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Morphological and chemical characteristics of the placer gold deposits from MeckinDol, locality BorovDol, Eastern Macedonia

VIOLETA STEFANOVA, Faculty of natural and technical sciences, University Goce Delcev Stip, R. Macedonia
TODOR SERAFIMOVSKI, Faculty of natural and technical sciences, University Goce Delcev Stip, R.Macedonia
GORAN TASEV, Faculty of natural and technical sciences, University Goce Delcev Stip, R.Macedonia

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This paper presents the latest results from schlichprospectionwhich was performed along the creek Meckin Dol. Research showed that the size of the tested gold aggregates ranges from 30 microns to about 600 microns, and the most frequently present form of gold aggregates was isometric - irregularform.The chemical composition of gold aggregates shows heterogeneity with an average gold content ranging from 74.15% - 99.32%, followed by silver with an average content of 0.3% - 24.68%,and an average copper content of 0.04 to 11.06%. Other impurities such as Fe, Bi, Se, and Te are represented with content less than 1%. In general it can be said that the examined gold aggregates, by their chemical composition, are characterized by high purity ranging from 750 to 996.

Key words: *gold morphology, flatness index, chemical composition.*

1. INTRODUCTION

Copper and gold occurrences of in the BorovDol locality and its vicinity surroundings were known as early as the 19th century, which is reflected in the remains of old mining and archaeological artifacts found. Old gutters along the KrivaLakavicarivershow the presence of gold in the recent alluvium of the River Lakavica.

In the period from 1952 until today, the site Borov Dol, its immediate vicinity and the connection of Borov Dol with the river KrivaLakavica, have been the subject of regional and detailed geological surveys and studies that resulted in the definition of copper and gold porphyry type of deposit in the locality BorovDol and the presence of alluvial gold in the drainage systems of Borov Dol and along the river Kriva Lakavica. Contributions to these numerous studies are presented in the works of [6], [4], [11], [17], [2], [13], [14], [15], [19], [12]. The results of these tests were the occasion that instigated performing prospection research with det--ailed schlich prospection of certain parts of the primary and disintegrated mineralization material of the narrower and wider environment of copper and gold deposits Borov Dol.The creek Meckin Dol was selected as best after recognizing this mineralized space whose spring areais in direct contact with the primary copper and gold mineralization in the BorovDol site, which makes the disintegrated material a potential carrier of elluvial-prolluvial-alluvial gold that was the subject our tests and study. Along the creek Meckin Dol certain sampling points were selected for schlich tests where during field work a total number of 13 schlichs were sampled. The procedure for their further treatment is described in detail in the chapter concerning the methodology of work. In the context of the above mentioned, and taking these facts account, in the frames of this paper studies to examine the rank of physical characte-ristics such as size and shape of the gold aggregates and their chemical composition were made.

Author's address: Violeta Stefanova, University Goce Delčev, Faculty of Natural and Technical Sciences Štip, Goce Delčev 89

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2. GELOGICAL CHARACTERISTICS OF THE TERRAIN

The BorovDol deposit is part of the mining region Bucim-Damjan-BorovDol, i.e.it occupies its southern parts. The metallogeny of this ore region is closely related to the evolution of the Tertiary magmatism represented with subvolcanic–volcanic facies of andesite, latites, quartz latites, trachyrhyolites etc. which are the product of intermediate to acid calc-alkaline magmatism. Numerous interesting mineralizations of Cu, Fe, Pb-Zn as well as Au mineralizations are related to this magmatism. The geological structure (Fig 1) of the BorovDol deposit, which is quite complex, contains Paleogene, Neogene and volcanogene-sedimentary and volcanic rocks ([11], [17], [12].

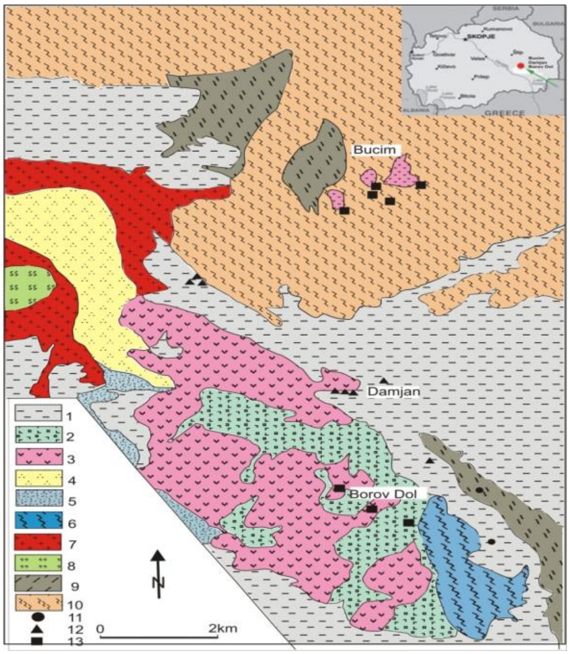


Fig. 1. Geological setting from Bucim-Damjan-BorovDol ore district (Denkovski, 1995, supplment, Stefanova, 2005):1.Paleogene, neogene quarter sediments, 2.Pyroclasts, 3.Andesite and latite,4.Cretaceusflusch.5 arbontites, 6.Carbonate-schists series, 7.Granites, 8 Serpentinites, 9. Micasists, 10.Gnajs, 11.Pb-Zn vein type of mineralization,12. Fe–skarns type of mineralization, 13 . Porphyry type of mineralizatio

Paleogene sediments occupy a large part of the terrain and are represented with conglomerates, paleogeneflysch and series of tuffites and sands. Conglomerates are heavily modified and built mostly of fragments of gneiss and quartz. Flysch facies is built of thin layers of fine-grained and large-grained sandstone and conglomerates. Volcanogenic sediment series is built of sandstones, marly sandstone and limestone, and pelitic tuffs and tuffites. Tuffs are determined as andesite and their presence indicates that the volcanic activity is synchronous with sedimentation of paleogenic sediments. Neogenic sediments, which are represented by conglomerates, are built of heterogeneous material dominated by pieces of quartz, crystalline shale and paleogenic sediments. Magmatic rocks are represented by volcanic and subvolcanic facies of latites, quartzlatites and andesites. Andesites in turn, depending on the degree of change and ore amount are divided into: propilitized andesites, hydrothermally altered andesites, hydro-thermally altered and mineralized andensites and andesite lava. Effusive rocks occur in the form of outcrop and lava. Large porphyritic propilitized andesites, i.e. latites and quartzlatites that occupy most of the terrain, are hydrothermally changed and mineralized. Latites and quartzlatites as products of the older phase hacked with dark grey fine-grained biotite amphibole-andesite which in the form of neck are imprinted in the central part of the Borov Dol circular structure.

3.METHODS AND MATERIALS

In this research schlich prospection was appliedfor which material of about 10-15 kg, from each sampling location was taken. After panning off, magnetic separation of the magnetic fraction was performed manually. Both fractions obtained were observed under binocular.The gold aggregates ound were separated manually and subjected to further study.

To determine the morphological features of gold-primarily the roundness, flatness, and serrations of grains-scanning electron microscopy (SEM) was used. This type of analysis allowed the length of transport and natureof the environment inwhich the schlich material was deposited to be determined. The SEM study was performed in the laboratory of electron microscopy within the Faculty of Stip University, Macedonia. Analyses were performed on a VEGA3 LMU . Etalons are from TESCAN. Specific operating conditions:

- Tension 20 keV
- Test Method: EDS
- Type of analysis:Quantitative
- X-act: 10mm2 (Slicon Drift detector)
- Max resolution125EV
- Resolutionof MnKα, FKα,CKα according to ISO 15632:2012

4.RESULTS AND DISCUSSION

Studies were performed along MeckinDol in the length of about 0.6 km (Fig 2).

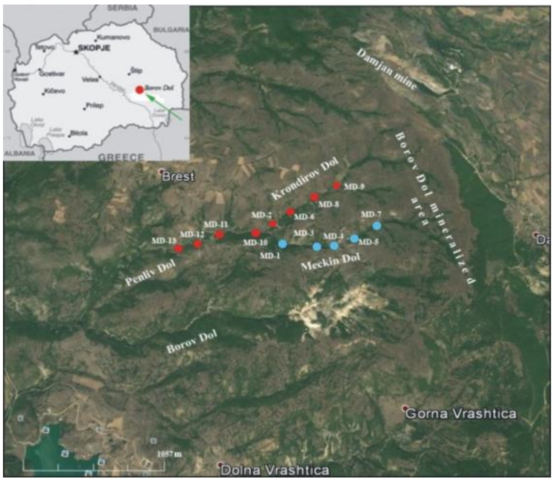


Fig. 2.Locationof sampling sites on shlich samples from localityMeckinDol

Out of the total 13 schlichs 5 schlichs were taken for more detailed processing. We found a total of 56 gold grains of different shapes and sizes (Table 1). The second mineral represented is chalcopyrite which is the bearer of the copper mineralization at this locality. Other metallic mineral in schlichs is pyrite, and in some schlichs galenite was significantly represented. Less prevalent are sphalerite, malachite, azurite, specularite.

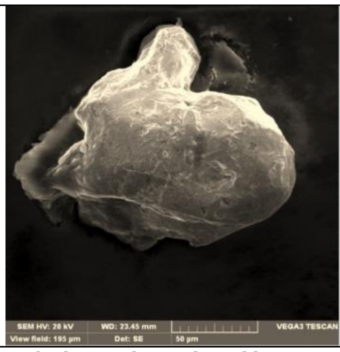
The nonmetal minerals, zircon, mica, and epidote are present.

Table 1. Results from sclichs investigations

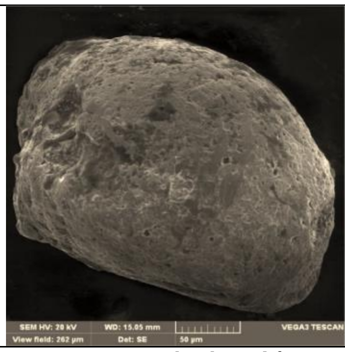
Schlich No.	Number of gold agregates
MD-1	5
MD-3	37
MD-4	3
MD-5	4
MD-7	4

The most important mineral of this prospection is gold. It is characterized by a beautiful yellow color and it has various sizes. Gold is found in elongated, dendritic irregular shapes and less frequently in spherical-round shape. In order to precisely define and determine the size and shape of gold aggregates detailed investigations scanning electronic microscope were performed (Fig. 3). From these examinations it can be said that isometric form prevails (Fig. 3f) while elongated gold aggregates (Fig. 3a and 3b), round-spherical shape (Fig.3b and 3c) and platness form were found also (Fig. 3e). The sizes of the gold aggregates examined in this locality ranged from 30 microns to about 600 microns.

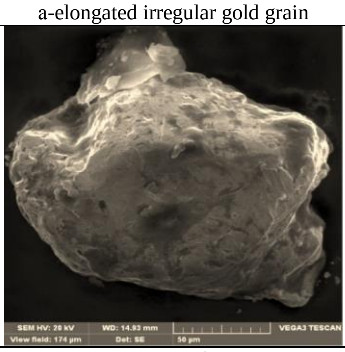
a-elongated irregular gold grain



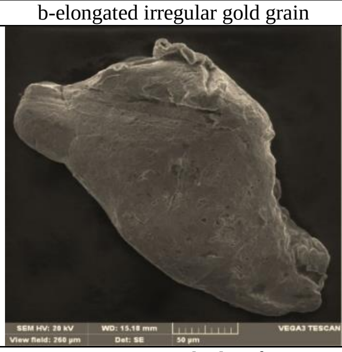
b-elongated irregular gold grain



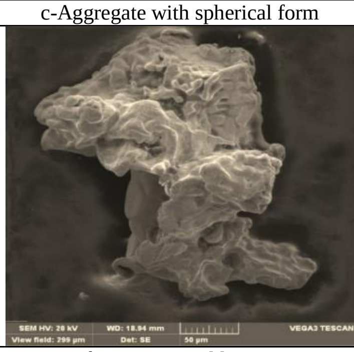
c-Aggregate with spherical form



d-rounded form



e- Aggregate with platy form

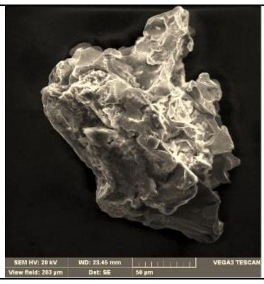
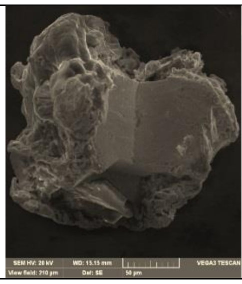
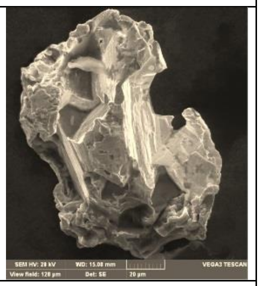
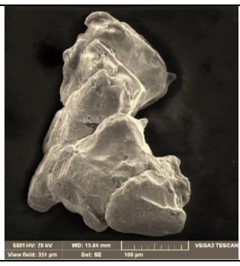
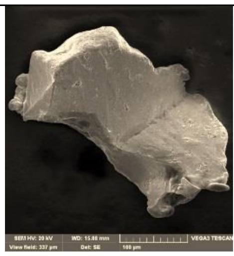


f–isometric gold grain

Fig. 4Morphological forms of matching gold aggregates of MeckinDol, Borov Dol locality

The physical characteristics of gold, such as the size of the grains, depend on the type of primary mineralization, type and length of transport and erosion processes which the terrain underwent ([8]). The morphology of gold aggregates in function of the length of transport can serve as an effective tool in determining the distance from the main source, i.e. the identification of the proximity of the primary gold source. Apart from the form and shape of the gold aggregates as a real indicator of length of transportation the flatness index can be used, which is calculated by the equation:$(L+b)$ / $2t$, where L is the grain length, b is the width, and t is the breadth, althoughthe roundness degree and the appearance of edges are also a good indicator ([16]). Studies of forms of gold aggregates from the tested locality show that irregular isometric shapes prevail in the vicinity of primary source while downstream of the creek as a result of transport these forms are lost, i.e. the grains are elongated and rounded off.Atadistance up to 50 m from primary mineralization almost identical shapes as well as primary goldprevail. At a distance of 50 to 300 m secondary grains become elongated, they even get triangular shapes with the appearance of small voids on the grain surface. At a distance greater than 300 m primary shapes of grains are lost ([16] and [9]). The flatness index of the examined gold aggregates from the creek MeckinDol ranges from 1.05 to 3.27. Based on morphological characteristics, form, shape, external appearance, flatness index two groups of gold aggregates can be distinguished(Table 2). The aggregates up to 50m belong in the first group, and the gold aggregates from 50 to 300m belong in the second group.

Table-2 Morphological characteristics of Au grains associated with distance from source

Distance to source	General shape, outline-surface of gold aggregates			
Flatness index 1-2				
to 50 м				
Flatness index2.1-3.3				
50-300м				

The first group of grains (Table 2) is characterized by a well preserved original form: square to rectangular shapes, angular edges. The general shape of the grains is irregular.They can often be found in the elongated shapes. Flatness index ranges from 1-2. The second group is represented by aggregates with the flatness index of 2.1-3.3 and are characterized by slightly elongated shapes. The general appearance is represented by a relatively regular shape. It could be said that the external shape of studied grains locality varies widely, which, according to [18], is due to the fact that primary grains show a wide variety of initial shapes. Such characteristic suggests that this gold probably has similar characteristics as the primary gold, [10] and that it has not suffered long transportation. Squamate or flat shape as well as elongated shape that is found on the tested locality is a feature of primary gold that typically occurs in such shapes, although it sometimes may occur in square to rectangular but very irregular shape with expressed sharp contours and edges on grains ([8], [16], [7], [9]). Beside the shape, analyses of the chemical composition of gold aggregates were performed, which showed that it was native gold characterized by high purity. According to [20] the gold with the purity of 900-950 is called high grade gold, and the gold whose purity ranges from 800-899 belongs to the group of moderate grade gold. Given this grouping it can be said that (Table 3) most of the tested gold aggregates belong to the group of high grade gold where the gold content ranges from 92% to maximum 99% of gold, and a smaller number with lower purity where gold content ranges from 71-84%

Table -3 Chemical composition of gold aggregates –MeckinDol, BorovDol locality (%)

sample	position of analysis	Fe	Cu	Ag	Au	Bi	Se	Te
MD-1 grain-1	periphery	0.25	0.09	0.23	99.42			
	centre	0.72			99.21	0.07		
	periphery	0.22	0.03	0.4	99.35			
MD-1 grain-2	periphery	0.28		7.51	91.40			0.82
	centre	0.05	0.16	10.46	88.13	0.74	0.16	0.31
	periphery	0.03	0.18	4.83	93.75	0.74		0.47
MD-1 grain-3	periphery		0.3		99.12	0.5	0.07	
	centre	0.01		0.74	99.25			
	periphery	0.09	0.48		99.43			
MD-3 grain-1	periphery	0.15	0.64	6.21	92.68			0.30
	centre	0.02	0.65	7.24	92.09			
	periphery	0.29	0.14	9.55	89.52	0.2		0.30
MD-3 grain-2	periphery	1.98	0.46	3.07	94.48			
	centre	1.61		5.29	92.80	0.29		
	periphery	0.11	0.59	3.06	96.24			
MD-3 grain-3	periphery	0.23		11.04	87.98	0.74		0.01
	centre	0.11	0.19	13.49	85.73	0.08	0.01	0.39
	periphery	0.30	0.25	13.23	86.20			
MD-4 grain-1	periphery	0.11		26.91	71.56			0.53
	centre			25.91	73.24	0.42		
	periphery		0.14	21.23	77.64			0.91
MD-4 grain-2	periphery		0.6	4.41	94.98			
	centre	0.54		2.21	97.26			
	periphery		21.52		78.48			
MD-4 grain-3	periphery	0.14		2.28	97.58			
	centre		0.59	2.39	97.02			
	periphery			0.42	99.58			
MD-5 grain-1	periphery	0.02	0.04	20.40	78.61	0.63	0.3	
	centre		0.28	14.16	85.43			0.14
	periphery	0.03	0.05	9.92	89.97		0.04	
MD-5 grain-2	periphery		0.32	10.18	89.10	0.4		
	centre	0.01	0.34	7.59	91.83	0.13		0.1
	periphery	0.75	0.29	9.21	89.28	0.13		0.33
MD-5 grain-3	periphery	0.02		20.52	79.29			0.17
	centre	0.03	0.84	12.64	86.41			
	periphery	1.01	0.31	21.89	76.02	0.4		0.36
MD-7 grain-1	periphery	0.1		21.65	77.53	0.41		0.32
	centre		0.3	19.30	80.19	0.21		0.08
	periphery		0.16	19.46	79.89	0.44		0.06
MD-7 grain-2	periphery	0.21	0.19	22.84	76.43		0.06	0.27
	centre	1.36	0.26	25.78	72.26			0.34
MD-7 grain-3	periphery	0.18	0.49	11.13	88.20			
	centre	0.24	0.03	12.91	86.73			0.09
	periphery	0.11	0.06	13	86.47			0.35

Examination of gold aggregates was performed on peripheral partsand one analysis in the central parts in order to illustrate whether there was zonality in chemical composition.Asthe dominant admixture in gold aggregates silveris present in the rank ranging from <1% to 26.91%.Fig. 4 shows a histogram display of the silver contents in the tested gold aggregates. In alluvial gold silver content can vary from 32 to 50% (with an average fineness of 630), and other elements do not exceed 1% [1].

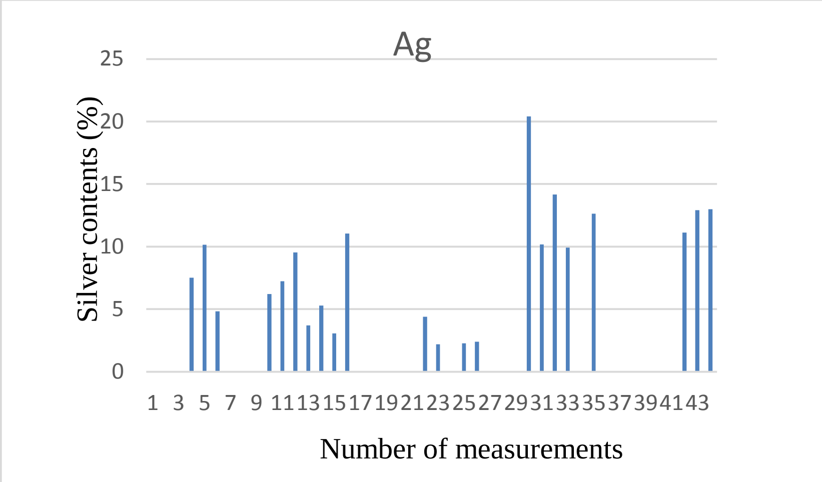


Fig. 4 Histogram display the contents of the tested silver gold aggregates of MeckinDol

In addition, regularity in the silver content was not noticed. In some central gold aggregatescentral parts are richer in silver than the periphery which can be seen in Table 3 (MD-1 grain 2, MD-7 grain 2) while in others reverse zonality is observed – the center of gold aggregates is poorer with silver than its peripheral parts. In most of the tested gold aggregates there is no regularity in terms of silver content.

Studies of the relationship between the composition of gold and length of transportation showed that there is no change in microchemical recordof alluvial gold during transportation ([3]).

As for other ingredients the presence of Fe, Cu, Bi, Se, Te is determined. Iron content range from 0.01 to 1.98%. Copper content is from 0.03 to 0.84%. Other impurities such as Bi, Se, Te are underrepresented and in some aggregates they are even not present.Based on these data it can be said that gold aggregates in general have a homogeneous composition which leads to the assumption that gold aggregates derive from one source ([5]).

5. CONCLUSION:

The results of investigations of the morphology of gold aggregates, the flatness index 1-2, from the locality MeckinDol suggests that there is a primary deposit in the immediate vicinity from where the material was disintegrated. The size of the gold aggregates found ranges from 30 to about 600 microns.Based on tests it was determined that gold aggregates commonly occur in irregular isometric form, then in a round-spherical shape, and in the shape of plates. The irregular shape is most common.

Studies of the chemical composition showed that gold is characterized by high purity, which ranged from 750 to 996. Of all impurities the silver content is greatest from <1% to 26.91%. As for other ingredients Fe, Cu, Bi, Se, Teare found in low content.

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REZIME

MORFOLOSKE I HEMISKE KARAKTERISTIKE NANOSNOG ZLATA SA MEČKIN DOLA, LOKALITET BOROV DOL, ISTOCNA MAKEDONIJA

U radu su prezentirani najnovii rezultati sa slihovske prospekcije koja je bila izvedena po teceniju potoka Meckin Dol. Istrazivanja su pokazala da je velicina ispitivanih zlatnih agregata od 30 do oko 600 mikrona, a najcesto prisutna forma zlatnih agregata je izometricna-nepravilna forma. Hemiski sastav zlatnih agregata ukazuje na heterogenost. Prosecna sadrzina zlata krece se od 74.15 – 99.32%, zatim srebro je prisutno sa sadrzinama od 0.3-24.68%, bakar sa prosecnim sadrzinama od 0.04 do 11.06%. Ostali primesi Fe, Bi, Se, Te su zasupljeni sa sadrzinama manjim od 1%. Generalno moze se reci da ispitivani zlatni agregati po hemiskom sastavu se karakterizuju sa velikom cistocom koja se krece od 750 do 996.

Kljucne reci: morfologija zlata, indeks spleskanosti, hemiski sastav