41.43 | 21.02 | 8 | 4.2 | 7.0 | Kičevska |
| 10 | 02.04.1921 | 05:04 | 41.30 | 21.06 | 15 | 4.2 | 6.0 | Kičevska |
| 11 | 02.08.1921 | 11:55 | 41.46 | 21.06 | 20 | 5.1 | 6.0 | Kičevska |
| 12 | 22.04.1922 | 12:45 | 41.50 | 21.00 | 20 | 4.1 | 5.0 | Kičevska |
| 13 | 18.11.1924 | 11:15 | 41.50 | 21.08 | 25 | 4.2 | 5.0 | Kičevska |
| 14 | 14.10.1926 | 18:30 | 41.50 | 21.00 | 20 | 4.1 | 5.0 | Kičevska |
| 15 | 14.10.1926 | 22:05 | 41.50 | 21.00 | 20 | 4.1 | 5.0 | Kičevska |
| 16 | 10.02.1935 | 06:45 | 41.38 | 21.08 | 20 | 4.1 | 5.0 | Kičevska |
| 17 | 16.01.1940 | 00:49 | 41.58 | 21.00 | 20 | 4.1 | 5.0 | Kičevska |
| 18 | 20.05.1952 | 15:03 | 41.42 | 21.00 | 15 | 4.2 | 6.0 | Kičevska |
| 19 | 19.06.1952 | 00:23 | 41.42 | 21.00 | 25 | 4.3 | 5.0 | Kičevska |
| 20 | 19.09.1952 | 02:31 | 41.42 | 21.00 | 30 | 4.4 | 5.0 | Kičevska |
| 21 | 01.03.1955 | 06:02 | 41.42 | 20.92 | 20 | 4.5 | 6.0 | Kičevska |
| 22 | 01.11.1960 | 16:13 | 41.10 | 21.32 | 15 | 4.1 | 6.0 | Bitolska |
| 23 | 02.11.1960 | 10:56 | 41.08 | 21.33 | 20 | 4.1 | 5.0 | Bitolska |
| 24 | 18.03.1966 | 02:58 | 41.55 | 21.00 | 10 | 4.0 | 6.0 | Kičevska |
| 25 | 31.07.1966 | 11:03 | 41.20 | 21.20 | 20 | 4.6 | / | Bitolska |
| 26 | 26.09.1967 | 05:05 | 41.52 | 20.97 | 15 | 4.7 | 7.0 | Kičevska |
| 27 | 16.11.1967 | 10:15 | 41.25 | 20.90 | 15 | 4.3 | 6.0 | Kičevska |
| 28 | 04.12.1967 | 00:48 | 41.47 | 21.30 | 10 | 4.3 | 7.0 | / |
| 29 | 17.03.1970 | 17:00 | 41.42 | 20.92 | 20 | 4.6 | 6.0 | Kičevska |
| 30 | 31.01.1971 | 09:14 | 41.38 | 20.95 | 15 | 4.3 | 6.0 | Kičevska |
| 31 | 02.12.1972 | 19:48 | 41.58 | 21.00 | 20 | 4.0 | 5.0 | Kičevska |
| 32 | 02.12.1972 | 22:40 | 41.57 | 20.95 | 13 | 4.3 | 6.0 | Kičevska |
| 33 | 17.08.1977 | 22:32 | 41.43 | 20.95 | 15 | 4.0 | 5.0 | Kičevska |
| 34 | 06.10.1979 | 06:40 | 41.62 | 20.88 | 15 | 4.3 | 6.0 | Kičevska |
| 35 | 04.09.1983 | 15:57 | 41.28 | 20.98 | 15 | 4.1 | 5.5 | Kičevska |
| 36 | 05.09.1983 | 08:30 | 41.28 | 20.98 | 15 | 4.2 | 5.5 | Kičevska |
| 37 | 05.09.1983 | 08:31 | 41.28 | 20.98 | 20 | 4.0 | 6.0 | Kičevska |
| 38 | 05.09.1983 | 08:39 | 41.25 | 20.95 | 15 | 4.0 | 5.0 | Kičevska |
| 39 | 05.09.1983 | 08:49 | 41.25 | 20.98 | 15 | 4.3 | 5.0 | Kičevska |
| 40 | 19.08.1984 | 04:08 | 41.60 | 20.87 | 15 | 4.0 | 5.0 | Kičevska |
| 41 | 21.10.1988 | 02:18 | 41.31 | 20.93 | 15 | 4.2 | 6.0 | Kičevska |
| 42 | 01.09.1994 | 16:12 | 41.13 | 21.24 | 23 | 5.2 | 7.5 | Bitolska |
| 43 | 01.09.1994 | 16:21 | 41.13 | 21.24 | 23 | 4.1 | / | Bitolska |
| 44 | 01.09.1994 | 16:23 | 41.14 | 21.25 | 25 | 4.8 | 5.5 | Bitolska |
| 45 | 01.09.1994 | 19:42 | 41.14 | 21.22 | 20 | 4.1 | 5.5 | Bitolska |
| 46 | 13.07.1995 | 12:13 | 41.58 | 20.91 | 17 | 4.4 | 6.0 | Kičevska |

**Kičevo seismogenic zone (I).** 32 earthquakes of magnitude higher than 4 have been registered in the zone but only one of them reached M=5.1 (2 August 1021). The occurrence of earthquakes in the zone is related to the neotectonic fault structures in the region: Jamski (4), Cer (12), Zajas (13), Kičevo (14) and Pesjka (15), which form a tectonic knot here and are seismically active.

**Bitola seismogenic zone (II).** Nine earth-

quakes with magnitude higher than 4 have been registered in the zone from 1902 to 1996. Only two earthquakes with M> 5 have been registered — on 14 September 1920 (M= 5.3), and on 1 September 1994 (M=5.2). The occurrence of these earthquakes is related to the Gavato fault (5), Bitola fault (6) and the Demirhisar fault, which are all sesimogenically active. Based on the classification of seismogenic sources in the territory of Macedonia (Jančevski, 1987), the Kičevo and Bitola seismogenic areas are placed into the group of second-order seismogenic sources.

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