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МАКЕДОНСКО ГЕОЛОШКО ДРУШТВО

ТРЕТ КОНГРЕС
на
Геолозите на Република Македонија

ЗБОРНИК НА ТРУДОВИ
-КНИГА 1-

Уредници:
Лепиткова, С. & Боев, Б.

Струга, 2016

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ПРЕДГОВОР

Геологијата како природна фундаментална наука има незаменливо значење за општеството и е оној камен темелник на кој се засновани голем број гранки од инженерството и индустријата.

Нејзиното значењето кај нас е многу јасно препознаено уште во далечната 1944 година, кога со одлука на Президиумот на АСНОМ е формиран Геолошкиот институт на НРМ, прва македонска геолошка институција.

Денес Македонското геолошко друштво како еден од главните промотори на геолошката наука во нашата земја, е пред нов предизвик, организирањето на Третиот Конгрес на геолозите на Република Македонија.

Организациониот и Научниот одбор на Третиот Конгрес, имајќи ја предвид долгата традиција на геолошката наука, но истовремено согледувајќи го актуелниот момент, одлучија носечките теми на Конгресот да бидат поврзани со:

- Геологијата и општеството,
- Фундаменталната геологија и
- Геологијата и економијата.

За овие теми во овој Зборник се публикувани вкупно 105 оригинални научни трудови, кои се подготвени од преку 350 автори и коавтори од поголем број на земји. Низ трудовите се елаборирани резултати од вредни и долготрајни истражувања на нашите и странските инженери и научни работници.

Од пристигнатите трудови може да се забележи поврзаноста на традиционалните истражни методи и примената на нови современи технологии и алатки при геолошките проучувања, вклучувајќи најсовремени теренски и лабораториски инструментални методи, системи за обработка, чување на податоци и следење на параметрите на животната средина. Се надеваме, дека прикажани ставови, размислувања и резултати ќе ги зацврстат досегашните знаења, и ќе се поттикнат идеи за значајни нови истражувања.

Затоа, Организациониот одбор искрено им се заблагодарува на сите автори, учесници и помагачи на Конгресот, кои сите заедно со пожртвуваноста овозможија овој Зборник да биде нешто со кое сите ќе се гордееме.

PREFACE

Geology as a natural and fundamental science is of great importance for the society and it is the foundation of many engineering and industry branches.

Its' importance in our country was clearly recognized in 1994, when the presidium of ASNOM reached a decision to establish a Geological institute of NRM, the first Macedonian geological institution.

Nowadays, the Macedonian geological society as one of the main promoters of the geological science in our country, has accepted a new challenge, the organization of the Third Congress of Geologists of Republic of Macedonia.

The Organizing and scientific committees of the Third congress, given the long tradition of the geological science, at the same time looking at its' current state, has decided that the main topics of the Congress are related to:

- Geology and society
- Fundamental geology and
- Geology and economy

There is a total of 105 original scientific papers published in these Proceedings, prepared by over 350 authors and coauthors from number of countries for these proceedings. Results from valuable and long investigations of our and the foreign engineers and scientific workers have been elaborated through the papers.

From the papers, it could be noted that there is a strong connection between the traditional investigation methods and the new contemporary technologies and tools in geological explorations, including the latest field and laboratory instrumental methods, systems for processing and data storage, and monitoring environmental parameters. We hope that, the presented views, considerations and results will strengthen the existing knowledge, and will encourage ideas for new significant research.

Therefore, the Organizing Committee would like to sincerely thank all the authors, participants and supporters of the Congress, who along with their devotion helped making us all proud of this Proceedings book.

Претседател на Организационен Одбор	**President of Organizing Committee**

Проф. д-р Соња Лепиткова

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VOLCANOLOGY OF KOZUF MOUNTAIN IN THE REPUBLIC OF MACEDONIA

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Abstract
The location of this volcanic complex in the Kozuf - Kilkis transverse zone) and the intersection with the Vardar zone indicates a central type volcanism, activated on the tectonic intersection formed by the reactivated regional fault structures of Vardar strike (NW - SE to N - S) and the Kozuf - Kilkis (E - W) fault structure formed during the neotectonic period. This type of volcanism is characterized by ring-radial structures.

Key words: Kozuf, volcanology, neotectonic period

INTRODUCTION

The Kozuf volcanic complex is east-west oriented being about 30 km long. On the east the complex spreads to the Demir Kapija-Gevgelija ophiolitic complex, whereas to the west it reaches the overthrust structure which separates the Pelagonian metamorphic complex and Vardar zone (Boev, 1988). The development and evolution of this volcanism is closely related to the development and evolution of the Vardar zone. Thereby the labile geotectonic unit is formed in the period from the Mio-Pliocene to the Quarter (Arsovski,1962). In the Neotectonic period (from the end of Oligocene to the Pliocene) the territory of the Republic of Macedonia is characterized by the processes of radial tectonics and formations of longitudinal and transferzal grabens structures (Kocneva et al., 2006; Volkov et al., 2006). Formation of some of these grabens is related to the activation of the neogen magmatism in the territory of the Republic of Macedonia (Boev, 1988) as well as with the neogen volcanism in the Mtn. Kožuf region (Fig. 1).

Fig.1 *Panoramic view of Kozuf volcanic mountain (Foto. I.Boev, 2015)*

GEOLOGY OF THE KOZUF DISTRICT

Geologically viewed the Kozuf district is built of several geologic formations distributed in several stratigraphic complexes (Fig.2).

- A complex of Precambrian metamorphic rocks
- A complex of Paleozoic metamorphic rocks
- A complex of Triassic-Jurassic sedimentary rocks
- A complex of Upper-Cretaceous sedimentary rocks
- A complex of Upper-Eocene rocks
- A complex of Pliocene sediments and pyroclasts and
- A complex of Quaternary sediments

The geologic structure also includes magmatic rocks represented by

- A complex of metamorphosed rhyolites and pyroclasts
- A complex of serpentinized ultramafic rocks
- A complex of basic igneous rocks, and
- A complex of volcanic of calc-alkaline suites.

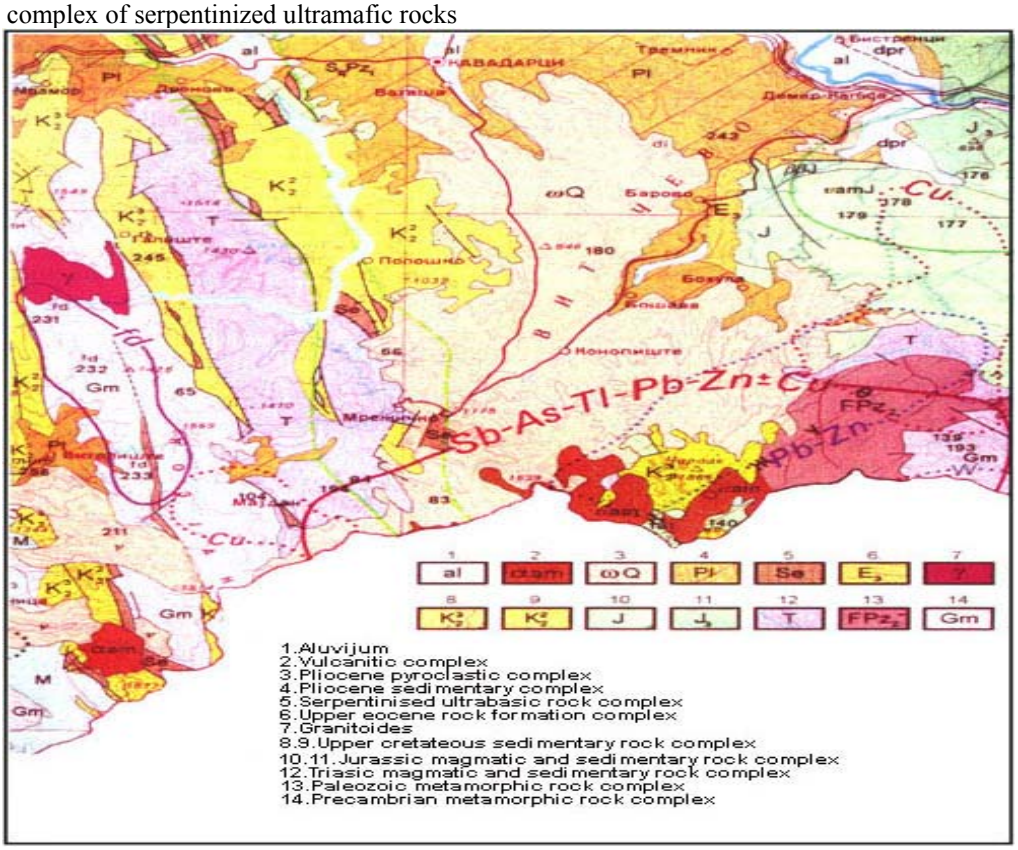

Fig. 2 *Geological map od Kozuf mountain (Boev, 1988)*

The complex of Precambrian metamorphic rocks is built of albitic gneisses and marbles situated in the vicinity of the Mala Rupa metamorphic block on the east. On the west (Mount Kozuf) the complex is built of gneisses and micaschists located in the Elen Supe tectonic block.

Gneisses and marbles have been found in the tectonically emersion block at Mala Rupa, west of the village of Konsko. Rakicevic and Pendzerkovski (1970) determined a Precambrian age, but Mersier (1973) reported Mesozoic or Triassic age for the rocks.

Gneisses are developed in the lower, but marbles in the upper parts of the complex. The gneisses of the lowermost part are albites with pronounced porphyroblastic texture, whereas those of the upper parts have amphibolite-biotitic composition with lenses of micaschists and cipolines. Besides albite, they contain potassium feldpar-microcline. They also contain coloured minerals such as amphibole, biotite, chlorite and mica.

Marbles are medium to large-grained rocks built of calcite. They overlie gneisses and grade into cipolines and calc-schists and along with gneisses comprise one metamorphic complex. The marble horizon is estimated at 600 m, while the horizon of gneisses at approximately 1000 to 1500 m thick.

Besides the metamorphic rocks in the Mala Rupa block in the western flank of the Vardar zone and the Pelagon (Kozjak Mt), a block of metamorphic rocks - Elen Supe containing rocks of different composition, but similar degree of metamorphism, was also determined. The Elen Supe block is built of gneisses and micaschists and its composition is similar to that determined for the lower parts of the Pelagonian metamorphic complex.

The complex of Paleozoic metamorphic rocks, unlike the Precambrian gneisses and marbles, is of lower metamorphic degree. It conformably overlies marbles of Precambrian age.

Paleozoic metamorfic rocks are most common in Adzibarica, between Keci Kaj and Gladnica, Jelovarnik and Porta as a phyllite horizon, a horizon of phyllitic schists and cipolines, quartzporphyry, phyllites, argilloschists and metasandstones with marble interlations and finally a horizon of quartzites, quartz schists and metadiabases.

The phyllite horizon also contains sericitic and epidotic schists, cipolines and marbles and metamorphosed quartzporphyry intruded by quartz veins (Adzibarica, between Keci Kaj and Gladnica). Graphitic schists have also been noticed in the series of sericitic schists. The horizon is approximately 750 m thick. It was also revealed in Adzibarica, Jelovarnik and Porta as well as in the vicinity of the Dusnica River source.

Cipolines and marbles alternate phyllitic schists in the horizon of cipolines and phyllitic schists west of Flora, Alcak, Ursa and Jelovranik along the River Dosnica course. They are overlain by schistose quartz porphyry distinguished as a separate horizon. They possess micro porphyroblastic texture, built of sericitized and kaolinized feldspars of albitic composition. They also contain potassium feldspar, quartz, epidote and chlorite.

A horizon of quartzites and metasandstones was determined in Boulska Reka near Dina, Kalugjerica and Usevica. It also contains meta diabases with sporadic sulphide mineralization.

Rakicevic and Pendzerkovski (1970) determined these metamorphic rocks as early Paleozoic. Mersier (1973) determined the age of this series and that of Porta as Jurassic based on the degree of metamoprhism and because it concordantly overlies the Mala Rupa - Tsena series which he determined as Triassic.

Upper Cretaceous limestones overlie the horizon of phyllites, argilloschists and metasandstones with intercalations of marbles in the upper course of the River Dosnica.

The complex of Triassic-Jurassic sedimentary rocks is subdivided into two facies near the village of Uma (Rakicevic and Pendzerkovski, 1970):

- A facies of poly coloured shales with intercalations of limestones
- A facies of limestones and dolomite limestones of Triassic age.

The Jurassic is present as a facies of slab-like stratified limestones and a facies of limestones and clayey schists, quartzites and cherts in the Dve Usi, Flora and Jelovarnik localities. The rocks in the River Boula valley are covered by a thick series of pyroclastic rocks and tuffs.

The complex of Upper Cretaceous rocks is present as a series of limestones and conglomerates that corresponds to the Barremian and Albian, as well as a series of limestones of Turronian age.

The series of limestones is present in the Cardak, Dudica and Gladnica localities and in the Rzanovo and Studena Voda where these sediments comprise the top part of the nickeliferous-iron ores. The stratified limestones in the lower parts consist of marls with residues of Nerinea olisoponensis cf. optuca, O. Turonica fauna. Temkova (1962) considers them to be of Turronian age. According to Maksimovic (1981) the top stratigraphic border is outlined by the transgression of Alb-Cennomanian and Cennomanian when the weathering crust was mostly destroyed and re-deposited as oolitic sedimentary iron and bauxite ores.

Large portion of the Kozuf district is occupied by massive limestones, particularly in the Cardak, Dudica and Gladnica areas where they transgressively overlie Paleozoic rocks. Limestones are rather broken and karstified and 400 to 600 m thick. This is the largest thickness determined for the Sennonian limestones found in the Republic of Macedonia. Poorly preserved rudists are discovered in them and based on that data the age of these limestones was determined as Sennonian. Because of the large fissure density and karsification they represent water collectors for the rich sources of the Rivers Stara and Zarnica. The limestones of the Dudica district are intensively hydrothermally altered and intruded by young subvolcanic rocks.

The complex of Upper Eocene sediments is present as basal conglomerates overlain by flysch sediments. The basal conglomerates near the villages of Kumanicevo, Dragozel, Gornikovo and Barovo are mainly built of marly and limestone pebbles. Gabbro pebbles, diabases and limestones predominate in the conglomerates between Krnjevo and Barovo. Conglomerates alternate limestones and marly limestones or

marls. The Upper Eocene sediments near the Barovo and Krnjevo villages are 800 m thick.
The complex of Pliocene sediments and pyroclasts is widespread in the Kozuf district. Essentially lacustrine sediments are built of coarse-clastic sediments that overlie the basement of various geologic formations. They overlie Upper Eocenic sediments between Barovo and Krnjevo. They are present as large-grained conglomerates and clayey sandstone sediments (between the villages of Dolna Bosava and Krnjevo).
Gravel sediments have been determined in the basement of the tuffs near the village of Gorna Bosava in the valley of the River Nistaica above the village of Cemersko. There are sands and clayey sands with intercalations of sand-clays or clayey sediments over the series of conglomerates near Krnjevo which itself is overlain by clayey carbonate rocks.
Marls overlain by clayey sand and clayey carbonate sediments with large amounts of fossil residues, bones and fauna (of mammals) occur near the village of Barovo. The last skeletons of this fauna were found in the topmost level of these clastic lacustrine sediments in diatomaceous earth beneath volcanic sediments - tuffs near Stukovi Orai in the vicinity of the village of Barovo (Garevski, 1960). The age of the sediments was determined as lower part of the Upper Pliocene based on the fauna (Izmailov, 1960). Radovanovic (1930) determined the age of these sediments as Pontian.
The Pliocene clastic sediments in the southern parts of the basin end with a travertine and lie immediately beneath the pyroclastic sediments (above the village of Boula).
Pyroclastic sedimentary rocks cover Pliocene lacustrine sediments in the south parts of the basin near Vitacevo and Gatenovo. In the southmost part they overlie the rocks of the northern slopes of Mount Kozuf and extend along the Macedonian - Greek border, south of the village of Mrezicko. In the north they extend close to the town of Kavardci and Dolni Disan (south of Negotino). The final tuffs and conglomerates can be seen in the vicinity of the village of Radnja. The volcanic sediments are from several meters up to several hundred meters thick.
A horizon of aglomerative tuffs overlain by a horizon of fine-grained volcanic ashes and glass occurs in close proximity to the Kokliski Monastery in the valley of the River Luda Mara over the clastic lacustrine sediments present as carbonate clayey material. The latest horizon of volcanic sediments consists of brecciated well banded volcanic tuffs - pyroclasts. The largest blocks of volcanic rocks were found in the north slopes of Mount Kozuf, beneath the volcanic craters and domes (above the village of Radnja and Bara, in the vicinity of Gladnica, Ametkova Glava and Konopiste).
The complex of Quaternary sediments: Large amounts of significant Quaternary terraces are found right of the River Konska. The layers are 20 to 30 m thick. They are large-grained sediments consisting of rounded fragments, built mainly of gneisses, marbles and quartz that formed from crystalline rocks from the vicinity of Mala Rupa and Keci Kaj. These terrace sediments were completely worked out - washed for gold during ancient period that is noticeable in the terrain.
Larger terrace sediments are not noticed along the valley of the River Dosnica because of the steep river sides. However, today's terrace layers can be found in the river bed. Traces of washed out river terraces can be seen in individual parts, particularly in the lower river course at the end of the cliff below the village of Dren.
Quaternary tuff sediments (20 meters thick) can be seen near the village of Sermenin in an area of approximately 200 to 300 meters in size.They are located in the mouth of the River Belica and the River Sermeninska. Similar tuffs can be seen in the River Boulska near Dina.
The River Bosava with its tributaries brings mainly volcanic material, because it passes through volcanic sedimentary seriez in its upper and middle courses.
Deluvial coarse-grained clastic sediments overlie the volcanic sediments near Vitacevo. Redeposited volcanic glass and ashes, known as pemza and pumice, as well as redeposited aglomerative tuffs can be noticed along the Mrezicko - Kavadarci road.
The complex of metamorphosed rhyolites and quartzporhyry is located in Paleozoic schists or Jurassic metasediments in Adzibarica and Gladnica (Mersier 1973). It is known that they are interstratified in phyllite horizon conditionally determined as Paleozoic without any stratigrafic data.

Quartzporphyry near Bel Kamen and Dve Usi in the vicinity of the villages Konsko and Dudica have also been identified.

Quartzporphyries are greyish-white to green rocks and represent metamorphosed magmatic rocks, or rhyolites and pyroclasts developed, most probably, at the same time period as the sedimentary rocks that formed the phyllites. Such rocks have also been established in the terrains of neighbouring Greece in Kastaneri, south of the village of Uma. Based on data reported by Mersier (1973) they are of Upper Jurassic age. Rakicevic and Pendzerkovski (1970) determined these rocks as early Paleozoic.

The complex of serpentinized ultramafic rocks is situated in the Studena Voda - Rzanovo - Kumanicevo zone. It represents a tectonic structure on which serpentinites along with Jurassic and Upper Cretaceous metasediments cover Paleozoic and Triassic metamorphic rocks.

Lateritic deposits of nickeliferous iron ore developed over the Rzanovo - Studena Voda zone and along with sediments of the top parts were dynamometamorphosed in conditions of prehnite pumpelite up to greenschist facies (Boev, 1982).

A large mass of serpentinized ultramafic rocks is located in the River Mrezicka above the village of Mrezicko. Serpentinized masses are also found near Alsar. The serpentinites near Mrezicko and wider are highly tectonized grading, in some parts, into serpentine and talcous schists. Smaal chromite pods are known in the ultramaphic rocks.

Large masses of serpentinized ultramafic rocks are also located along the Rzanovo - Studena Voda tectonic zone. Detailed petrologic investigations determined these rocks as dunites and harzburgites. They are almost completely altered to serpentinites and only in some places relicts of fresh ultramafic rocks can be seen. Gabbro pegmatites and rodingites have also been found in the zone.

The complex of mafic igneous rocks is present as gabbro diabase complex that occupies the eastern and north-eastern parts of Kozuf district. Gabbros, diabases and spilites predominate in the complex. Minor intrusions of leucocratic granitic rocks quartzmonzonitic in composition like those in Gornicet were determined in the bordering parts between intrusive mafic rocks - gabbros and effusive rocks - spilites. Granite porphyry dikes were also determined in the mafic rocks near Smokvica, Davidovo and Dren.

Quartzdiorites and granodiorites were identified in the north-west part of the gabbro diabase complex, near the village of Boula and Radnja as well as near Milovan and along the valley of the River Dosnica. Smaller pegmatitic lodes intersecting quartzdiorites or granodiorites were also found near Radnja.

Tajder (1939) carried out detailed petrologic investigations of the gabbros of this complex and determined the following major types: wehrlite, troctolite, olivine gabbro, gabbro-eucrite, uralite-gabbro, diorite and quartzdiorite, basalts and diabases.

The easternmost parts of the gabbro diabase complex on both sides of the River Vardar (from Demir Kapija to Udovo) and even further to Gevgelija are represented by diabases, spilites and keratophyre. Spilites are the most abundant among them.

Karamata (1973) gave the basic genetic assumptions related to this gabbro diabase complex. He reports that Dren - Boula gabbro diabase complex is a product of multi stage extrusions of large amounts of basaltic magma forming, first, the diabase spilite parties. Later, the prompted new masses intruded beneath the diabase crust (rarely intersecting it) forming new diabase spilite extrusions. The intruded igneous masses partiallly differentiated, but the tectonic processes and magma pulasations precluded magma differentiation.

STRUCTURAL AND VOLCANIC CHARACTERISTICS OF THE KOZUF DISTRICT

The Kozuf district is a large volcanic complex situated in the south of the Republic of Macedonia. It spreads in the area of Mount Kozuf. According to the regional geologic setting of the Balkans, it is part of the Vardar zone. In the east the Kozuf district is limited by a fault zone which is the west border of the Demir Kapija - Gevgelija gabbro diabase ophiolite massif. In the west it is bordered by a fault zone that separates the Pelagonian massif and the Vardar zone.

The location of this volcanic complex in the Kozuf - Kilkis transverse zone (Arsovski, Ivanov, 1977) and the intersection with the Vardar zone indicates a central type volcanism, activated on the tectonic intersection formed by the reactivated regional fault structures of Vardar strike (NW - SE to N - S) and the Kozuf - Kilkis (E - W) fault structure formed during the neotectonic period. This type of volcanism is characterized by ring-radial structures.

A schematic morphostructural map of the Kozuf district, was made using the anlaysis of satellite scanograms, aerophotos and geologic data obtained by field investigations (Fig.3). The neotectonic fault structures grouped into three systems.

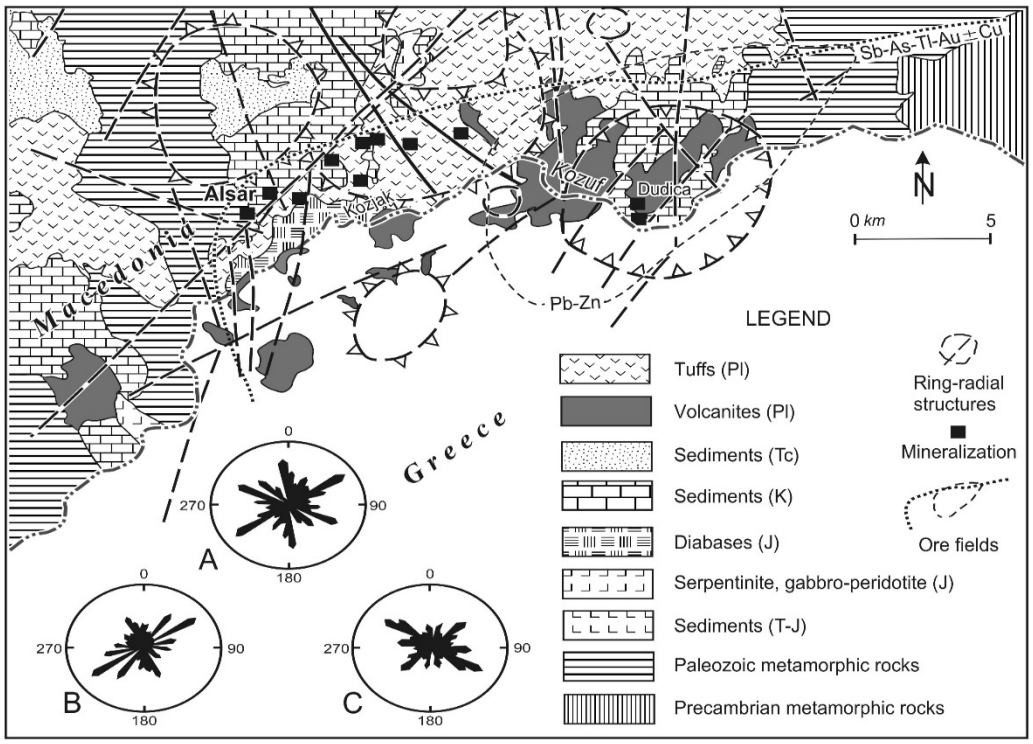

Fig. 3 *Morphostructural Map of the Kozuf district - Schematic (Boev, 1988)*

In the east the Kozuf district is limited by a fault zone which is the west border of the Demir Kapija - Gevgelija gabbro diabase ophiolite massif. In the west it is bordered by a fault zone that separates the Pelagonian massif and the Vardar zone.

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A schematic morphostructural map of the Kozuf district, was made using the anlaysis of satellite scanograms, aerophotos and geologic data obtained by field investigations (Fig.3). The neotectonic fault structures grouped into three systems.

A fault system of Vardar strike are reactivated fault structures, the oldest being those of NW - SE and the youngest of N - S orientation. Products of both incipient and major phases of volcanic activity are located along these faults. Intensive hydrothermal activity (in the area of Dudica and Alsar) of N - S strike took place affecting the products of incipient volcanic activity.

A system of faults of NE - SW to E - W strike. This system is relatively younger than the Vardar system manifesting recent seismic activity. The intersection between this fault system and faults of Vardar strike points to the younger and final volcanic activity in the Kozuf district.

Ring structures are represented by several morphologically negative shapes (that can be seen in scanograms) and a positive structure in the area of Dudica. The area of the most striking negative ring structure (Vasov Grad-Mrezicko-Topli Dol-Rozden-Alsar) is built mainly of volcanic material but it also includes Pliocene as well as Triassic and Cretaceous sedimentary material. This composition, the concentric shape and radial pattern of internal rupture structures, the type of drainage indicate that this large ring structure is a collaps caldera.

The Dudica positive ring structure cannot be seen in scanograms, but it can clearly be defined by field investigations and analyses such as drainage system. Most probably the volcanic activity started in the area of this positive structure (Stara Mircevica). The products of initial volcanic activity are hydrothermally altered and covered by the products of later and final volcanic activity. The volcanic activity in the Kozuf district started in the Miocene and the isotopic age of rocks was determined as 12.1 m.y. (Troesch and Frantz, 1994).

The volcanic characteristics of the Kozuf district were determined by field investigations and analyses of plane photographs. The volcanic activities produced volcanic necks, frozen supply channels, large quantities of pyroclastitic material. Lava flows and development of typical volcanic domes have not been identified. This results from the nature of the magmatic activity and the composition of magma that gave the material for the rocks during the final phases of differentiation.

The magmatic activity included intermediary, occasionaly acidic, magma which was immobile and fairly rich in volatile components. This led to a rapid closure of supply channels resulting in a large explosive phase during volcanic activities. This is proved by the large presence of pyroclastic and epiclastic material such as lacustrine tuffs, conglomerates, volcanic glass and ashes. The large amounts of borone and fluorine in the volcanic rocks from Kozuf points to the existence of a long duration of emanation phase in the evolution of this volcanism.

A review of some specific geologic cross-sections through products of volcanic activity will be given for better interpertauion of the volcanologic characteristics of the volcanism.

The Katuniste geologic cross-section (Fig. 4) is most distant from the centres of volcanic activity and starts from the marginal parts of the Tikves valley (in the vicinity of Kavadarci) and extends to the Vitacevo plateau.

Lacustrine Neogene sediments with no volcanic materials in them, present as sands and sandy clays (with carbonate or limestone parties in the top parts) can be noticed along the Luda Mara River valley up to the Vitacevo plateau.

Neogene lacustrine sediments with no volcanic material disappear at peak of about 470 meters. They are overlain by epiclastic sediments and rocks present as conglomerates. Fragment in the conglomerates are rounded and partially sorted. They are present as volcanic rocks that correspond to latites and quartzlatites.

The series of epiclastic conglomerates is overlain by lacustrine deposited tuff with pemsa. Pronounced stratification can be noticed in the series. Pemsa is a redeposited material and epiclasts are rounded and partially sorted. They are overlain by a series of lacustrine deposited tuff with epiclasts of 2 mm to 64 mm in size and clearly pronounced stratification. Epiclasts are represented by fragments of volcanic rocks. This series underlies a lacustrine deposited white tuff of pronounced stratification.

A horizon of conglomerate tuffs with epiclasts present as large fragments of volcanic rocks occurs before reaching the Vitacevo plateau. Epiclasts are not rounded in shape and their size has not been sorted.

Based on general geologic characteristics it can be inferred that the material was deposited in water environmnet with pronounced redeposition due to the large distance of the profile from the centres of volcanic activity.

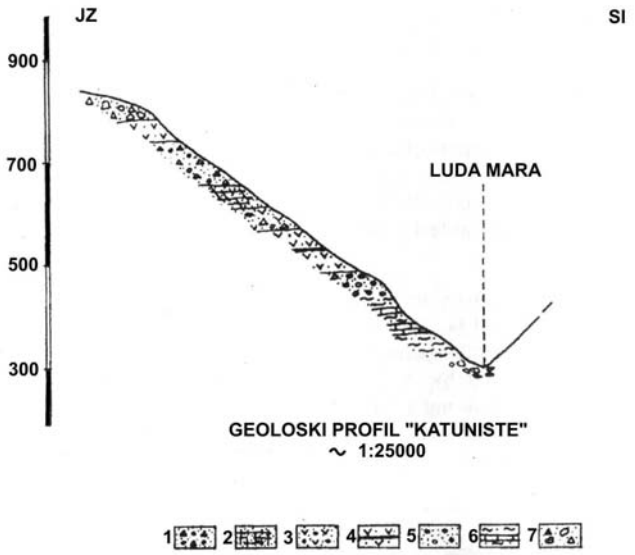

Fig. 4 *Geological cross-section of Katuniste (Boev, 1988)*
1.Conglomerate tuff; 2. Lacustrine deposited tuff; 3. Lacustrine deposited tuff with epiclaste larger than 2 mm but smaller than 64 mm in size; 4. Lacustrine deposite tuff with pemsa; 5. Epiclastic conglomerate; 6. Sands, clays and limestones; 7. Alluvium

The Parnapes - Vitacevo geologic cross-section, (Fig. 5) is located close to the centres of volcanic activities. From the River Parnapes valley further on to the Vitacevo plateau, Neogene lacustrine sediments with no volcanic material are identified. They are found as sands, sandy clays and limestones in the top parts.

Neogene sediments disapear at approximately 470 m sea level. They are overlain by lacustrine deposited tuff with epiclasts of 2 mm to 64 mm in size. Epiclasts are present as fragments of volcanic materials of clearly pronounced stratification. This series is ovrelain by white lacustrine deposited tuff overlain by a series of conglomerate tuff. The epiclasts vary in size and are mainly unrounded. Stratification is pronounced in the lower parts of the series, whereas in its upper parts (above the level of 900 meters) stratification cannot be noticed and the series has characteristics of pyroclastic breccia.

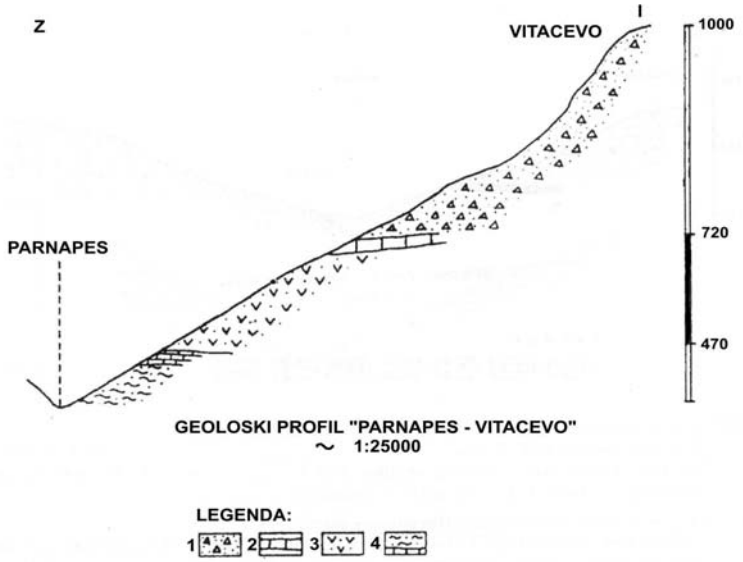

Fig. 5 *Geological cross-section of Parnapes-Vitacevo (Boev, 1988)*
1.Conglomerate tuff; 2. Lacustrine deposited tuff; 3. Lacustrine deposited tuff with epiclaste larger than 2 mm but smaller than 64 mm in size; 4. Sands, clays and sandy clays

The Barovo-Vitacevo geologic cross-section (Fig.6) is located near the village of Barovo. It is not close to the centres of volcanic activity. Neogene lacustrine sediments with no volcanic material can be seen in the area between the village of Barovo and the Vitacevo plateau. Sediments are found as clays, sands and sandy clays with carbonate sediments occurring in some of them. Sediments are overlain by a horizon of lacustrine tuff with epiclasts of over 2 mm to 64 mm in size. Stratification is distinctly pronounced and epiclasts are partially rounded. The horizon is overlain by a series of white lacustrine tuff with clearly expressed stratification that itself is overlain by a series of conglomerate tuff of unrounded and unsorted epiclasts. Presence of epiclastic breccias can be noticed in the top parts of the series.

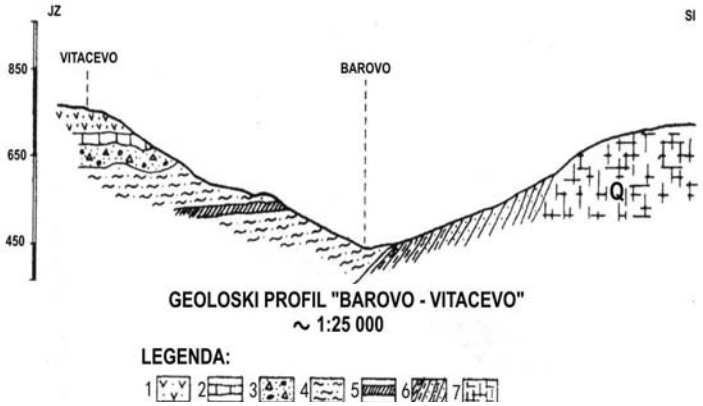

Fig. 6 *Geological cross-section of Barovo-Vitacevo (Boev, 1988)*
1.Conglomerate tuff; 2. Lacustrine deposited tuff; 3. Lacustrine deposited tuff with epiclaste larger than 2 mm but smaller than 64 mm in size; 4. Neogene lacustrine sediments; 5.Tuffs; 6.Eocene marls;7.Quartzites

The Bosava geologic cross-section (Fig. 7) is situated close to the centres of volcanic activities near the village of Bosava. A series of Neogene sediments with no volcanic material represented by sands, sandy clays and carbonate travertine on the top was established near the village of Bosava. The series is overlain by a deposited lacustrine tuff with epiclasts of various sizes. The stratification is clearly pronounced. There are horizons with pemsa intercalations of epiclastic provenance. It is overlain by a series of lacustrine tuff. The uppermost party of the cross-section consists of conglomerate tuffs without pronounced stratification that look like pyroclstic as breccia. The absence of stratification in the series is due to filling of the lacustrine basin and transportation of the material by the violent flows.

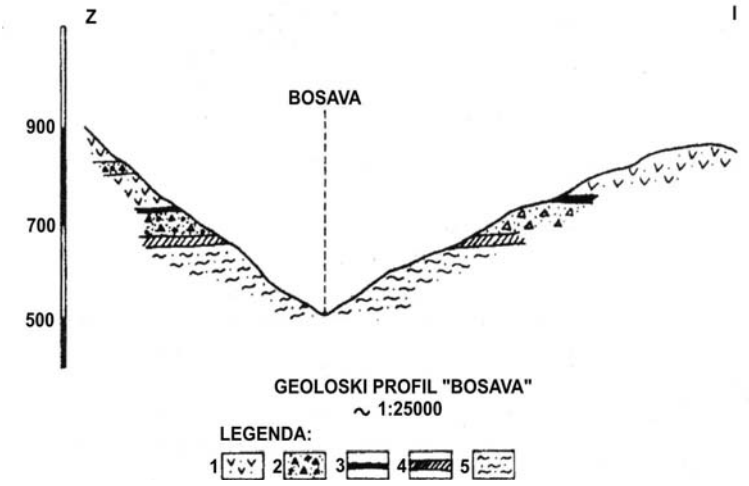

Fig. 7 *Geological cross-section of Bosava (Boev, 1988)*
1.Conglomerate tuff; 2. Lacustrine deposited tuff; 3. Lacustrine deposited tuff with epiclaste presence of various sizes; 4. Pemsa; 5.Tufas; 6.Neogene lacustrine sediments

The Studena Voda - Prasnik geologic cross-section is located close to the centres of volcanic activity and to the Prasnik volcanic neck (Fig.8).

The area of the Studena Voda deposit is composed of serpentinites overlain by a horizon of lacustrine tuff with unrounded epiclasts of 2 mm up to 64 mm in size, represented by fragments of volcanic rocks. The series is overlain by a horizon of white lacustrine tuff, which itself is overlain by a series of lacustrine tuff with epiclasts of various sizes. The epiclasts are unrounded and unsorted with clear stratification. The series is overlain by lacustrine tuff with presence of pemsa. The uppermost part of the cross-section consists of blocks of volcanic rocks formed as a result of weathering of volcanic necks or frozen supply channels.

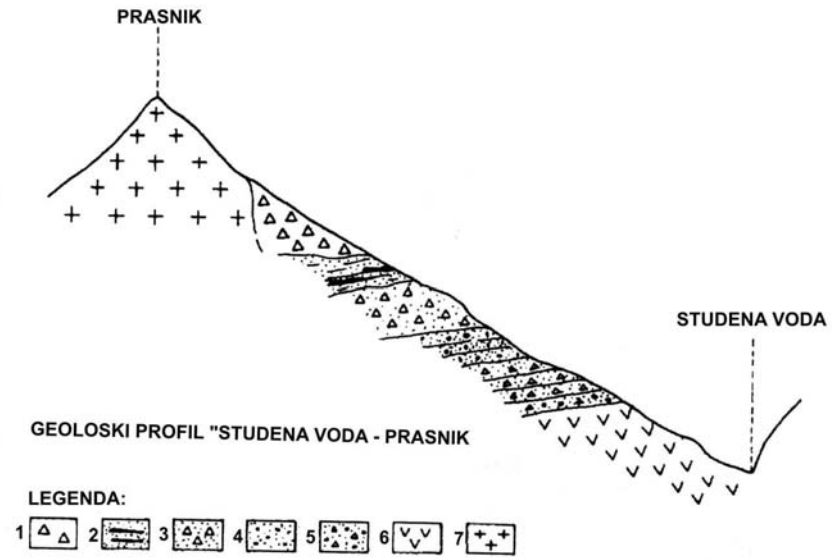

Fig. 8 *Geological cross-section of Studena Voda-_Prasnik (Boev, 1988)*
1.Epiclast blocks of volcanic rocks; 2. Lacustrine tuff with pemza; 3. Lacustrine deposited tuff with epiclaste presence of various sizes; 4.Lacustrine tuff; 5.Lacustrine tuff with epiclaste of 2 to 64 mm in size;6.Serpentinite; 7.Primary volcanic rocks

Based on the composition of the aforementioned geological cross-sections that pass through the volcanic-sedimentary materials the following conclusions can be drawn:

1. Recurrence of individual series of epiclastic and pyroclstic materials within the volcanogene sedimentary series in the Kozuf district indicates the polyphase or repetition volcanic activities.

2. Deposition of voluminous quatntities of volcanic material took place in water environment and successive filling of Tikves Lake.

3. The level of the Vitacevo peneplane or peak 900 meters, is the highest mark in the Neogene Tikves Lake within the vertical movements in the last 5 million years.

4. Based on analyses carried out of volcanic activities it can be inferred that these volcanoes had an increased explosive phase in their evolution.

CONCLUSIONS

The multistage activity of the volcanoes or the recurrence of volcanic activities is due to the nature of volcanoes and magma characteristics. Magma was intermediary to acid in nature and fairly immobile and rich in volatile components. The slight mobility resulted in very rapid closing of supply channels and in an increase of concentration of volatile components inside volcanic sources. When internal pressure due to increased amount of volatile components became very high, a phase of destruction of volcanic domes and increased volcanic activity followed as a result. Large amounts

of pyroclastic material came down the volcanic slopes as voluminous hot masses of broken material, hot gases and vapours. This volcanic material flowed into Lake Tikves and started its filling. The lack of typical volcanic bombs in the sedimentary series indicates that there was no lava throws in the air, nor catchment of molten lava along the volcanic slopes.

Volcanic destruction or the moment of volcanic opening is accompanied by an explosion of gases forming silicate foam that is more acid than the volcanic material. This foam or pemza along with the pyroclastic material erupted into the air and the surrounding slopes and deposited in the coastal portions of the lake.

When volatile components come out, the internal pressure decreases due to volcanic destruction. This will result in a decrease in the intensity of explosive activity and grade into poor emanation phase or a phase of eruption of gases, vapour and volcanic ashes and complete the volcanic activity due to a closure of supply channels.

The period of weak emanation phase and termination of volcanic activity is followed by erosion of volcanic shapes. Rapid flows entrained voluminous amounts of pyroclstic material from volcanic slopes and deposited it to neighbouring lake forming various kinds of epiclastic sediments.

The activity of lake erosion resulted in erosion of volcanoes and large cuts of volcanic necks in the marginal parts of the lake in the foot of the volcanoes. This slightly rounded material of various sizes deposited in the coastal part of the lake and mixed with materials brought from the slopes of neighbouring volcanoes.

Inside the lake, sedimentation processes gave the primary pyroclstic material characteristics of lacustrine deposited tuffs and epiclasts. The presence of pemza in individual epiclastic horizons points to the phenomenon of its resettling along with other primary pyroclstic material. The end of the volcanic activities is marked by the occurrences of diatoms in the formation of Lake Tikves. Today they can be found as a horizon of diatomaceous earth in the epiclastic materials.

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