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GEOMORPHOLOGICAL CHARACTERISTICS OF KRATOVO-ZLETOVO PALAEOVOLCANIC AREA

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Abstract: Kratovo-Zletovo palaeovolcanic area is known as one of the largest in Macedonia, F.Y.R. and wider, covering a total of 970.1 km^2. A huge amount of pyroclastic material is expelled here, with an average depth of about 700 m (Arsovski, 1997). According to Serafimovski (1993), Arsovski (1997) etc., volcanic activity in the Kratovo-Zletovo volcanic area started at the end of Eocene or lower Oligocene, and with some pauses, lasted until the lower Pliocene. In that period, the volcanic activity successively was moved from north-east to south-west (Boev and Yanev, 2001), with changes in volcanic intensity (violent eruption followed by expel of pyroclastic material; with silent phases followed by lava flows). The volcanism in this region was generally caused by deep submeridian dislocations, activated by the Paleogene east-west extension. At the end of Miocene, volcanic activity is reestablished by longitudinal neotectonic dislocations, starting with an earlier north-south extension. Geomorphologically, in Kratovo-Zletovo area there are about 20 volcanic cones and calderas, highly eroded by post-volcanic fluvial-denudation processes. Only Plavitsa cone (1297 m) and Lesnovo cone (1167 m) are better preserved, especially their calderas on the top (Milevski, 2005). These two volcanic centers, together with the Uvo-Bukovec cones, Zdravči Kamen, Živalevo and other volcanic necks, belong to the older volcanic phases, while younger centers are located in the south and west part of this palaeovolcanic area (Crni Vrv (1115 m), Preslap (1117 m) and Rajčani (867 m) cones with some remnants of calderas). After finishing of the volcanic activity, due to strong erosion, the volcanic forms subdued significant morphologic modifications. Today, on the remnants of palaeovolcanic cones, there are many fluvial, denudation landforms and even fossil coastal terraces. For that reason, the recent nature of Kratovo-Zletovo palaeovolcanic landscape is polygenetic.

Key words: Kratovo-Zletovo area, palaeovolcanic landscape, erosion, denudation

1.Introduction

The most remarkable palaeovolcanic area in Macedonia F.Y.R. and one of the most characteristic on the Balkan Peninsula is the Kratovo-Zletovo area. It is located in the north-east part of the country (Fig. 1), between Kozjak Mountain to the north, Osogovo Mountain to the east, Bregalnica valley to the south and Ovče Pole basin to the west, taking up an area of 970.1 km^2. The palaeovolcanic area is extended from Žegljane village on NW to Krupište village and Kočani on SE, it is 55 km long and 15-20 km wide. This NW-SE direction matches the deep dislocation (fault) line which separates the Serbo-Macedonian tectonic unit to the east from the Vardar unit to the west. The main volcanic centers are located in the central and southern part of this area, around Kratovo, Probištip and Zletovo, where larger cones and calderas still exist as part of the landscape. However, several centers are located to the north of these (Dudarova Korija, Kaludjerica), and few are located south (Preslap, Rajčani). Apart from these large structures (cones and calderas), there are also many smaller landforms, directly or indirectly related to previous similar volcanic rocks shaped by weathering, earth pyramids, characteristic valleys, gullies and even badlands in tuffs.

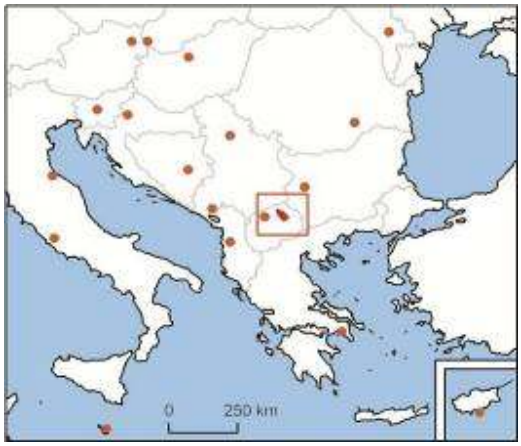

Fig. 1. Location map of Kratovo-Zletovo palaeovolcanic area.

The first geological and geomorphological knowledge of palaeovolcanic relief of this area dating from the late XIX and early XX-th century. Thus, Bouèe (1840) give its opinion on the geological structure of the area and present data about the mining in the Kratovo area. A little later, Cvijić on several occasions between 1902 and 1906, make detailed geological and geomorphological studies in the Kratovo-Zletovo area. In this, particular attention devoted to the determined palaeovolcanic forms and their later destruction. After World War II, because of the commercial use of significant ore (Pb-Zn) deposits, comprehensive geological studies in the Kratovo-Zletovo area were carried out. The results of these studies have been published in dozens of papers. In some of them, aside of geologic research, some geomorphological data's were presented, especially in the works of Marković (1971), Stojanovic (1986), Serafimovski (1993), Dumurdzanov et al. (2004) etc.

2. Methodological approach

For detailed geomorphological study of Kratovo-Zletovo area several methods were used. First of all, former geological research and data (bibliography, geologic maps) are considered to introduce with views of geotectonic settings of Kratovo-Zletovo area, then the driving causes and timeline for tectonic and volcanic activities. With field research and GPS tools, some landforms are identified, recorded, precisely located and analyzed. In identification and interpretation of larger palaeovolcanic structures, satellite imagery (Landsat ETM+; Google Earth) as well as DEM (3"SRTM, 1"ASTER GDEM) of this area is used, which also were used for morphometry analysis.

3. Preconditions for the emergence of the volcanic landscape in the area

The appearance of the volcanism in the Kratovo-Zletovo area is in close connection with the development of Cenozoic extension tectonics in the southern Balkan Peninsula. After a period of old-Alpine compression and collision of more megablocks, in South-Balkan-Aegean area N-S extension (relaxation) mode of the development started. This mode is characterized with radial tectonic movements which created a grabens and horsts, due thinning, stretching and cracking of the Earth's crust (Mantovani et al., 2002). In the southern Balkan Peninsula to the Aegean Arc, two phases of extension appear: the first at the end of Paleogene and the second from the middle Miocene until today. During the first east-west extension phase, more dislocations in northwest-southeast direction were activated (Dumurdzanov et al., 2004). That is the intersection of these dislocation lines with local fault lines where volcanic centers are created. Parallel with the appearance of volcanic activities, according to Graf (2001) and Zagorchev (1995), in-depth granitic intrusion is created under Osogovo and Ruen block which conditioned their tectonic rise. Paleogene (Eocene-Oligocene) volcanism in the above area is characterized by a discharge of acid to intermediary lava: andesite, dacite, quartz-latites, ignimbrites and others (Boev and Yanev, 2001). Younger, north-south extension started in the middle Miocene and lasts until today. It is expressed by the formation of young (neotectonic) fault structures with opposite (longitudinal) direction (Kjustendil-Debar fault; Kočani fault). At their intersection with the old fault lines, were reactivated old or new volcanic centers was formed. Interestingly explanation for Neogene magmatism have Petkovski (1998), by whom it is due to extrusion of magma through fault lines because of sinking of the surrounding grabens. Magma that could not come to the surface is intruded under Osogovo block that caused his rise. Stratigraphy and K-Ar dating of volcanic rocks, indicate that in the Kratovo-Zletovo area, volcanic activity began in the Oligocene, i.e. 32-29 million years ago (Boev and Yanev, 2001). Active volcanism with some interruptions, lasted almost 25 million years, and finally ended in the early Pliocene. For this period, volcanic areas of east parts of the region gradually move towards the south-west. The presence of acid to intermediate volcanic rocks: andesite dacite, and their tuffs and breccias, indicates violent-type eruptions, so that despite outbursts of lava has dropped a considerable amount of pyroclastic material. Taken as a whole, volcanic activity was of mixed type; calm eruptions with lava flows, occasionally changed with violent explosions and disposal of pyroclastic material. Volcanic phenomena were mainly of continental type, with the middle Miocene to Pliocene have emerged phases of accumulation and consolidation of material from eruptions in the surrounding Neogene lakes.

4. Basic morphological features of the palaeovolcanic landscape in the Kratovo-Zletovo area

Today, from the former turbulent volcanic activity in the Kratovo-Zletovo volcanic area, reminded a little well-preserved morphological remnants. The-

se are mostly highly modified and eroded volcanic cones, and much less remains of craters in the form of calderas. According to Cvijić (1906), volcanic cones between Zletovo and Kočani are arranged in series and between Kratovo and Zletovo, they are deployed in groups. If the terrain is analyzed in detail, it will realize that these cones represent: a) real volcano cones which are mainly from strato-type; b) pseudo-eruptive cones uplifted by intruding the magma near the surface; c) volcanic necks which because of faster erosion of the surrounded erodible terrain obtained cone-shaped form and d) conic hills shaped by fluvial-denudation processes.

Morphologically better expressed volcanic cones in the area are: Plavitsa (1297 m), Crni Vrv (1115 m), Uvo (1472 m), Lesnovo (Ilin Vrv, 1127 m), Kunovska Čuka (1347 m) etc. Their relative height to the surrounding terrain is 200-400 m, and diameter at the base is 1-3 km. They are dominantly of strato-type, with the lava layers (andesitic-dacitic lava and ignimbrites) interchanged with pyroclastic material (tuffs, breccias). Laterally, smaller cones often appear as a secondary or parasite cone. Thus, only around Plavitsa there are 7 parasitic cones with relative height from 50 to 150 m: Kundinska Čuka (817 m), Marčinska Čuka (1044 m), Kala (798 m), Gradište (995 m), Uši (1205 m), Baba (908 m) and Gro (1023 m). Several parasitic cones are present around volcanic centers: Uvo, Lesnovo, Crni Vrv, Preslap and others. Parasitic cone are often younger than the main cone, suggesting more phases of volcanic activity. Between main and parasite cone small passes are created, remnants of broken down "inter-colline" (Cvijić, 1906) or inter-cone depressions. After cessation of volcanic activity they predisposed formation of short rivers. In the inter-cone depression between Plavitsa (1297 m) and Kundinska Čuka (817 m), small Kundino Lake is formed by erosion of tuffs surrounded by harder rocks.

Due to continuous fluvial-denudation processes and young tectonic movements in the area, volcanic cones are significantly lowered, eroded and reduced, so it is not possible to reconstruct their initial shape and height. Particularly devastated are the peaks where the crater was located. Alongside, cones are incised by river valleys which radially spread-out towards the foot. For the intensity (speed) of the destruction of volcanic cones in this area can hardly speak, because the long-term processes that affected a number of factors and variables. Certain studies in Europe and worldwide (Karátson, 1996; Thouret, 1999; Ramsey, 2003), show that the average reductions of fossil cones are approximately 20-40 m / million yr. At this intensity of destruction arise that in the initial period, the volcanic cones in the Kratovo-Zletovo area were significantly higher, about 300-600 m.

It is interesting that some volcanic cones in post-volcanic period not only reduced, but increased their relative height, due to intense incision of the nearby river valleys. Thus, relative height of the cone Kunovska Čuka (1347 m) above the valley-bottom of the Zletovska River is 600-700 m, and above highest (Pleistocene) river terrace the relative height is only 400 m.

From the previous follows that upon the termination of volcanic activity today, volcanic cones are significantly modified, mainly due to erosion processes and also with tectonic movements. Such palaeovolcanic cones, that are much changed by erosion-denudation processes are actually polygenetic.

Regardless of poor preservation, palaeovolcanic cones are important landscape feature in the Kratovo-Zletovo area. Unlike the cones, most craters have been completely destroyed. In this area can identify the remains of five craters in the form of erosive calderas. Well preserved is caldera on the top of Lesnovo cone and less are preserved calderas of Rajčani, Crni Vrv, Štalkovica (Preslap) and Plavitsa cone. According to Marković (1971), palaeovolcanic forms located north of Lesnovo are poorly preserved because they are older. In our opinion, the good preservation of the Lesnovo caldera is because of the dense dacite lava flows and arranged necks that slow-down the fluvial-denudation processes. Also, it is possible that lower cones and calderas during upper Miocene to Pliocene were covered with lacustrine sediments, which later (in Quaternary) are exhumed. On that way, some period of time they were protected from erosive processes. Thus, between the Lesnovo and Plavitsa cone now runs a belt of Miocene lake sediments covering older palaeovolcanic relief to a height of 900 m.

5. Morphological characteristics of larger palaeovolcanic centers in the Kratovo-Zletovo area

As already mentioned, typical palaeovolcanic landscape, which is also better preserved is found in the central and south part of Kratovo-Zletovo area. In the northern part-on the west side of Kozjak

Mountain, there are number of conic hills and necks, from Kokino and Žegljane village on north, to the Stracin village, 10 km on southeast. But morphological reconstruction on these centers is very difficult because they are largely destroyed, especially through fluvial erosion and denudation. Northernmost, near Kokino village, characteristic neck called Tatičev Kamen (1013 m) composed by andesitic lava with columnar (prismatic) emission, remarkably rises in the landscape. This neck, together with Visoka (878 m) on south, probably belong to the large volcanic center near the village Bajlovce on east, which was highly altered by erosion of river Petrošnica. According to Karajovanovic and Hristov (1972), large masses of tuffs, up to 400 m deep, suggest that eruptions in this area were explosive and very violent, especially toward the end of the Miocene and beginning of Pliocene. Some remnants of volcanic cones and calderas appear in south direction, i.e. on the south side of Kozjak Mountain, toward Stracin village. Thus, Vitlič (1073 m) and Nepci (938 m) are remarkable cones with about 350 m of relative altitude. Vitlič cone with near ridges on the NE (toward Drenok village), has semicircular shape of caldera, heavily eroded by the Vetunica river from the east side.

Here, large masses of lava and pyroclastic material are expelled. In the vicinity, there are small parasitic cones, such as the ideally shaped Luda Mogila (673 m) and others. South of Vitlič and up to the Stracin pass, the andesitic rocks are much flattened, with occurrences of small denudation hollows and caverns on the surface, called lithotelmes.

Near the village Ketenovo, on several hills from both sides of Kriva River, traces of flowing andesitic lava are notable. This is the result of volcanic activity of nearby hot spots Vidim (825 m) and Kaludjeritsa (791 m) from right (north) side of the Kriva River and Ramni Rid (757 m) from left (south) side. Typical volcanic cone do not exist, only several necks on the mentioned hills. However, according to the arch-shaped remnants around, probably Kriva River was deeply incised and destroyed the large volcanic cone and its crater in the middle. Here the volcanic activity was the explosive type, so it formed small lava outbursts, surrounded by thick, extensive deposits of tuffs, which then extend to the northeast Ilin Rid (574 m) near the village Opila. There are several parasitic cones also, such as Ostrovica (641 m), Pobien Čovek, etc.

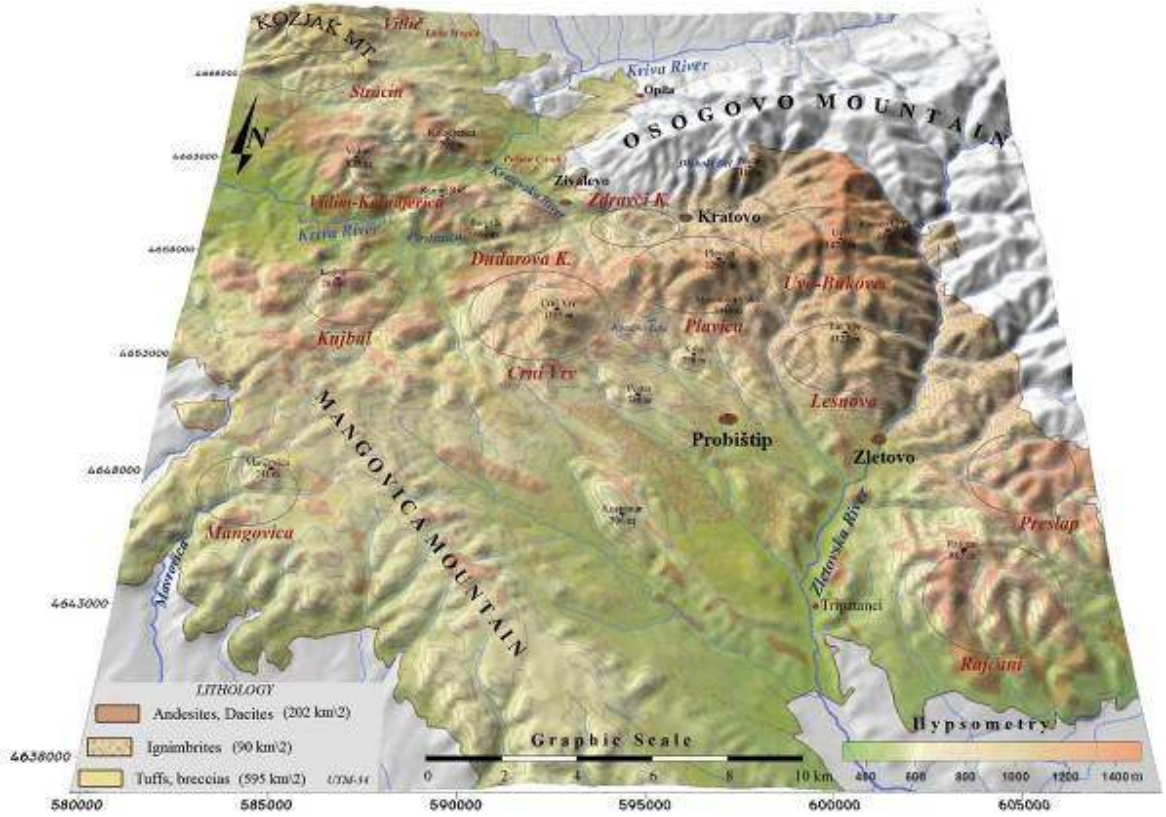

Fig. 2. Map of the most significant volcanic centers in Kratovo-Zletovo palaeovolcanic area (explanation in the text).

Taken as a whole, this volcanic center occupies a large area of 25 km^2, and with the surrounded pyroclastic material almost 60 km^2. According to the stratigraphic position and type of rocks, volcanic activity here belongs to the Oligocene-Miocene phase. It is interesting that on the right valley side of Kriva River, near the village Kuklica, significant occurrence of earth pyramids exist. These forms (about 120 "stone dolls") were created by differential weathering and pluvial erosion of the tuffs with andesitic blocks inside (Milevski, 2000).

In south direction is volcanic center Dudarova Korija (768 m) with several semicircular caldera-like remnants on the west side, and several parasitic cones in vicinity (Živalevski Rid, 723 m; Borovik, 664 m; Gradište, 639 m). Because of augite-biotite andesitic lavas, this structure, which is significantly eroded by Petrošnica River, is considered to belong to the earlier (Miocene-Pliocene) phases of volcanism (Serafimovski, 1993). Similar characteristics and dimensions has palaeovolcanic center Kujbul, 5 km west of Dudarova Korija, identified by Marković (1971).

On the left valley side of Kratovska River, 2 km west of Kratovo, rising remarkable andesitic neck Zdravči Kamen (844 m) with columnar emission. Laterally are thick deposits of tuffs which are quite eroded by fluvial-denudation processes. On the eastern side, Zdravči Kamen is deeply cut by the Kratovska River, and on west by the short Šlegovska River. As a result of that and due to selective erosion, this structure highly rise in the landscape and give the look of a well preserved volcanic cone with relative height of 300 m. With weathering of andesitic rocks interesting denudation forms like columnar rocks, needle rocks, shallow hollows etc. has created. In the highest part of the neck, remains of Pliocene coastal terrace on 780-800 m are preserved.

In the vicinity of Kratovo the remains of many palaeovolcanic forms can be observed. Cvijić (1906) believes that the city Kratovo itself lies in a volcanic crater, which was cut in the middle with the Tabačka (Kratovska) River. However, detailed analysis of elevation and geology do not go in favor of this assumption. Our opinion is that such morphology of the terrain around Kratovo, in the form of a circular depression, is actually the result of selective erosion of the Kratovska River and its tributaries, which intercepted the northeastern part of the complex Plavitsa center. Thus, the Kratovo River morphologically separated volcanic centers north of Kratovo from Uvo-Bukovec to the southeast and Plavitsa to the southwest.

With field research, along the right valley side of Kratovska River (upstream of Kratovo), traces of flowing lava in the southern direction are observed. Probably the center of volcanic activity here is a structure Dlaboki Del, north of Kratovo, in which are located several necks (Peštar 1113 m, Kratovski Rid 1108 m and Kamen 994 m). Such arch morphology, probably is the secondary segment of Plavitsa or Uvo-Bukovec structure, which in turn has very similar characteristics and meets the older volcanism.

Among Kratovo and Probištip is remarkable palaeovolcanic center, Plavitsa (1297 m). From the south side, this volcanic cone rises about 400-500 m over the Neogene lacustrine terrace (780-800 m), and the diameter is 3-4 km. Around the major cone, concentrically went up 7 smaller parasitic cones high 50 to 150 m. The slopes of Plavitsa have noticeable traces of the flowing lava, especially in the south and southeast direction. According to presence of lava and large amount of pyroclastic material, there are probably interchanged stages of silent and explosive eruptions, and the cone is of strato-type. The higher part of Plavitsa (above 1000 m) has a semi-circular shape and looks like a quite destroyed caldera, particularly on the west and north side. However, concentric outbursts of dacitic-andesitic lava reflect the contours of caldera and suggest a possible volcanic center. According to the position of surrounding ignimbrites, probably here volcanism began in Oligocene, i.e. in the first phase. Andesites and tuffs originating from surrounding parasitic cones (Marčinska, cones near Šlegovo and Prikovci), with upper Miocene or lower Pliocene age are mixed or partially penetrate the Miocene lake sediments south of Plavitsa. This means that during the lake stage were strong volcanic activity.

Only 3 km to the west of Plavitsa is one also very remarkable volcanic structure Crni Vrv, with volcanic cone in the center (1115 m), connected with ridge to Gradište (1009 m) on NW. According to Marković (1971), this structure is remnant of caldera eroded on the north side, while Serafimovski (1993) mean that south and west sides are destroyed by faults with NW-SE and NE-SW directions; its north side is better preserved. However, together with near parasitic centers (cones and

necks), entire structure covers an area of 50 km^2 - one of the biggest in the area. Abundance of tuffs implies explosive eruptions, with maximum activity during the upper Miocene or early Pliocene.

East of Plavitsa (4 km) and above the village Blizanci there are two cones: Bukovec (1423 m) to the west and Uvo (1472 m) to the east. They are mutually far only 1 km and are separated by a shallow saddle, caused by a fault in the direction NNE-SSW. Cones have very symmetrical appearance, and their relative height is about 250 m (Fig. 3). Here, the volcanic activity is represented mainly through lava outbursts of dacites (dacite ignimbrites). The whole structure Uvo-Bukovec together with the several surrounding parasitic cones stretches over an area of 10 km^2, and lava-pyroclastic material is distributed in an area of 35 km^2. Age of this structure is probably Oligocene.

Fig. 3. Volcanic cones Uvo (right) and Bukovec (left) with smaller cones in front

At a distance of 3.5 km northeast of the volcanic center Uvo-Bukovec, and west of the village Muškovo, rising palaeovolcanic cone Golem Rid (1532 m), with the relative height of 200 m. According to Serafimovski (1993), it is a parasitic center associated with the activity of the Uvo center, although on the position and morphology, Golem Rid could be considered as a separate volcanic center. West of Golem Rid are several small parasitic cones (Valanovec, Potes, etc.), about 50 m high and indicating several phases of volcanism in this area.

About 5 km southwest of Plavitsa, near the village Lesnovo, is one of the best preserved structures in the Kratovo-Zletovo palaeovolcanic area and wider. The entire structure with an area of 12 km^2 resembles volcanic cone with diameter of 4 km. The cone has steep sides and over the surrounding landscape rises up to 400 m. It is particularly well expressed on the south and southwest side. From the east side, the Lesnovo cone was cut by Zletovska River and from the west by Dobrevska River. Actually, the cone from several sides is incised by shallow valleys which Cvijić (1906) calls circum-crater valleys. On top of the Lesnovo cone, there has been impressive, well preserved caldera with a diameter of 1.5 km and depth in the middle 150 to 200 m. Around the caldera center, circularly are located 7-8 conic hills, i.e. volcanic necks. Most remarkable of them is Ilin Krst (1127 m) on north, which was probably a major volcanic center where the largest amount of lava and pyroclastic material expel. On the southern and eastern side appear 3 other necks: St. Troica (1012 m), Nuševa Čuka (1025 m) and Gumički Rid (1048 m).

Lesnovo caldera is morphologically well expressed, except on its southwest and northeast side, where it is cut with Lesnovo stream. It should be noted that the initial appearance of the crater was considerably different, if we note that the structure belongs to the older volcanism in the area. It derives from the age of dacitic lava (dacitic ignimbrites) which according to Serafimovski (1993) is Oligocene. Also, on the southern side of the Lesnovo cone, younger Pliocene-coastal terrace of 900 m and of 780-800 m is incised, therefore, the structure is certainly pre-Pliocene. If you take into account the aforementioned values for average reductions of andesitic-dacitic strato-volcanic cones of about 20-40 m per million years (Karátson, 1996; Thouret, 1999), it is clear that during the initial period, the Lesnovo cone was at least 200-400 m higher. Indeed, the Lesnovo caldera has polygenetic characteristics, because for its contemporary shape, great importance had subsequent erosion processes.

With field research, on the Lesnovo cone are seen traces of the radial flow of lava, especially in the southern direction. Dacitic lavas today are exposed to selective erosion with numerous small denudation forms (stones, hollows, footprints, etc.). On certain incisions along the road Dobrevo-Lesnovo, one can notice that dacitic lavas lie on tuffs, suggesting that the Lesnovo cone represents a strato-volcanic structure.

In the southeast end of the Kratovo-Zletovo area toward Kočani, several palaeovolcanic cones are registered that the omitted material belonging to the younger stages of a volcanic activity.

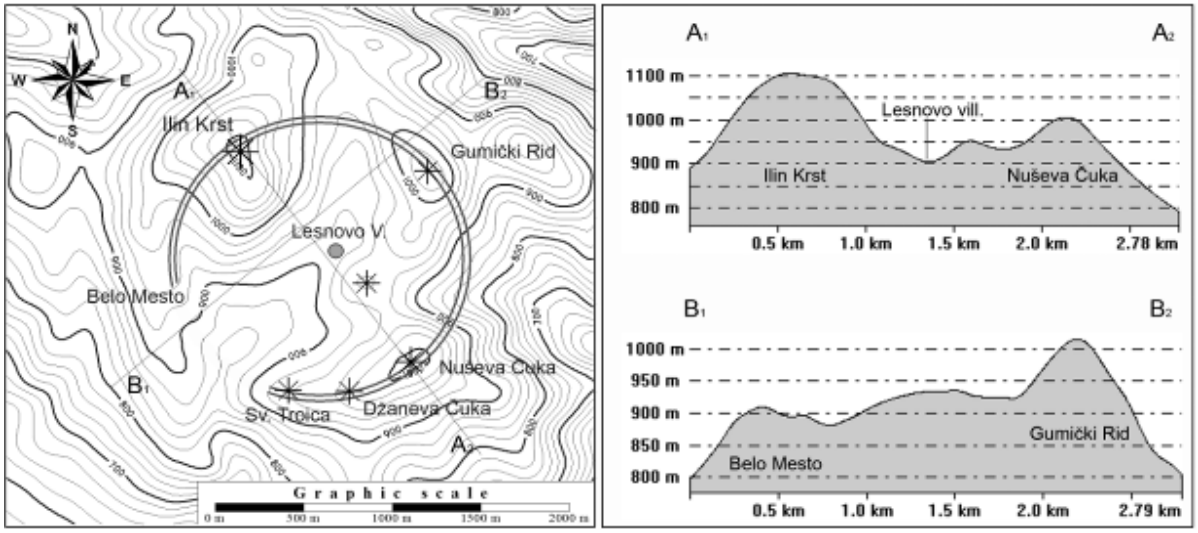

Fig. 4. Drawings and sections of the main crater (caldera) Lesnovo and secondary centers.

Characteristic residues of caldera are recognized north and northwest of the village Pantelej. The poly-phases volcanic activity here formed a major center of Preslap (1117 m), as well as several parasitic centers, like: Iliica (859 m), Spasovica (851 m), Pantelejska Čuka (825 m) and others. The caldera ring, itself, is hard to be morphologically reconstructed, because it is eroded to a great extent. It is better to be seen on the north side, whereas the south side has been eroded by the Koselska River (a tributary to the Štalkovica River). According to the preserved remains, the caldera had a diameter of about 2.5 km. The volcanic activity of this structure was largely calm, with outbursts of large masses of young andesites, whose traces of flowing can be noticed in the southern direction, towards the villages Pantelej and Rajčani. Occasionally a stronger (more explosive) eruption would emerge, leaving behind deposits of andesitic tuffs, accumulated on land or in water environment (stratified). The volcanic activity took place during the upper-Miocene or lower Pliocene.

Southernmost, morphologically better expressed volcanic structure and the youngest in the area stretching west of Kočani and cover an area of about 25 km^2. Today, from the former cone with impressive dimensions, two calderas left, external and internal, both better preserved from the northern side. Pyroclastic material is presented with breccias and to a lesser extent with andesitic tuffs, mostly deposed in water environment. Their status and composition suggest lower-Pliocene volcanic activity. However, large calderas with vast pyroclastic material are evidence of powerful eruptions in this area. Around Rajčani calderas, several lower hills have been observed as small parasitic cones. These are: St. Gjorgji (570 m), Golak (559 m) from the southern side; Bakovo (596 m) above the

Fig. 5. West ridge of the Lesnovo caldera, incised by the Lesnovo stream.

village Tripatanci to the west and others.

Remnants of a volcanic center are also evident in the western part of the area surrrounding Kratovo and Zletovo, located on the mountain Mangovica. Three andesitic cones, that is Mangovica (741 m), Golem Osoj (734 m) and Gložje (655 m), as well as several smaller ones are arranged in such a way that resembles a caldera, about 2 km wide, heavily eroded by the Mavrovica (Kiselica) River. Here, large amounts of the pyroclastic material are expelled on about 50 km^2, showing explosive volcanic activity. After an intensive volcanism during the Pliocene, these structures are being gradually destructed by many occurrences of denudation landforms today (earth pyramids, columnar and mushroom rocks, balls etc.).

6. Conclusion

In the paper are analyzed larger palaeovolcanic landforms in the Kratovo-Zletovo area represented by about 20 volcanic cones and several calderas. Beside these, many smaller landforms are observed, usually associated with the lava flow, accumulation of pyroclastic material and its erosion. There are many pseudo caves, volcanic bombs, stone blocks, columnar rocks and blocks, hollows, caverns and rills in horizontal andesites, as well as rills, gullies, earth pyramids and even badlands in tuffs as sites of excessive erosion.

Imposes the conclusion that, taking into account the age of volcanic activity, the palaeovolcanic forms are still well preserved. According to the study of Ramsey (2003), the period between the initial stage to the stage of today's palaeovolcanic forms in the field (according to its classification, it is the third of five stages), usually lasts a period of 3 million years in areas with drier, continental climate. This is significantly less compared to the aforementioned 5-30 million years. In the future remains to be explored whether Neogene palaeovolcanic forms were covered with lake sediments and protected from erosion or if the intensity of erosion and tectonic destruction was weaker than expected.

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