Preliminary data on the morphology of electrum from the layer-like pervasive silicification in Stenata outcrop, Khan Krum gold deposit, SE Bulgaria

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Introduction

The layer-like pervasive silicification in the Stenata outcrop is a well-marked body in the field. Its formation is differentiated by Кунов и др. (2001) in the first quartz-adularia-sulfide stage (pyrite and pyrite-marcasite parageneses). The electrum in the Khan Krum (Ada Tepe) deposit is related to a later quartz-gold paragenesis and represented by microscopic grains of oval and dendritic shape in quartz and quartz-adularia veinlets. Marchev et al. (2004) differentiated the formation of layer-like pervasive silicification in a first stage deposited microcrystalline to fine-grained quartz with rare pyrite and adularia. Electrum has not been described from this stage. It has been referred to a next stage as "black millimeter-scale bands of opaline or microcrystalline chalcedony-adularia and electrum". These authors distinguished intersticial and dendritic electrum. Marinova (2005, 2006a) reported micron-sized electrum from the pervasive silicification in the Stenata outcrop.

The layer-like pervasive silicification in the outcrop consists of quartz (98-99%), adularia and kaolinite (1-2%), electrum, marcasite and goethite pseudomorphs after pyrite (below 1%) according to the X-ray powder and optical data (Кунов и др., 2001; Marchev et al., 2004; Marinova, 2005, 2006a).

The aim of the present paper is to report a preliminary data on the morphology of electrum from the layer-like pervasive silicification in the Stenata outcrop predominantly just above the Tokachka Detachment Fault and to discuss the morphogenesis of electrum.

Sampling

It was carried out in 2004 just above the Tokachka Fault plane. Hand specimens of Balkan Mineral and Mining were also used for more detailed characterization.

Results and discussion

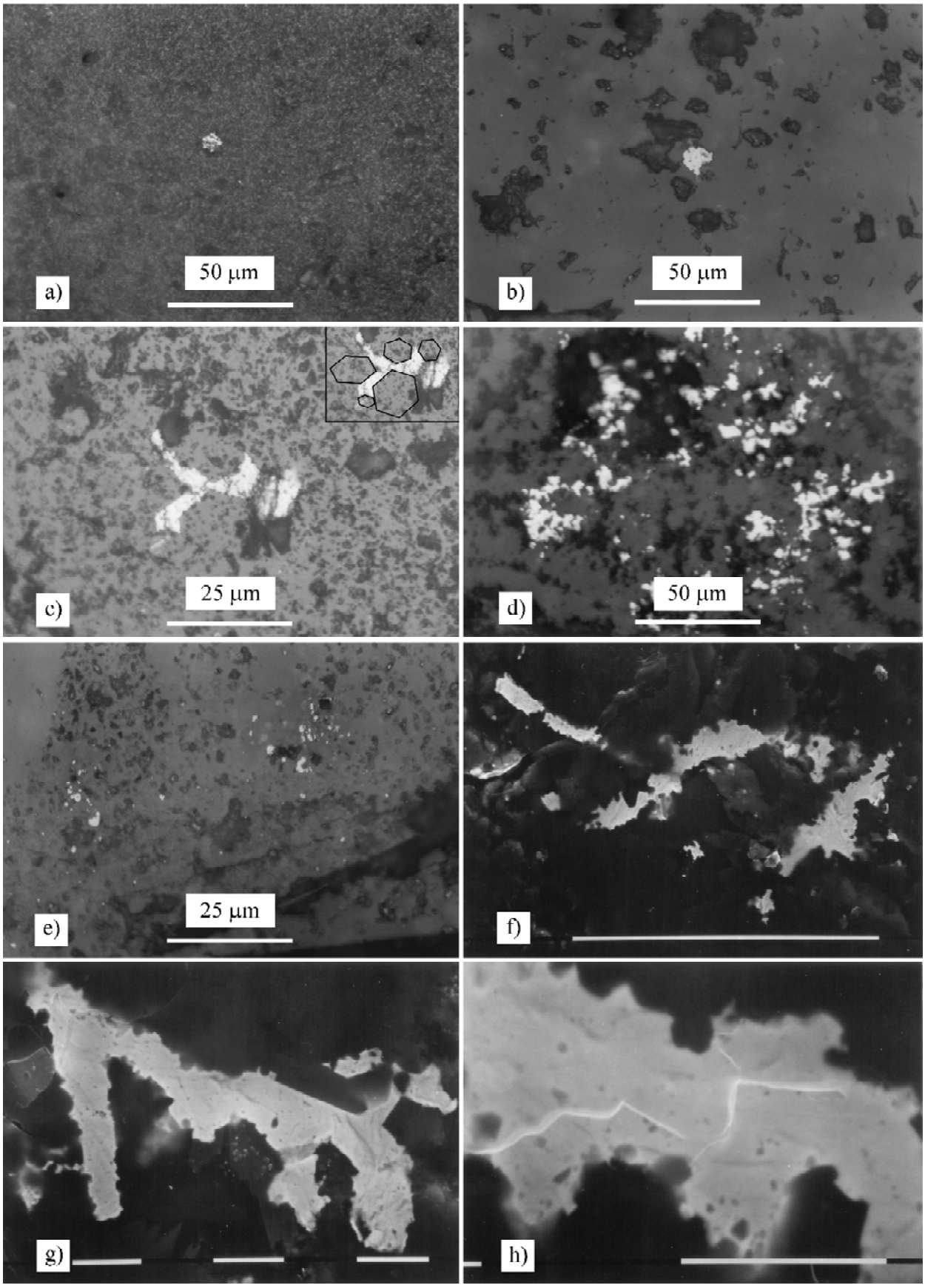
The electrum from the layer-like pervasive silicification in the Stenata outcrop is represented by: 1) dispersed grains in the massive, microcrystalline quartz; 2) grains in interstices of the massive, microcrystalline quartz; 3) filamentary crystals; 4) clots of irregular grains, and 5) dendrites.

A part of electrum in our samples is characterized by randomly dispersed grains of micron sizes (fig. 1a, b). It forms groups of several grains or is represented by single grains with few microns of size. More rarely electrum can be observed as coarser single grains with an average size of about 20-50 μm across (up to 100 μm). Commonly, the electrum grains are isometric with an oval shape but facetted shapes are also developed. We observed random sections of electrum with a square outlining as well as such an outlining with cut corners probably reflecting development of cubic and/or combination of cubic and octahedral shapes (fig. 1a, b). More complicated outlinings are probably twins and aggregates.

The common occurrences of microcrystalline quartz and dispersed micron-sized electrum could be explained by their simultaneous deposition. Studying the solubility of gold and silica in sulfidic solutions, Летников, Вилор (1981) found out a similarity of their curves of solubility versus temperature and proposed their simultaneous transport and crystallization.

In the massive, microcrystalline quartz intersticial electrum is observed. One can draw hexagonal quartz sections by the outlines of this electrum thus proving its later deposition (fig. 1c).

Numerous filamentary crystals of electrum are observed also in a half-centimetre void within the massive quartz. Electrum crystals are of micron sizes (below 100-150 μm) and grow out from the massive quartz starting with straight-linear stem which


a)
50 μm
b)
50 μm
c)
25 μm
d)
50 μm
e)
25 μm
f)
g)
h)

←

Fig. 1. Electrum from the layer-like pervasive silicification in the Stenata outcrop: a-e — in reflected light; f-h — in secondary electrons (Philips SEM-515, U=28kV); a) single electrum grain in massive, microcrystalline quartz with square outlining; b) single electrum grain in massive, microcrystalline quartz with octagonal outlining; c) intersticial electrum in massive, microcrystalline quartz; d) clot of irregular electrum grains in banded quartz cross-cutting the pervasive silicification; e) clot of irregular electrum grains in massive, microcrystalline quartz; f) poorly developed dendrite in banded quartz and later metasomatic quartz crystals in the dendrite, Scale bar — 100 μm; g) asymmetrically developed dendrite in banded quartz and later metasomatic quartz crystals, Scale bar — 10 μm; h) coinciding of concave surfaces of electrum dendrite with convex surfaces of quartz aggregates and vice versa as well as layered microrelief of electrum dendrite in banded quartz. Scale bar — 10 μm

free end is curved inward. The filamentary crystals of gold and electrum form under near surficial conditions (Петровская, 1973), where the solutions can reach supersaturation and create nonequilibrium crystal forms (Bonev, 2005). The analyses of textures from the layer-like pervasive silicification in the Stenata outcrop showed a presence of textures indicative of similar conditions (Marinova, 2006a, b, c).

Micron-sized clots of irregular grains were observed in rhythmical colloform banded textures of filling of joints that cross-cut the pervasive silicification. In these textures the electrum clots are included in banded quartz (milky, colourless and brown) alternating rhythmically with bands of quartz +adularia, adularia and partially crystallized opal (Marinova, 2006b). The clots are elongated along the bands and the largest of them are 200/150 μm in size (fig. 1d).When single clots formed closely one to another they become visible with the naked eye. These electrum clots are very rare in the massive, microcrystalline quartz and have smaller sizes (fig. 1e).

Electrum dendrites are very rare in the massive, microcrystalline quartz where they form single inclusions. They are often observed in the electrum-rich rhythmical colloform banded textures in association with coarse electrum grains and electrum clots. The dendrites and the clots are attached to the finest banding of the colloform banded textures, where the banding thickness do not exceed 1 mm and the separate bands are thick up to 100-200 μm. Generally, the finest banding is represented by alternation of milky, colourless and brown quartz.

The base of dendrites lies most often in the first band or the first several ones and their final terminations are covered by several quartz bands without dendrites. The stems of dendrites are perpendicular or obliquely to the quartz bands they are included. That means the side development of electrum dendrites has been cumbered by quartz deposited in the bands simultaneously with the electrum. A synchronized development of quartz and electrum dendrites is obvious in polished sections and secondary electron images: the concave surfaces of electrum dendrites coincide with the convex surfaces of quartz aggregates and vice versa (fig. 1f, g, h). These observations show that the electrum dendrites and the banded quartz including them has grown simultaneously. Such relationships could not exist if the electrum dendrites were earlier or later than the quartz including them. Numerous later metasomatic quartz crystals are developed in the dendrites (fig. 1f, g).

The typical well-developed dendrites with a stem and branches are rare in the studied samples greatly dominated by poorly developed dendrites. One-stem dendrites with poorly developed branches, dendrites with 2-3 branches and bush-like dendrites are observed (fig. 1f, g). The height/length ratio of dendrites varies from 10:1, for the one-stem dendrites, to 1:1, for the bush-like ones, and the largest dendites we observed do not exceed 150 μm in height.

Such as the filamentary electrum, the dendrites and the rhythmical colloform banded textures are indicators of nonequilibrium conditions of formation. The rhythmical banded textures are also described by a self-organizational crystallization model under nonequilibrium conditions and involving a morphological instability of the crystallization front (Wang, Merino, 1990; Летников, 1997). The presence in the electrum dendrite-containing samples of adularia — an indicator of intensive boiling of fluids (Browne, 1978; Dong, Morrison, 1995), and of opal — an indicator of high supersaturation of fluids and low temperature of precipitation (Xu et al., 1998) are indicative of a sudden drop of pressure and temperature of the hydrothermal system upon the formation of the layer-like pervasive silicification, high supersaturation of the fluids and rapid nonequilibrium crystallization of filamentary and dendrite electrum.

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Предварителни данни за морфологията на електрума от пластообразното, масивно окварцяване в разкритие Стената, златно находище „Хан Крум", СИ България

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Изследвана е морфологията на електрума от пластообразното, масивно окварцяване в разкритие Стената. Електрумът е отложен под формата на: 1) разсеяни зърна сред масивния, микрокристален кварц; 2) електрум в интерстициите на масивния, микрокристален кварц; 3) нишковидни кристали; 4) гнездовидни струпвания от зърна с неправилна форма; 5) дендрити. Разсеяните зърна от електрум сред масивния, микрокристален кварц са с изометрична, овална форма. Те се разполагат на групи и поединично с размери на единичните зърна до няколко микрона. По-рядко се наблюдават по-едри зърна с размери 20—50 μm, като най-едрите достигат до 100 μm. От наблюдаваните случайни прерези с квадратни и квадратни със скосени ъгли очертания може да се допусне развитие на кубични и комбинация от кубични и октаедрични форми (фиг. 1a, b). Някои по-сложни форми вероятно са срастъци и агрегати. В масивния кварц се среща и електрум, по очертанията на който могат да се възстановят шестоъгълни кварцови прерези. Този електрум явно е отложен в интерстициите на кварцовите кристали (фиг. 1c). Нишковидните кристали са с микронни размери (под 100—150 μm) и са наблюдавани в половинсантиметрова кухина сред масивния кварц. Те имат прав ствол, развит върху кварцова подложка, и завит навътре свободен край. Гнездовидните струпвания и дендритите от електрум са наблюдавани в ритмични коломорфно-ивични текстури на запълване на пукнатини и жилки, сечащи масивния кварц. Текстурите представляват ритмично редуване най-често на кварц (млечен, прозрачен и кафяв), като понякога присъстват и ивици от адулар, кварц+адулар и прекристализирал опал. Гнездовидните струпвания се разполагат по протежение на ивичестите текстури и най-големите от тях са с размери 200x150 μm (фиг. 1d). Те са много редки сред масивния кварц и са с по-малки размери (фиг. 1e). Дендритите от електрум не превишават 150 μm по удължението. Те са привързани към най-фината ритмичност на коломорфно-ивичестите текстури с дебелина под 1 mm, като дебелината на отделните ивици от кварц е от порядъка на 100—200 μm. Преобладават едноствовли дендрити със слабо развити странични разклонения, както и храстовидни дендрити (фиг. 1f, g). Синхронното морфоложко развитие на дендритите и включващия ги кварц (съвпадане на изпъкнали повърхности на дендритите с вдлъбнати повърхности на кварца и обратно) е указание за техния едновременен растеж (фиг. 1f, g, h). Според автора нишковидният и дендритният електрум е признак за силнонеравновесни условия на образуване близо до повърхността — кипене на разтворите и силно пресищане. Този извод се подкрепя от присъствието на адулар и опал, както и от развитието на ритмични ивичести текстури — показатели за такива условия, и се съгласува с литературните данни.