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Using Complex Geophysical Data for Determining Tectonic Setting of Čačak - Kraljevo Basin and it's Basement (Serbia)

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SUMMARY

Research has been done with the task of identifying structural and tectonic characteristics of the Čačak – Kraljevo basin, and the goal was to determine tectonic setting of the basin and it's basement. Complex geophysical and geological data were used: gravity and geomagnetic maps, Landsat 7 satellite imagery and map of temperatures, derived from thermal bands of the satellite imagery.

It was obtained that tectonic characteristics of the investigated area are complex, due to it's complex geotectonic setting. Kinematic and dip angle of the ruptures were obtained from the combination of standard visual methods and map of vertical gradient of gravity acceleration. Map of temperatures can confirm existence of the ruptures, on the places which are not highly visible on any other set of data used. Geotectonic setting of basement of the basin was obtained from the combination of interpretation of the tectonic fabric and geological and petrological data.

Introduction

Geological setting of the Central Balkan Peninsula is very complex, and it is dominated by complex suture zone, which was most probably formed through multiphase subduction and accretion processes (Trivić et al., 2010). The suture zone consists of NNW-SSE elongated units that include huge masses of ophiolites, trench and accretionary wedge sedimentary assemblages that sometimes form metamorphic soles, and dismembered Palaeozoic units. This suture zone is in many places overlaid by Early Cretaceous to Quaternary sedimentary overstep sequences, which cover the original structural relationships. Čačak – Kraljevo is one of the Tertiary overstep sequences in this suture zone.

There is a wide range of opinions about the spreading and closure of the Tethyan domains mostly involving differences in the number of the existing oceans, nature of the emplaced ophiolites and age and orientation of the operating subduction (Karamata, 2006; Schmid et al., 2008; Robertson et al., 2009). Basement of the Čačak – Kraljevo basin is situated on the margin of the suture zone, so it already has complex tectonic setting. Its tectonic setting is even more complex, because it is covered by 2000 meters thick Tertiary and Quaternary sediments, so structural characteristics can't be investigated directly on the field.

The aim of this research was to determine tectonic setting of the basin and its basement. Pursuing to the order, the task was to identify structural and tectonic characteristics of the investigated area, using several sets of data: map of Bouguer anomalies, map of anomalies of vertical component of the geomagnetic field, map of vertical gradients of gravity acceleration, Landsat 7 satellite imagery, map of temperatures and geological map.

Investigated area is located in western Serbia, in the Zapadna Morava Valley (Figure 1). The central part of the investigated area, Čačak – Kraljevo basin, is formed between mountain Jelica in the southwest, and dacite-andesite Kotlenik massif in the northeast. Southern parts of the terrain are in the area south of Ibar and Zapadna Morava and belong to the northern branches of the Goč and the Stolovi mountains. On the northwest, terrain extends to the southeastern parts of the Rudnik mountain, which is connected to massif of the Kotlenik range.

Figure 1 – Physical setting of the investigated area

From the geological and geotectonic aspect, investigated area is situated in the complex area, which conditioned complex relationships between geological units in this area. In the geotectonic view, investigated area is situated on the contact of three big geotectonic units. In this paper, geotectonic division according to Dimitrijević (2000) is accepted. According to this division, in the south-western parts of the investigation area Drina-Ivanjica Element (DIE) is situated, the central parts of the investigation area is dominated by Extern Vardar Zone (EVZ) and the easternmost parts are in the Central Vardar Zone (CVZ). Although geotectonic division by Schmid et al. (2008) was not used during the investigation, it was considered during defining relationship between Drina-Ivanjica Element and Extern Vardar Zone (in original, name of this geotectonic unit is Western Vardar

Ophiolitic Unit, but in the area of investigation it has the same characteristics as the EVZ unit, by Dimitrijević). According to authors of this paper, EVZ was obducted on the DIE by the end of Jurassic, and on the end of the Cretaceous it was thrust in the same direction. This fact was of great importance during further consideration of geological and geophysical characteristics of the investigated area. Two regional normal faults of the northwest-southeast direction, are dominating on the investigated area. On the end of Cretaceous, basin has been formed along to those faults (Novkovic, Terzin 1957).

For purpose of this investigation, a specific geological map of this area was developed – geotectonic division is in the first plan, while lithostratigraphic division is subordinated (Figure 2). Drina-Ivanjica Element is composed of Palaeozoic metamorphic rocks. According to the grade of metamorphism, they belong to the green schist facies. Extern Vardar Zone is composed of the following units: Triassic limestones, ophiolitic complex, Tertiary and Quaternary sediments and volcanic complex of the Borač and Kotlenik. Ophiolitic complex is divided into two stratigraphic units: one from Jurassic and one from Cretaceous. Jurassic ophiolites are northwest – southeast direction, and are presented by ultramafites, gabbro and diabase. Cretaceous ophiolites are presented by arenites, clays and marls, mafites and rarely ultramafites (ophiolitic mélange). Dacite-andesite volcanic formation from Tertiary is situated in the central part of the terrain. It is part of the Kotlenik – Rudnik volcanic complex. It is made of tuffites, dacites and labrador andesites, and rarely basalts. According to Obradović and Vasić (2007), basement of the basin is composed of the Borač-Kotlenik volcanic complex. Tertiary and Quaternary sediments are made of sandstone, conglomerates, sandy limestone, marls and clays. Thickness of these sediments is the greatest in the area of Kraljevo, reaching about 2250 meters (Marinković et al., 1978). Central Vardar Zone is composed of flysh sediments from Cretaceous.

Figure 2 – Geological map of the investigated area

Materials and Methods

The survey was conducted in two phases, which implied analyses and interpretation of geological data, and drafting, analyses and interpretation of gravity and geomagnetic maps.

Analysis of geological data consisted of analysis of satellite image and interpretation of tectonic fabric. This phase was carried out using visual methods of Remote Sensing, whereby the entire attention towards defining the position of regional structures for a given area of research. For better insight of the extending of faults and their mutual relations, a much wider area was observed. Color-composite, made of bands 7, 5 and 4 of the Landsat 7 imagery, was used for visual analysis. The imagery was passed through all stages of preprocessing and enhancement. Also, a transformation of DN values in the relative values of temperature was obtained. This data was also used to determine tectonic fabric of this area.

On the basis of measurement data on 2044 points, a map of Bouguer anomalies was made. By analysis of the geological setting and by using a method of Parasnis, a calculation of the average density of rocks on the investigated area, was made. It is 2400 kg/m^3 . Also, a second derivate of the gravity acceleration in the vertical direction, i.e. vertical gradient, was calculated. Data from this map was used to correlate with data obtained by analysis of satellite imagery.

On the basis of measurements data on 1600 points, a map of vertical component of geomagnetic field was established.

Results and Discussion

Analysis and interpretation of all data used, was primarily focused on the determination of tectonic fabric of the investigated area. Interpretation of the tectonic fabric is shown on the Figure 3 - left.

Map on Figure 3 – right, was obtained by a transformation of DN values in the relative values of temperature. Ruptures are located in areas where temperatures rapidly change their values. All ruptures couldn't be determined by standard visual analyses of remote sensing. Based on the map of vertical gradients of gravity acceleration, existence of other ruptures could be assumed, but it was necessary to confirm their existence in those places. Now, there are two maps which can confirm the existence of these ruptures in places, which are not highly visible on the satellite image in visual analysis.

Figure 3 – Left: Interpreted ruptures on the satellite imagery; Right: Map of ruptures obtained from temperature data

Figure 4 – Left: Map of vertical gradients of gravity acceleration; Right: Geomagnetic map

It can be seen that two families of ruptures are dominated on the investigation area. Older set of ruptures extends in the northwest-southeast direction. Along these ruptures, on the end of Cretaceous, Čačak – Kraljevo basin was formed. Second, younger group of ruptures, extends in the NNE-SSW direction. This group of ruptures was most probably responsible for forming Borač-Kotlenik dacite-andesite complex. Interpretation of tectonic fabric on the basis of satellite imagery and map of temperatures are generally the same as on the basis of map of vertical gradients of gravity acceleration (Figure 4 – left). The only difference between these interpretations is position of same ruptures – there is slightly shift between ruptures obtained from satellite imagery and map of temperatures and those ones obtained from map of vertical gradient of gravity acceleration. Because of this shift, kinematics of the rupture can be obtained. Ruptures on the edge of the basin can be interpreted as normal faults, with dip angle of about 60-70 degrees. Ruptures situated near to the Jelica mountain (contact between CVZ and DIE), can be interpreted most probably as reverse faults, with dip angle of about 5-10 degrees (thrust). This interpretation is in accordance with geological facts, and theory of the contact between CVZ and DIE.

Also, by analyzing of geophysical maps, composition of the basement of basin can be obtained. According to Obradović and Vasić (2007), basement of the Čačak – Kraljevo basin is mostly composed of andesites and dacite-andesites (from the Borač-Kotlenik volcanic complex). However, according to Cvetković (1997), volcanic activity in this area started by the end of Lower Miocene, and it had syndimentational characteristics. Also, on the geomagnetic map, a continuity of the anomaly can be seen, which indicates that basement of the basin is most probably composed of ophiolites.

When composition of the basement is known, it's tectonic setting can be obtained. On the basis of the interpretation of all geophysical and geological data, it can be said that all these interpretations is in accordance with theory given by Schmid et al. (2008) – ophiolites were obducted and then thrust on the Drina-Ivanjica Element, and Čačak-Kraljevo basin represents an overstep sequence to the suture zone.

Conclusion

Tectonic characteristics of the investigated area are determined by designing, analysing and interpreting of complex geophysical and geological data. Tectonic characteristics of the investigated area are complex, due to it's complex geotectonic setting. Kinematic and dip angle of the ruptures was obtained from the combination of standard visual methods and map of vertical gradient of gravity acceleration. Map of temperatures can confirm existence of the ruptures, on the places which are not highly visible on any other set of data used. Geotectonic setting of basement of the basin was obtained from the combination of interpretation of the tectonic fabric and geological and petrological data.

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