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NEOTECTONIC AND SEISMOTECTONIC CHARACTERISTICS OF GRABENS IN THE STRUMA FAULT ZONE (SW BULGARIA)

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ABSTRACT

In SW Bulgaria many Neogene-Quaternary grabens are developed along and across the Struma fault zone. In the region the summary values of neotectonic vertical and horizontal displacements vary mainly from hundreds to thousands meters. The seismic events are remarkable ones (Krupnik earthquake, 4.4.1904, M=7.8). The hypocenters of the earthquakes are distributed mainly in four seismogenic layers, situated in the depth 4-18, 20-30, 35-45 and 50-65 km. In the most cases the epicenters are concentrated in or near the transversal to the Struma fault zone grabens and mainly in the fault and lineament crossings or in limited segments of faults and lineaments.

1. INTRODUCTION

The subject of investigation is the Neogene-Quaternary grabens and graben systems, situated in the Struma fault zone between the towns of Kyustendil and Petrich in SW Bulgaria. The region is of a high Neogene-Quaternary and Recent geodynamic activity, including earthquakes with magnitude M≥7. The tectonic development is mainly realized in the conditions of collision between the African and Eurasian plates. But in the region the local extension tendences are also very well manifestated. The processes of the fault generation and regeneration, of a swell-block and horst-graben disintegration are well presented. The earthquakes, including the events with magnitude M≥7 and others generated in the upper and lower crust, are characteristics to the region.

That is a region of a dense population and of a significant historic, economic, cultural and tourist development, of active relations with the neighbouring countries and of a perspective future, where a part of the seismotectonic researches is as a result of special practical needs.

2. NEOTECTONIC DATA

2.1. Main morphostructures

According to the morphostructural interpretations, the investigated grabens of the Struma fault zone are developed on the boundary territory situated between the Serbo-Macedonian and the Rhodopian massifs (Vaptzarov, Mishev, 1977).

The morphostructures are of different characteristics. The well expressed linear lineament zones, swell-block and horst-block uplifts, inter-swell subsidence and concentric structures exist (fig.1, 3). The formation and the development of the grabens and the graben systems are related to the evolution of the swell structures of different scales, the specific development of their

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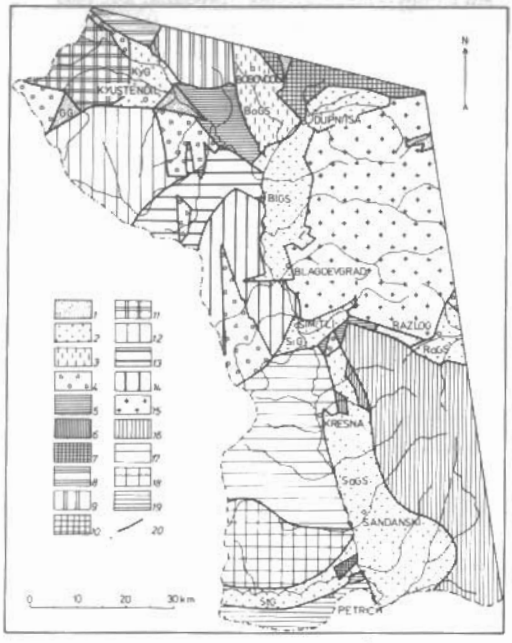

Fig. 1: Morphostructural scheme of part of Struma fault zone.
1 - Quaternary graben, 2 - Neogene-Quaternary graben, 3 - Upper Oligocene-Lower Miocene graben, 4 - Paleogene graben, 5 - step structure (horst), 6 - foot of mountain, 7 - inner depression horst, 8 - Zemen mountain, 9 - Konyavo mountain, 10 - Verila mountain, 11 - Lisets mountain, 12 - Osogovo mountain, 13 - Piyanets mountain, 14 - Vlahina mountain, 15 - Rila mountain, 16 - Pirin mountain, 17 - Maleshevo mountain, 18 - Ograzhden mountain, 19 - Belassitsa mountain, 20 - morphostructural boundary fault. Supplementary symbols: BlGS - Blagoevgrad Graben System, BoGS - Boboshevo Graben System, GG - Gyueshevo Graben, KyG - Kyustendil Graben, RaGS - Razlog Graben System, SaGS - Sandanski Graben System, SiG Simitli Graben, StG - Strumeshnitsa Graben.

central and peripheral parts, the presence of crossing points of longitudinal, transversal and oblique faults and lineaments. During the Neogene-Quaternary, the vertical displacements vary from 200-300 m to 400-600 m in the inner parts of the morphostructures and from 800 m to 3700 m in its peripheral parts.

The Struma fault zone or the Struma lineament is treated either as a part of long time developed Kraishte-Vardar lineament (Boncev, 1965; Zagorcev, 1992) or as a young manifested lineament in the alpine poliphase collision structures (Gocev, 1991; Dabovski ,1991). We follow the second conception. Many faults in NNW-SSE (160°) direction are traced in the region with a length of 20-60 km and a width of 0.5-3 km. During the Neogene and the Quaternary the final formation of the structures is realized. At the end of the Lower Miocene, in the conditions of NW-SE compression (Zagorcev, 1992), some folds with SW vergency, overthrusts in NE board of the Bobovdol graben system and some inverse faults, overthrusts with inclination from 25° to 60-70° are generated. We establish the same manifestations in a sector of the NE bord of the Simitli graben, in the vicinity of the village of Gradevo. The last lithological and Neogene structural investigations show that in the region the thick graben sedimentation and the formation of the Struma rift are as results of four regional microcycles with beginning from the Badenian (Zagorcev, 1992).

2.2. Main stages of the graben development

The main stages are six: Badenian-Sarmatian, Maeotian, Pontian, Dacian-Romanian, Quaternary and Recent ones.

2.2.1. Badenian-Sarmatian stage

At the beginning of the stage a number of faults and grabens are formed in

the condition of extension (Zagorcev, 1992). The Sandanski graben appearance is related to the development of two local grabens. The sedimentation is of alluvial and proluvial origin, realized in an aridian climate, and presented by the Katuntsi formation (Nedjalkov et al., 1986) in the Eastern part of the Sandanski graben with a thickness of 400 m and by the Delchevo formation (Koyumdgieva et al., 1982) in the Northern part of the Struma graben, near the town of Kresna, with a thickness of about 600 m. That is the time of the initial peneplain formation. The traces of the Sandanski graben basement are situated on the depth of 2000 m in the central part of the structure.

2.2.2. Maeotian stage

The faulting goes on. The Sandanski graben is more subsided. The thickness of the Sandanski formation reaches up to 1580 m (Koyumdgieva et al., 1982). The sedimentation is localized mainly in the central part of the Sandanski graben system on the territory of the town of Kresna and of the village of Marikostenovo.

The Simitli, the Blagoevgrad and the Kyustendil grabens appear in that stage. The river nets and the alluvial sedimentation, from one side, and the intensive proluvial sedimentation near Rila, Pirin and Krupnik faults, from the other, are well presented in the cited grabens. The Simitli formation of alluvium with a thickness of 500 m and the Chernichevo formation of proluvium with a thickness of 500 m (Koyumdgieva et al., 1984) are developed in the Simitli graben near Krupnik fault. In the Blagoevgrad graben system near the Rila fault the Djerman formation with a thickness up to 500 m (Bakalov, 1977) and in the Sandanski graben system near the Pirin fault the Kalimantsi formation with a thickness up to 800 m (Koyumdgieva et al., 1982) are presented too. Locally, on the territory of the Kyustendil graben, there are a marsh sedimentation and formation of a coal basin with thickness up to 500 m. In the beginning of the Maeotian in the Blagoevgrad graben system the general Struma river flow in North direction (Bakalov, 1977) is as a result of a local swell formation (fig.1).

The processes of a regional planation are developed. They are marked by a 20 m thick weathering crust.

2.2.3. Pontian stage

The faulting is accompanied by the new subsidence of the pre-existing basins and the formation of new ones in the conditions of an considerable block desintegration. Along the Struma valley the sedimentation is very intensive and includes coarse sands, gravel and blocks of different size. In the Blagoevgrad and the Sandanski graben systems in the vicinity of the Rila and the Pirin faults the proluvium sediments similar to the alluvium ones are well presented and the Sandanski formation reaches a thickness of about 580 m (Koyumdgieva et al., 1982). The same sediments are developed in a new-formed local Oshava graben and in the Eastern part of the Simitli graben, where the thickness of the Djerman formation is up to 500 m (Bakalov, 1977). In the Kyustendil graben an alluvial sedimentation with a thickness up to 100 m is established.

In the Sandanski graben system, where the alluvium and proluvium are well presented, there is a tendency of not interrupted Pontian-Dacian evolution. Generally the alluvium is reduced, but in the Eastern part of the graben in the upper part of the Kalimantsi formation (Koyumdgieva et al., 1982) the alluvium is predominant deposit and it is difficult to be compared with the proluvium.

2.2.4. Dacian-Romanian Stage

For all of grabens the alluvial sedimentation is reduced, but not

interrupted.

In the Blagoevgrad graben system the Barakovo formation of thickness up to 300 m (Bakalov, 1977) and in other grabens the sediments of thickness up to 100 m are developed.

2.2.5. Quaternary stage

The beginning is marked by a tectonic phase. Some significant reverse faults and overthrusts are generated (Mercier, 1979) in compression conditions along the Western and Southern boundaries of the Balkan Peninsula. At the same time in the inner part of the Peninsula, in the region of Struma river, the main uplift and the block disintegration of the Serbo-Macedonian and the Rhodopian massifs with their block inclination to the Struma valley are realized.

In the Pleistocene the movements are very clearly differentiated. The subsidence of some blocks and the accumulation of sediments are quite irregularly. The maximal values of the sediment thickness are 100 m in the Kyustendil graben, 80 m - in the Djerman one, 60 m - in the Blagoevgrad one, 120-180 m - in the Sandanski and in the Strumeshnitsa grabens. The values of the positive movements are also specific. During the Villafranchian they reach 320 m in the Kyustendil graben, 460-660 m - in the Djerman one, 440-560 m - in the Simitli one, 1090 m - in the Sandanski one. After the Villafranchian their maximal values are not so representative: 180 m in the Kyustendil graben, 160-220 m in the Djerman one, 50 m in the Strumeshnitsa one, 100-160 m in the Sandanski one and 90 m in the Simitli one.

The Holocene generally positive movements have a specific spatial and intensity characteristics, but the maximal value of the uplift is about 40 m (in the region of Kresna).

2.2.6. Recent stage

The periodic geodetic leveling show different values of the annual vertical movements in the region. The general tendency is of uplifting. The registered values are as following: 0.6 mm/a in the region of the town of Kyustendil, 1.8 mm/a - in that of the town of Dupnitsa, 2.2 mm/a - in that of village of Djerman, 2.6 mm/a - in that of the town of Blagoevgrad, 2.4 mm/a - in that of the town of Simitli, 3.8 mm/a - in that of village of Krupnik and 3.2 mm/a - in that of the town of Petrich. In some small blocks the values are bigger.

The horizontal displacements are observed only in some localities and they reach a value of 1.8 mm/a.

3. SEISMOTECTONIC NOTES

3.1. Seismologic and tectonic basement of investigations

A lot of seismologic data for the region under investigation are available (Grigorova, Grigorov, 1964; Grigorova, Rizhikova, 1966; Shebalin et al., 1977; Matova, Rizhikova, 1980; Solakov, Simeonova, 1993). The region is characteristics by high seismic activity in time, space and energy domain (some of earthquakes are of M≥7). We follow the conception, that the earthquakes are the part of the tectonic movement of the Earth masses (Riznichenko, 1965) and for us the seismic events indicate the presence of recent mobile structures, from one side, and the development of some recent tectonic processes, from other one. Now we explain the earthquake distribution in space on the basis of tectonic conditions of the study region and we try to receive some more structural information from the seismologic analysis.

The main tectonic data about the region are taken from publications of Gocev, Matova (1977, 1989), Dachev (1988), Katzkov et al.(1985), Gocev (1991), Dabovski (1991), Bokov et al.(1993), where the problems of the important

horizontal displacements of the structures and their inner disintegration are interpreted in the light of the plate tectonic conceptions.

3.2. Depth distribution of seismic events with M=4 and its tectonic interpretation

On the basis of the graph about the magnitude-depth distribution of the hypocentres of earthquakes with M=4 (Shebalin et al., 1974) four seismogenic layers are established in region (fig.2). This method of research is used by Grigorova et al. (1980), but for a larger territory without application of some structural principles. In our seismotectonic investigations we apply this method in tectonic defined spaces, mainly in a tectonic unit (Matova, 1986). In the study region the seismogenic layers are situated in following deep levels and the earthquakes in them reached the following Mmax:

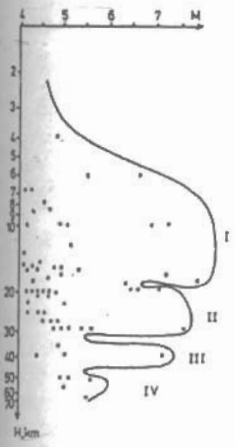

Fig. 2: Scheme of seismogenic layers on the basis of the graph of magnitude-depth distribution of the seismic events with M≥4.

first seismogenic layer - 4-18 km, Mmax = 7.8
second seismogenic layer - 20-30 km, Mmax = 7.5
third seismogenic layer - 35-45 km, Mmax = 7
fourth seismogenic layer - 50-65 km., Mmax = 5.7.

The seismic activity of the first and the second layers are considerable. In the third and fourth layers the seismic mobility is limited. The highest M value M=7.8 is reached in the first seismogenic layer, which proves to be a serious seismic danger in the region. That is important to indicate that in the second and the third seismogenic layers the hypocenters of the earthquakes with M equal or more of 7 are also registrated.

The presence of four seismogenic layers, the frequent activity of two of them, the considerable seismic energy (high M values) of three of them, all these characteristics show that in the region the crust and the upper part of the upper mantle participate in intensive recent tectonic movements. The first and the second layers, where the hypocentres are concentrated on the layer's boundaries, may be correspond to recent developing horizontally moving structures.

3.3. Structural localisation of the considerable seismic events

In many cases the spatial concentration of the epicenters of earthquakes (fig. 3) with M=5 -5.9 show some relations with the Simitli, the Blagoevgrad, the Kyustendil, the Sandanski grabens of the Struma fault zone, where the neotectonic subsidence is considerable. But the same is also established under the Rila and the Pirin horst-blocks, the most uplifted structures, situated on the East of the Struma river. Some more the indicated epicenters are frenquently distributed in a vicinity of fault and lineament crossing points. The epicenters of the seismic events of M=6 -7.8 are located mainly in the grabens or near the boundaries of the grabens and the horsts and they are generally related to transversal and oblique to the Struma fault zone faults and lineaments and its crossing points with longitudinal faults and lineaments.

The geophysical (Dachev, 1988; Dobrev, Ryazkov, 1986) and the tectonic data (Gocev, 1991; Dabovski, 1991) indicate the presence of considerable accumulation of horizontally displaced structures in the region. The neotectonic researches show as well the significant block disintegration of the structures and the

3.4. Seismotectonic researches about regional practical needs

In this territory of significant human, technological, cultural and tourist potential there are some local and regional seismologic and seismotectonic investigations. Among them the most important ones are the seismic microregionalization of the largest political and economic center in the region - the town of Blagoevgrad, of the most significant cultural and tourist center in the region - the Rila monastery, of the dam of Logodash, situated in the west near to the town of Blagoevgrad. Perhaps in the future some similar researches must be organized in the regions of the towns of Sandanski, Petrich and Melnik in the Southern part of the region and in the towns of Kyustendil, Dupnitsa - in the Northern part.

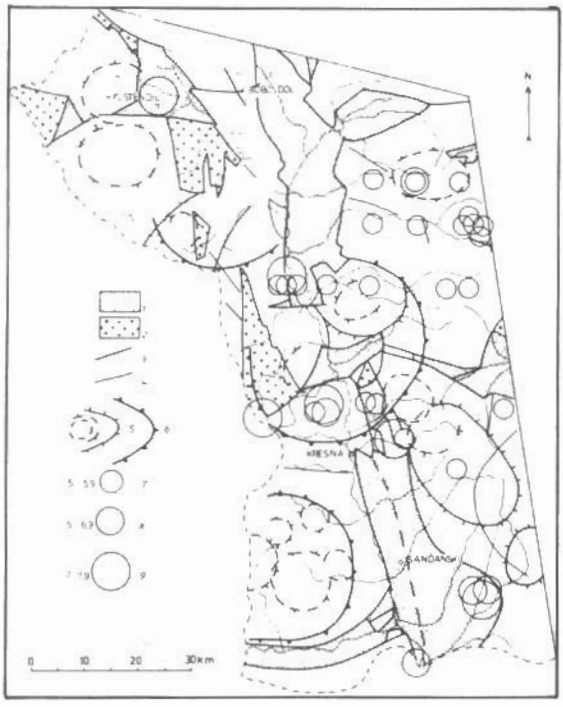

Fig. 3: Scheme of the main morphostructures and of the epicentres of the most representative seismic manifestations in the region.
1 - Neogene-Quaternary graben, 2 - Paleogene graben, 3 - morphostructural boundary fault, 4 - other fault with Neogene-Quaternary movements, 5-6 - concentric morphostructures (Katzkov et al., author's interpretations): 5 - local, 6 -regional ones, 7-9 epicentres of earthquakes with M=5 (7 - M=5-5.9, 8- M=6-6.9, 9= 7-7.8)

intensive vertical and horizontal displacements, concentrated on the boundaries of the main structures. So in the region the generation of numerous and strong earthquakes is related mainly with the processes of the block displacements on the peripheries of the structure units, as the Rila and the Pirin horsts, the Sandanski, the Simitli and Kyustendil grabens.

4. CONCLUSIONS

In the region some of the structures, grabens, graben systems, lineaments and faults, are of Paleogene-Quaternary and others are of only Neogene-Quaternary age. That is as result of a regional neotectonic evolution and of a local inherited alpine development. In the study region the seismic activity is the highest under the grabens

With Paleogene-Quaternary development and with an important neotectonic activation as the Simitli graben (Krupnik earthquake, 4.4.1904, M=7.8).

The investigated grabens sediments are of specific characteristics about the lithology and the thickness. Some more in the study region a lot of the grabens and of the presented horst is strongly fragmented by faults and lineaments. The geophysical information indicates about the presence of small sizes gravic and magnetic fields of variable intensities and of gradi-

ent zones with NE-SW, NW-SE and E-W directions. The above mentioned characteristics are in accordance with the block mosaic desintengration of the structural unit's basement and the lithological heterogeneity of the sediment covers (Boyanov et al., 1983). Some of the strongly block disintegrated grabens and horsts as the Blagoevgrad graben and the Rila horst are with considerable seismicity.

The main neotectonic movements in the region are characterized by vertical displacements with extent up to 10 km and by horizontal displacements with extent up to 3.5-4 km in the Struma fault zone. The epicentres of the strongest earthquakes with M≥7 are localized in territories of some considerable, but not always with the most expressive block displacements. The Kyustendil earthquake of May 1641 with M=7.2 is developed in a region of moderate block displacements.

Only some segments of the faults and the lineaments are neotectonic, including seismic active. The sedimentation and the displacements reach high values in and near the crossings (knots) of submeridional and subequatorial faults and lineaments. In a part of them the seismicity increases, for example in the crossing points of the Krupnik fault and the Struma lineament the seismic events reach the maximal value of M=7.8.

In the study region the presence of four seismogenic layers indicates a very significant and deep recent activation of the crust and the upper part of the upper mantle. We think that this specific characteristic of the seismic movements in the region could be interpreted as a result of preneotectonic and neotectonic horizontal and vertical desintegration of the earth crust and the upper mantle, from one side, and of recent going formation and deformation of some structures with seismic active boundaries. The concentration of the hypocentres of the first and the second seismogenic layers mainly along the layer's boundaries indicates the biggest importance of the horizontal moving structures in the depth up to 30 km, than in the other layers.

So the structural characteristics of the region are of a great importance to the development of the seismic processes. The research of the seismic manifestations could given some information about the tectonic evolution of the investigated territory.

The seismotectonic research proposes some direct and indirect answers of some practical needs of the region.

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