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GEOLOGY OF THE TERRAIN WHERE THE JAVORSKA RIVER WATERFALL APPEARS, IN THE VICINITY OF THE SITE OF TALIUM ALSHAR DEPOSIT, NORTH MACEDONIA

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Abstract: *In the southwestern parts of the Alshar deposit, on Kozjak Mountain, along the course of the Javorska Reka, there is a small waterfall that has exceptional visual and aesthetic features. The waterfall itself appears on a tectonic structure with a direction of stretching N-S and with a vertical movement along the gap of the fault of about 10 meters. The waterfall itself is found within the Elen Shupe metamorphic complex, which represents a tectonic block of the Pelagonian metamorphic complex within the Vardar Zone*

Keywords: *geology, metamorphic rocks, Elen Shupe, Vardar Zone.*

ГЕОЛОГИЈА НА ТЕРЕНОТ КАДЕ СЕ ПОЈАВУВА ВОДОПАДОТ НА ЈАВОРСКА РЕКА, ВО НЕПОСРЕДНА БЛИЗИНА НА НАОЃЛИШТЕТО НА ТАЛИУМ АЛШАР, СЕВЕРНА МАКЕДОНИЈА

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Апстракт: *Во југозападните делови од наоѓалиштето Алшар, на Козјак Планина, по течението на Јаворска Река има појава на мал водопад кој има исклучителни визуелни и естетски одлики. Самиот водопад се појавува на една тектонска структурата со правец на протегање С-Ј и со вертикално движење по рамнината на раседот од околу 10 метри. Самиот водопад се наоѓа во рамките на метаморфниот комплекс Елен Шупе, кој преставува тектонски блок од Пелагонискиот метаморфен комплекс во рамките на Вардарската Зона.*

Клучни зборови: *геологија, метаморфни карпи, Елен Шупе, Вардарска Зона.*

1. INTRODUCTION

The dominant lithological members comprising the Kožuf ore district are the following: a complex of metamorphic rocks of Pre-Cambrian and Paleozoic age; the sediment rocks of the Triassic, Jurassic and Upper Cretaceous; a complex of sediments of upper Eocene age; the sediments and pyroclastic rocks of Pliocene age; the Quaternary

sediments; as well as the magmatic rocks of various composition and age (metamorphosed rhyolites and pyroclastic rocks; serpentinized ultrabasic rocks; basic magmatic rocks; and the complex of volcanic rocks) (Boev et al, 1991, 2001, 2002). Magmatic and structural control factors, that is, the complex of volcanic rocks with extensively developed extrusive facies, formed in the period between 6-1.8 My (Lippolt and Fuhrmann 1986; Kolios et al. , 1980, 1988; Boev 1988; Yanev et al. 2008, Dumrganov et al, 2004, 2005; Elefteriadis, 1988, 1989, 1991, Elefteriadcis et al, 2003), as well as numerous faults and cracks of various genesis and spatial orientation, are of special interest for the formation of Sb-As-Tl-Au ore mineralization (Volkov et al, 2006, Yanev et al, 2008).

2. LOCAL GEOLOGIC SETTING

The research area belongs to two geo-tectonic units: the Vardar zone and the Pelagonian horst anticlinorium. In these two geo-tectonic units, there are complexes of Precambrian and Paleozoic metamorphic rocks, and complexes of Mesozoic and Tertiary-Quaternary sedimentary and magmatic rocks (Fig.1, Fig.2)
The gneiss-micaschist series represents the lower part of the Precambrian complex, lithologically quite heterogeneous, made up of gneisses, micaschists, amphibolites and amphibolite schists, which mutually alternate vertically and horizontally.
The gneisses are the dominant lithological member in the series which, based on the mineralogical composition and structural-textural characteristics, are represented by banded muscovite-biotite and banded muscovite gneisses.

Banded muscovite-biotite gneisses (Gmb)
These gneisses are mainly developed in the deeper levels of the geological column, but also near the granodiorite masses, where their mineralogical characteristics are closely related to the granodiorite intrusion and they represent migmatites. The mineralogical composition and the structural-textural build of such migmatites characterize them as an epibolic type in which bands of para substrate are most often replaced by bands of feldspathic neosome, and rarely by pegmatite composition. Except for a part of the feldspar mass, in the gneisses and a part of the biotite there is metasomatic origin and it occurs in a higher concentration only near the granodiorite masses or in intensively feldspathized zones, while moving away from the contact of the granodiorite masses, its quantity decreases significantly. The banded muscovite-biotite gneisses are gray, medium- to coarse-grained rocks with a lepido-granoblastic structure. Quartz, feldspar, plagioclase, muscovite and biotite occur as essential minerals. Locally they contain garnet, which locally reaches a content of up to 5%, and epidote.

Banded muscovite gneisses (Gm)
These gneisses are most widely distributed on the terrain and, as a rule, they are almost always developed at the transition from two mica gneisses to micaschists. The boundaries with the micaschists are gradual and they are such with the rocks of the marble series also. At the contact with micaschists they have the character of leptinolites. The mineralogical and structural-textural characteristics indicate that these gneisses were affected by the metasomatic process of the Pelagonian granitoids, but the intensity of feldspathization in them is significantly weaker, which is why they did not unergo major changes. That is why they are mainly found in the upper parts of the gneiss-micaschist series, where there are no larger granitoid rocks.

Muscovite gneisses are gray to gray-white, fine- to medium-grained rocks with a banded texture and lepidogranoblastic structure. They are composed of quartz, microcline, placioclase, muscovite, less biotite and locally fenite. Garnet also occurs locally.

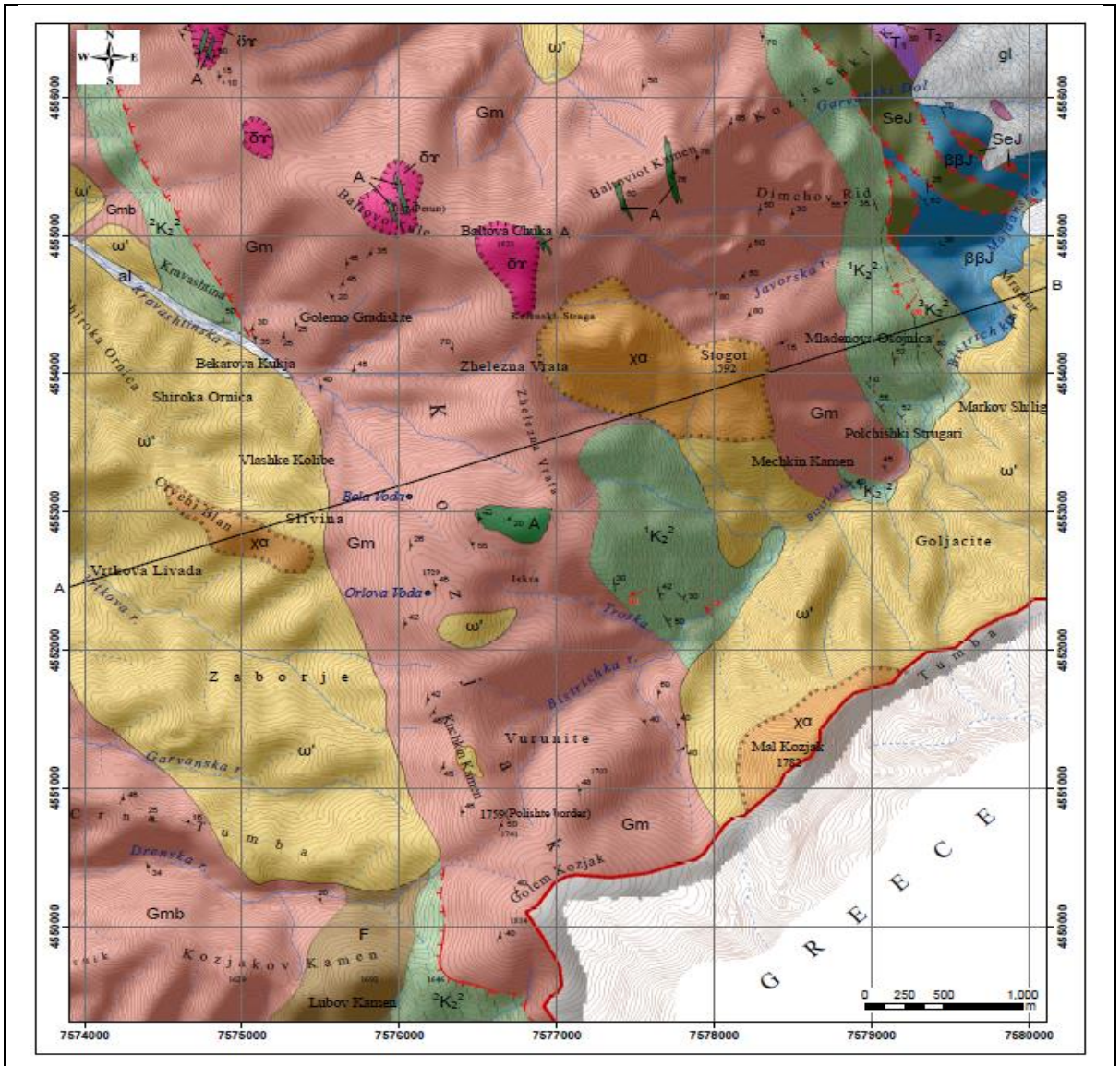

Figure 1. Geological map of wider area of Javorska Reka

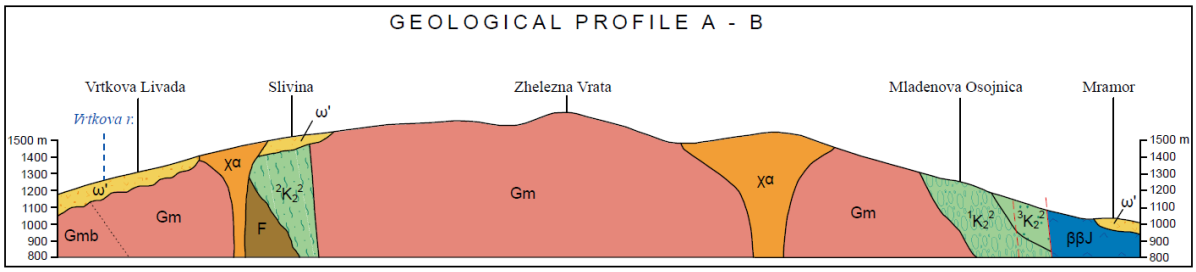

Figure 2. Geological profile of investigated area

Amphibolites and amphibolite shists (A)

Amphibolites and amphibolite schists occur in several levels of the series, as sharply separated concordant bands and masses containing relict remains of metagabbro. The presence of relict remains of metagabbro indicates a magmatic origin of the amphibolites. With detailed investigation of all separated masses and bands of green rocks a wide mineral association has been determined; epidote, epidote-pyroxene-garnet and epidote-biotite amphibolites are represented as separate varieties.

Amphibolites are light to dark green, fine to coarse-grained rocks, mostly schistose and less often massive. The main minerals are amphibole, oligoclase, andesine, less often albite-oligoclase and epidote, while garnet, zoisite, biotite, diopside, titanite, quartz and rutile vary in quantity. They are often represented in minor quantities, but locally they occur as essential minerals.

Amphibolite shists occur in the marginal parts of the amphibolite masses or as separate thin bands. They are characterized by a higher content of quartz and albite, intensively schistose and locally passing into amphibole gneisses.

Phyllito-mica-schists, green and carbonate schists (F)

The lower part of the Cambrian complex is built of shales that lie transgressively over the Precambrian rocks. These rocks change vertically and horizontally in bands of varying thickness.

Within this group, based on their mineralogical composition, several varieties of shists can be distinguished, the most common of which are: quartz-muscovite-sericite phyllitomicaschists, quartz-chlorite-sericite, chlorite-amphibole-epidote and carbonate shists and cipolins.

The quartz-muscovite-sericite phyllito-micaschists are shaly to platy, gray to dark gray, locally rich in garnet, graphite, and albite.

The green shales are fine to medium grained, gray green to dark green and the main minerals in them are epidote, chlorite, and amphibole.

Cipolines and carbonate shales occur in thin sheet bands, which gradually pass into green and other varieties of schists.

Massive medium- to coarse-grained granodiorites (δY)

They occur in the hypsometrically highest parts of the terrain in the form of bodies of several meters, with a NW-SE stretching direction.

During intrusion, the magma used the foliation direction and the older anticlinal and vertical structures, it performed intense migmatization of the surrounding metamorphites and included enclaves of them. Enclaves appear as bands or have a

rounded shape and are usually oriented in the direction of the extension of the masses and bodies.
With microscopic studies it has been established that the massive granodiorites in their distribution are not completely homogeneous and that there are variations in the representation of individual minerals. In some parts, alkali feldspars are more richly represented and they represent quartz monzonites or granites, or they are present with a content of less than 5%, and then they change into quartz diorite. Such variations are also demonstrated in the chemical composition, which is most likely a reflection of the magmatic differentiation and assimilation of the matter from the surrounding rocks.
The massive granodiorites are gray to dark gray, medium to coarse grained. They have hypidimorphic-granular structure and massive structure. As essential minerals, they contain plagioclase, feldspar, quartz and biotite, and as secondary minerals apatite, titanite, amphibole, zircon, garnet, orthite, and magnetite.

Shales and sandstones (T)
The Triassic occurs as a tectonic block in the Vardar zone and is made up of shales, sandstones, marbleized limestones, and dolomites, diabases and green shales.
Pelitic and pelitic-psamitic sediments represent a basal part and a facies change in the sedimentation of carbonate deposits. They are represented by shales, sandstones, and rarely slates. They occur at the base of the Triassic mass or inter-serial as interlayers and layers in the limestones and dolomites, into which they gradually pass over the carbonate shales. Shales are gray-greenish or gray-yellow, made up of quartz, hydro-mica type clay minerals, and some quantities of sericite, chlorite, organic and ferric matter.
Slates are richer in sericite and chlorite, with pronounced perfect cleavability.
Sandstones occur in thin interlayers and lenses in shales and represent a fine- to medium-grained variety of feldspathic sub-greywacke and subarkose. They are made of quartz, pieces of quartzite, shale, mica, and feldspar.

Marbled limestones and dolomites (T)
Carbonate sediments, represented by limestones and dolomites, significantly marbleized, dominate the Triassic mass. They are gray, gray-white and white in color, also rarely blue, with grain sizes of up to 1 mm in the marbled parts. Most often they are flat and less often they are massive.

Diabases and green schists (ββ)
In the eastern part of the terrain, along the valley of the Maidanska Reka, there is a zone of diabases and green slates, which lies concordantly in the carbonate sediments.
The diabases are strongly altered, and for the most part they have been transformed into green shales. The green shales are represented by clay-chlorite, chlorite-quartz and epidote-chlorite-actinolite slates. Interlayers of shale also occur in them.

Serpentinites and Peridotites (SeJ)
In the area of the Vardar zone, along several tectonic structures, there are diapirically imprinted, small elongated lenticular bodies and larger masses of ophiolitic rocks. Their appearance in common bodies and masses indicates that these rock masses belong to one magmatism.

Serpentinites occur as the most dominant ophiolitic rocks, which strongly dominate in relation to other ophiolitic lithological units. Serpentitites are light to dark green, made up of serpentine, with relics of olivine and pyroxene. Comparatively they contain chlorite, talc, magnetite and chromite.
The peridotites present are intensely serpentinized and difficult to distinguish from straight serpentinites. They are dark green in color, built of rhombic pyroxenes and olivine, partially serpentinized, and of serpentine and rarely chlorite, magnetite and chromite.

Conglomerates and sandstones (2K22)
These sediments represent the senon base. They were discovered on smaller surfaces in individual profiles on Maidan, under Tribor and on Sokol. Conglomerates are made up of pebbles of gneiss, greenschists and marbles. The size of the pebbles locally reaches up to 3 meters.
Sandstones have a subordinate role and occur as rare interlayers.

Sandstones, claystones and conglomerates (1K22)
They make up the middle level of senon. Depending on the size of the grains, sandstones are divided into fine-grained, medium-grained and coarse-grained, and according to the composition, quartz and arkose varieties are represented. The cement binder has a clay carbonate composition. Claystones occur less often and in many cases make a transition into clay shale. Conglomerates occur in thicker banks, most often with sandstones.

Flysch - Sandstones, claystones, siltstones and limestones (3K22)
The composition of this facies is dominated by sandstones, followed by siltstones, claystones and limestones. All the lithological members are finely layered and give this level a flysch character, manifested by the vertical repetition of the members, with the occurrence of lamination in claystones and siltstones, pronounced gradation in the directions and traces of damming and traction. Sandstones are finely bedded to bankite coarse-grained, medium-grained and fine-grained. Siltstones usually make a transition to siltstone clay, they are thinly layered with a distinct gray to dark gray color. Limestones occur less often on the ground and most often occur in thin layers, such as slabs and banks. By composition, they are mostly sandy and clay-sandy.

Quartzlatite breccias (ω')
Quartzlatite breccias, as the second most represented lithological unit in the research area, occur as a result of the reactivation of the volcanic activity of Kozhuf, after a relatively calm period of deposition of tuffogenic sediments in the freshwater lake, a period in which large areas of the terrain around the Moriovo basin are covered with volcanic breccias and small basins of quartzlatites. The breccias are made up of quartzlatite pieces of different sizes, often blocks up to 2 meters long, connected by tuff or lava material.

Quartzlatites (χα)
Quartzlatites are gray to dark gray, compact and hard rocks with a porphyric structure and fluid texture at the base. They are built from a fine-grained base of quartz and feldspar with phenocrysts of sanidine and plagioclase. They contain less biotite, pyroxenes, epidote, apatites and opal nests. The quartz in these walls does not occur

in phenocrysts, but it is represented in the fine-grained base and it characterizes them as quartzlatites, which locally pass into latites.

Glacial sediments (gl)
High mountain terrains caused the formation of glacial deposits on larger surfaces, which were mostly eroded by intense erosion, and larger masses are preserved near the village of Maidan. The material is composed of pebbles and blocks up to several meters large, of volcanic rocks, ophiolitic rocks, Triassic sediments, and gneisses.

Alluvium (al)
Alluvial sediments are developed only along the Kravashtinska river valley. They are mainly composed of sands, clays, and sandy loams.
From a tectonic point of view, the Pelagon and the Vardar zone are characterized by their specific tectonic structure.
The Pelagonian horst-anticlinorium, built of Precambrian metamorphic and igneous rocks, is characterized by a large number of large anticlinal and synclinal structures, often with a domed character. The older structures generally have a west-east orientation and their axes sink towards the east, while the newer forms are oriented in the N-S and NW-SE directions.
The Vardar zone is characterized as a very labile tectonic unit with intense north-south radial tectonics. It is separated from the Pelagon by a deep rupture, which on this terrain is masked by Cambrian and Tertiary-Quaternary formations. The radial tectonics is represented by a large number of faults and scales, masked by diapiric occurrences of ophiolitic rocks. The terrain is cut into several tectonic blocks and grabens, which give the Vardar zone a specific feature. These are the Kozjak block built of Precambrian rocks, the Rozden Triassic block, the Drensko-Vitoliste graben of Turonian-Senonian sediments, the Galician-Arnician Senonian graben and the Poloshko-Rzhanovski graben with Turonian sediments.
Both Triassic and Upper Cretaceous sediments are intensively folded, mostly in isoclinal folds.

3. THE WATERFALL IN JAVORSKA RIVER AS PART OF THE NATURAL HERITAGE OF MACEDONIA

Heritage geologic features are recognized special places of intertwined geology and landscape. Heritage geologic features may include unique or exemplary outcrops, scenic views, or other geologically significant features that together represent the geologic diversity of the Macedonia. Such features may be classified into different types that may be enjoyed, studied, and appreciated by all.

Hydrographic occurrences
In the territory of over 4.000 springs only 58 yield over 100 l/s. In fifteen of them the yield exceeds 1 m3/s. Of interest are the Ostrovo spring at Sveti Naum and Koritiste at the Matka canyon. In terms of mineralization, 170 mineral water springs have been registered, of which with eight the mineralization exceeds 8 g/l. The temperature in 15 springs exceeds 35oC. A dozen sinking rivers have been registered. The most important are the Rivers Krapska, Patiska and Cerska. Some 250 waterfalls (different in their formation), some fifty glacial lakes in Mt Sara, Korab, Jablanica, Stogovo, Pleister and Jakupica and about 200 river islands in the River Vardar have also been found.

Javorska Reka (in the lower part Majdanska Reka) rises below the Golem Kozjak peak (1,814 m) at an altitude of 1,720 m. In fact, under this name (Majdanska Reka) it appears from the area where the Javorska Reka joins the Bistrichka Reka as a left tributary. The river Javorska rises under the Baltoa Chuka peak (1,822 m) on the Kozjak mountain at 1,710 m above sea level. The upper part of the Maidanska Reka, known under the name Bistrichka Reka, rises on the northern slopes of Golem Kozjak (1,814 m) and from its source moves to the northwest in a length of 4.5 km2. In the locality of Mramor, it and Javorska Reka create the Maidanska Reka. Under this name, it has a length of 6.0 km2 with a direction of extension to the north all the way to its left tributary Kruša. From here, under the name of Bistra near the village of Rozhden, and as Blaštica near the village of Mrežičko, it stretches towards the northwest. In addition to the mentioned river Kruša, as a left tributary of Blaštica, there is also the river course that comes from Kovačevska Chuka (1,556 m) to the west. East of Arnicko is known under the name Dlabok Dol. The total length of its course, which has a predominantly successive direction (west - east), is 9.5 km2 and has an average fall of 0 /oo.

GEOMORFOLOGY

The river valleys of Javorska Reka, Maidanska reka, Kruška, Mrežička and others in the upper (source) parts are distinguished by a significant drop in the longitudinal profile and steep valley sides. From the confluence of the Krushka River into Maidanska Reka, i.e. at the stretch where Maidanska Reka changes its name to Bistra and further towards the village of Mrežichko in Blaštica, an imposing gorge valley has been built, which in some places has a canyon character. Here the river bed is cut into a solid bedrock represented by Triassic marbleized limestones and dolomites . Smaller cascades and giant pots can be seen along the river bed.
In the upper parts of Javorska Reka in the Elen Shupe metamorphic block, a small, impressive waterfall with dimensions of about 7 to 8 meters and a width of about 4 meters appears on a fault structure with a N-S stretching direction (Fig.3)

Figure 3. Waterfall of Javorska Reka, North Macedonia (foto: Boris Georgiev, 2023)

4. CONCLUSIONS

Geological rarities are an extremely important moment in the development of the tourist offer of a certain region, and in that context, the presentation of the waterfall of Javorska Reka in the geological magazines has a significant contribution. Enriching the tourist offer of the mountain region of Kožuf and Kozjak Mountain and with certain rarities of the natural heritage can greatly contribute to the development of this region. In this region is also the world rarity in mineralogy, the thallium mineral deposit, Alshar, the development of this locality in the direction of a geopark is an extremely important idea.

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