NATIVE GOLD FROM SEDEFCHE DEPOSIT, EASTERN RHODOPES, BULGARIA

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ABSTRACT: The epithermal Sedefche deposit is located in the Eastern Rhodopes (Bulgaria). It is part of the Zvezdel-Pcheloyad ore field. The ore mineralization is hosted in intermediate volcanic tuffs, affected by intensive hydrothermal alteration. The primary ore minerals are sulfides and sulfosalts, including silver-bearing minerals (mostly sulphides and sulphosalts such as acanthite, pyrargyrite, freibergite and others). The upper parts of the deposit are near the ground surface and are subjected to supergene changes. The presence of gold in the deposit is proven by geologic surveys and chemical analyses. Still until now, gold from the deposit has not been observed as a standalone macroscopic phase or under optical or electron microscope. As part of this study, 8.63 kg ore-bearing host rock from the deposit is crushed, milled, sifted and processed by Knelson's concentrator and pan in order to extract heavy minerals. Subsequently the heavy mineral fraction was bonded in polymer resin and polished in order to expose the surface of the minerals and facilitate their observation under optical and electron microscopes. In one of these specimens native gold was discovered. The discovered native gold is of sub-microscopic size. Despite its small size, it is a physical proof of the presence of gold in Sedefche deposit. This discovery may improve and refine techniques for gold extraction from the deposit. At least some of the gold from the deposit could be recovered by using conventional physical-mechanical techniques.

Keywords: native, gold, epithermal, Sedefche deposit

САМОРОДНО ЗЛАТО ОТ НАХОДИЩЕ СЕДЕФЧЕ, ИЗТОЧНИ РОДОПИ, БЪЛГАРИЯ

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РЕЗЮМЕ: Епитермалното находище Седефче се намира в Източните Родопи (България). То е част от Звездел-Пчелоядското рудно поле. Рудната минерализация е вместена в среднокисели вулкански туфи, засегнати от интензивна хидротермална промяна. Първичните рудни минерали са сулфиди и сулфосоли, включително среброносни минерали (предимно сулфиди и сулфосоли като акантит, пираргирит, фрайбергит и др.). Горните части на находището са близо до земната повърхност и са подложени на хипергенни промени. Присъствието на злато в находището е доказано от геоложките проучвания и химични анализи. Въпреки това, досега злато от находището не е наблюдавано като самостоятелна макроскопска фаза или под оптичен или електронен микроскоп. Като част от това изследване, 8.63 kg рудоносна вместваща скала от находището е натрошена, смляна, пресята и обработена с Нелсънов концентратор и промивна купа, за извличане на тежки минерали. В последствие тежката минерална фракция е споена с полимерна смола и полирана за разкриване на минералите и улесняване на наблюдението им с оптичен и електронен микроскоп. В един от изработените образци е открито самородно злато. Откритото самородно злато е със субмикроскопични размери. Въпреки малките си размери, то е физическо доказателство за присъствието на злато в находище Седефче. Това откритие би могло да подобри и усъвършенства техниките за извличане на златото от находището. Част от златото от находището би могла да се извлече с използване на конвенционални физико-механични техники.

Ключови думи: самородно, злато, епитермално, находище, Седефче

Introduction

The Sedefche deposit is located in the Eastern Rhodopes, South Bulgaria, roughly between the towns of Momchilgrad and Krumovgrad (Fig. 1). Sedefche has been known as ore occurrence at least since 1963, when modern prospecting and surveying in the area were initiated (Atanasov and Breskovska, 1964; Atanasov, 1965). These early geologic surveys have discovered traces of ancient mining works in the deposit (Tsekova, 1965; Dragiev and Dragieva, 2006).

Geological setting

The deposit is part of the Zvezdel-Pcheloyad ore field in the area of Zvezdel paleo-volcano (Georgiev, 2012).

The ore field belongs to Momchilgrad ore sub-region, which coincides spatially with Momchilgrad depression (Fig. 2). The area of the deposit consists of two tectonic complexes (Georgiev, 2012):

Fig. 1. Location of the Sedefche deposit in the Republic of Bulgaria.

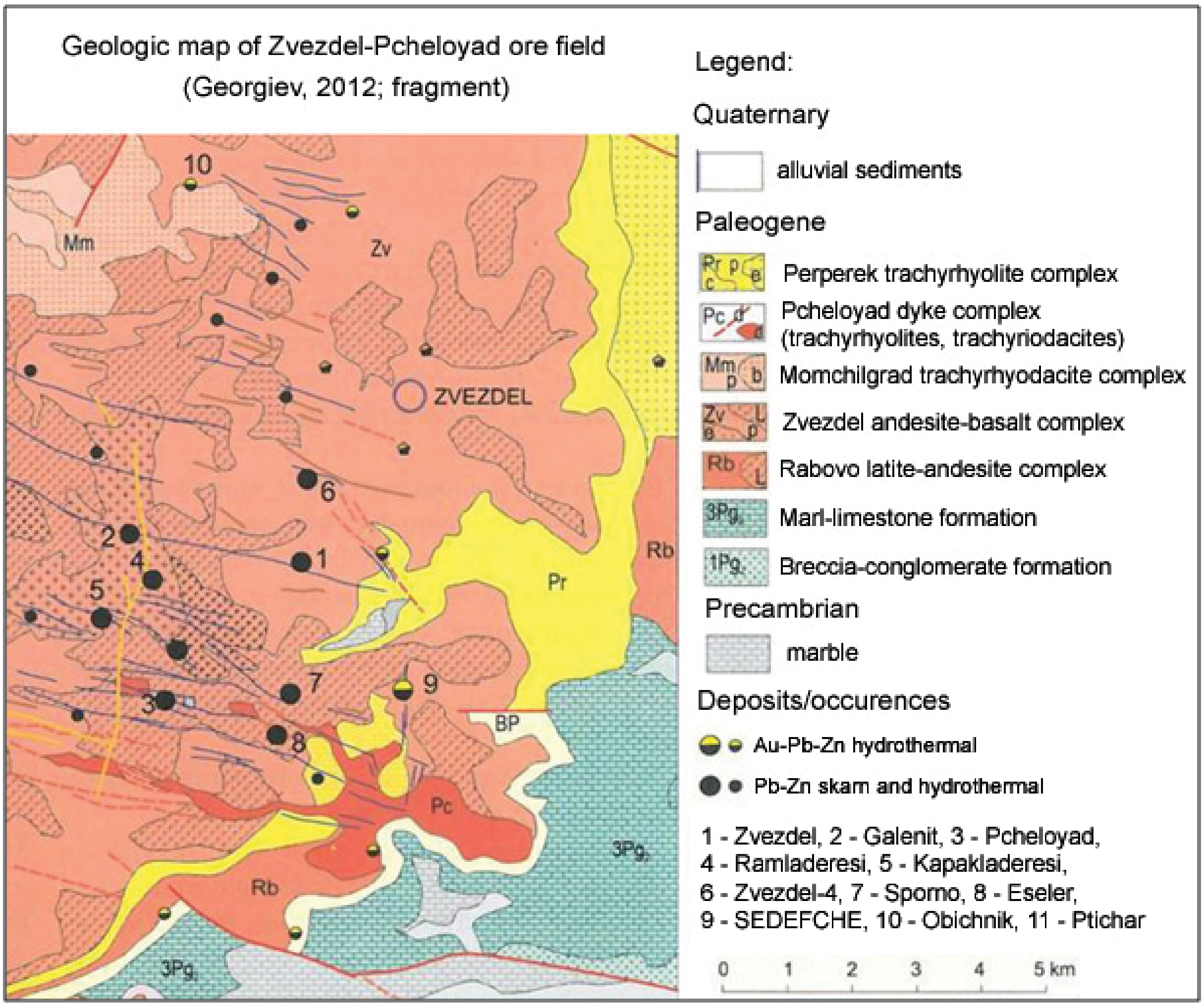

Fig. 2. Momchilgrad depression and Zvezdel-Pcheloyad ore field (Georgiev, 2012). On this map, the Sedefche deposit is marked with #9.

Pre-tertiary metamorphic complex – it consists of metamorphic rocks, represented by biotite and dual-mica gneiss, amphibolite-biotite gneiss, marble and kyanite-garnet-biotite schists. Their age is considered to be Precambrian.

Tertiary volcanogenic-sedimentary cover – it is represented by sedimentary, volcanogenic-sedimentary and volcanic rocks. Limestones and sandy-loam rocks lie above the metamorphic rocks. In some areas, limestones are partially silificated. Volcanic manifestations in Oligocene (Pg_3) formed acid to intermediate lava plains and dykes of rhyolite, dacite and andesite.

Geologic surveys outlined three ore bodies in the deposit - Northern (central) ore body, Southern ore body and Ralitza Dere. The Northern (central) ore body is the most promising one for finding Au and Ag according to the results of geological surveys. The ore minerals are hosted within intermediate volcanic tuffs, subjected to heavy hydrothermal alteration, such as silification, sericitization, propylytization (Atanasov 1965; Radonova 1973). The ore bodies in the Sedefche deposit have layer-like, pseudo-conform shape (Georgiev, 2012).

Ore minerals

The Sedefche deposit exhibits diverse mineral composition. More than 20 ore minerals have been reported by various studies and authors (Mladenova, 1998; 1999), (Strashimirov et al. 2005), (Milev et al., 2007). The primary ore minerals are sulphides and sulphosalts (pyrite, marcasite, arsenopyrite, sphalerite, galena, chalcopyrite, acanthite, tennantite-tetrahedrite-freibergite, pyrargyrite, miargyrite and others). Earlier studies suggest the presence of "invisible gold" as sub-microscopic particles/inclusions within primary ore minerals such as pyrite, marcasite and arsenopyrite (Mladenova, 1998). Supergene ore minerals are represented by oxides, hydroxides, sulfates, carbonates and arsenates. The most widespread supergene ore minerals in the deposit are goethite, scorodite and jarosite.

Methods of study

For more profound investigation of the ore minerals (and particularly searching for native gold), heavy mineral fraction was extracted. A total of 8.63 kg rock samples from the trial quarry in the Northern (central) ore body were subjected to the following operations: crushing with jaw crusher, milling with hammer-mill, sifting, extraction of heavy minerals by Knelson's concentrator, thereby obtaining fraction K1. Afterwards part of fraction K1 was bonded with polymer resin (butyl-2-cyanoacrilate) and polished to expose fresh surfaces of the heavy minerals in the form of briquette-like specimens (K1-1 and K1-2). The remainder of heavy fraction K1 was washed with pan to extract heavy fraction K2. In the same way as above, two more briquette-like specimens were made from it (K2-1 and K2-2) (Fig. 3).

Fig. 3. Specimens of heavy minerals' fractions bonded with polymer resin and polished ("briquettes").

The crushing, milling and panning were carried out in the laboratories of UMG "St. Ivan Rilski" with the support of eng. V. Nojarov and eng. I. Raikov.

The processing with Knelson's concentrator was done in "Eurotest Control" with the help of eng. St. Stamenov and eng. N. Nestorov.

The 4 specimens were investigated with optical reflected-light microscopes and subjected to semi-quantitative electron microscope EDS analyses in order to determine their mineral composition. The diameter of the electron beam was about 4 μm.

The optical microscope observations were carried out in UMG "St. Ivan Rilski" and Montanuniversitæt Leoben with microscopes Meiji 9430 and Olympus BX60 respectively.

Electron microscope investigations of the samples were completed in Montanuniversitæt Leoben with device Zeiss EVO|MA10, EDS detector Bruker, with the help and guidance of Prof, PhD Frank Melcher.

Results of the study

The microscope observations revealed only the most common ore minerals present in the deposit (such as pyrite, marcasite and arsenopyrite). Many of the smaller mineral grains in the "briquettes" could not be identified by this method due to their small size. For this reason the specimens were carefully examined with electron microscope in order to determine and identify the small-sized mineral grains. A total of 34 analyses were made and they discovered the following primary ore minerals – acanthite, barite, pyrite, marcasite, arsenopyrite, sphalerite, galena, gersdorffite, gold and secondary (supergene) minerals – jarosite, scorodite and Fe-hydroxides. One of these semi-quantitative EDS analyses discovered a small grain of native gold (Fig. 4), within a matrix of jarosite.

The result of the semi-quantitative analysis, corresponding to the gold grain and surrounding area is shown in Table 1.

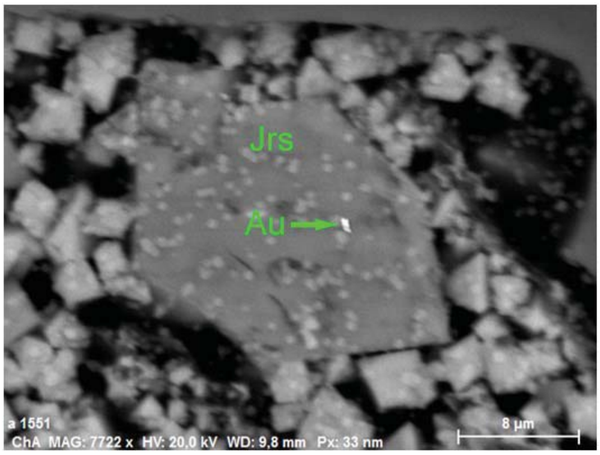

Fig. 4. Miniature grain of native gold within a matrix of jarosite.

Table 1.
Results from semi-quantitative analyses of jarosite hosting a grain of native gold

Element	*mass %*	*normalized mass %*	*atom.%*	*Error (3σ) [mass %]*
O	*35.06*	*34.72*	*63.77*	*4.51*
S	*12.96*	*12.84*	*11.76*	*0.50*
K	*6.72*	*6.66*	*5.01*	*0.24*
Fe	*31.70*	*31.40*	*16.52*	*0.89*
As	*1.39*	*1.37*	*0.54*	*0.11*
Ag	*1.34*	*1.33*	*0.36*	*0.08*
Au	*11.47*	*11.36*	*1.69*	*0.44*
Sum:	*100.97*	*100.00*	*100.00*	*-*

The discovered grain of native gold is slightly elongated, with size not larger than 0.5 × 1 μm. Due to its small size the analysis contains data from the matrix's composition as well. The sharp boundaries and brightness of the gold grain, which is typical for elements with greater atomic mass, are well defined and visible on the image from the electron microscope. The image is taken at magnification of 7722 times. The results from the semi-quantitative analyses, of the jarosite matrix are shown in Table 2.

Table 2.
Results from semi-quantitative analyses of jarosite matrix

Element	*mass %*	*norm. mass %*	*atom. %*	*Error (3σ) [mass %]*
O	*31.99*	*36.50*	*62.10*	*3.91*
S	*13.72*	*15.66*	*13.29*	*0.52*
K	*5.49*	*6.26*	*4.36*	*0.20*
Fe	*34.86*	*39.78*	*19.39*	*0.97*
As	*1.29*	*1.47*	*0.54*	*0.11*
Sum:	*87.64*	*100.00*	*100.00*	*-*

As a typical endogenous mineral, gold has formed in association with some of the primary minerals in the deposit. Most likely, during the supergene processes, gold was liberated from its matrix of primary minerals as they were transformed and later enveloped by a matrix of secondary jarosite. The origin of this gold grain cannot be linked directly with some of the primary minerals as these relationships were erased by the supergene processes.

Conclusions

The current study confirmed the assumed presence of native gold in the Sedefche deposit, although it most likely appears as grains of very small, sub-microscopic size (0.5 – 1 μm or smaller), originally as inclusions ("invisible gold") in primary minerals. In the oxidation zone of the deposit original primary minerals hosting gold have been transformed to secondary minerals, such as jarosite, which in turn may contain native gold. The current study suggests that at least some of the gold from the deposit could possibly be recovered by using conventional physical-mechanical techniques. For extraction of gold particles with smaller sizes, other technologies may need to be applied.

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