Mineralogy and genetic aspects of gold in the Lahóca (Recsk, Hungary) high sulfidation type epithermal deposit

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Mineralogické a genetické aspekty prítomnosti zlata na epitermálnom ložisku HS v Lahóci (Recsk, Maďarsko)

Epitermálne vysokosulfidické (HS) zrudnenie viazané na vrchnoeocénske andezity oblasti Lahóca, je súčasťou rudného komplexu pohoria Matra v Maďarsku, pri dedinke Recsk. Tento komplex je charakterizovaný skarnovým, Cu-porfýrovým a epitermálnym HS zrudnením. Cu-Au ložisko HS epitermálneho zrudnenia pri Lahóci ťažili viac ako 130 rokov, predovšetkým pre získanie medi. V HS ložisku má výskyt zlata vysokú jemnosť, tvorí zrnká veľkosti 1-30 mikrónov a nepravidelné plôšky. Zlato sa viaže najmä na pyrit. V prekremenelom matrixe sa zlato objavuje aj samostatne. V pyrite sa nevyskytuje v inklúziách, je vždy narastaný na povrch pyritových kryštálov.

Key words: *HS type epithermal deposit, native gold, silicified andesite, hydrothermal breccia.*

Introduction

Examination of the morphological and mineralogical characteristics of gold has not been the essential point during the exploration of Hungarian epithermal deposits. As the size of gold grains is generally a few microns, they can be studied only by electron microscope. Thus, earlier their presence was not realized in the rocks, or they were apostrophized as “invisible gold”. Even during the exploration of the Recsk epithermal deposits in the late nineties, first of all the gold content of rocks was assayed, not examining the mineralogical features of gold. However, the latter is not simply a scientific question but it can be an important factor in mineral processing. Examinations during this study were focused on the Lahóca area.

Geology and mineralization of the Recsk complex

The Lahóca HS-type epithermal deposit is a part of the Recsk mineralized complex, located in the eastern part of the Mátra Mountains. The main part of the Mátra Mountains formed during the Carpathian Neogene volcanism. The smaller and older Recsk volcanic complex formed during the Paleogene, and has an allochtonous position. The Recsk Paleogene volcanic unit was a part of the internal island arc in the subduction zone that was located between the Northern and Southern Alps during the Laramian-Pyrenian orogeny. Due to a large-scale northeastward movement along the Darnó strike-slip fault, the Recsk Paleogene complex was emplaced at the recent position during the Lower Miocene (Csontos et al., 1992).

The pre-volcanic basement of the Recsk area consists of Triassic limestone, quartzite and shales. Due to the post-Triassic uplift, Jurassic and Cretaceous rocks are absent. The Paleogene series starts with Upper Eocene, shallow marine limestone and marl, underlying, intermingling and overlying intermediate volcanic rocks. The Paleogene volcanic cycle comprises four stages: (1) submarine lavaflows, agglomerates, peperites (the rocks of this stage do not outcrop on surface); (2) stratovolcanic sequence of dacitic character, shifting gradually to subaerial environments; (3) stratovolcanic sequence of biotite-hornblende andesites, pyroclasts and reworked andesitic volcanic sediments, with the emplacement of diorite porphyry and quartz diorite intrusions hosting the porphyry copper mineralization; (4) development of the central explosive caldera in the area of the third-stage volcanism, formation of dyke-pattern bodies and laccoliths within and around the caldera. Oligocene sandstone, clay and marl cover the area except the central, a few km^2 andesitic horst (Baksa et al., 1988; Gatter et al., 1999).

The Recsk mineralized complex consists of ore formations of different types genetically linked to each other. In the intrusive body, a typical porphyry Cu-Mo mineralization developed with little amount of gold. Along the exo- and endocontact with the Triassic limestone, skarn Cu-Zn-Pb-Fe mineralization was formed. In the Triassic limestone metasomatic and vein-type Zn-Pb ores occur. During the alteration of the intrusive body, slight silicification developed in the central part. Outward it is followed by a phyllic zone containing quartz-sericite-anhydrite assemblage. The surrounding propylitic zone (with albite, chlorite, epidote, anhydrite and calcite) is not continuous and overlaps with the endoskarn, containing diopside, amphibole and phlogopite. The exoskarn is fringed by a metasomatic zone in which the limestone recrystallized to marble (Csillag, 1975).

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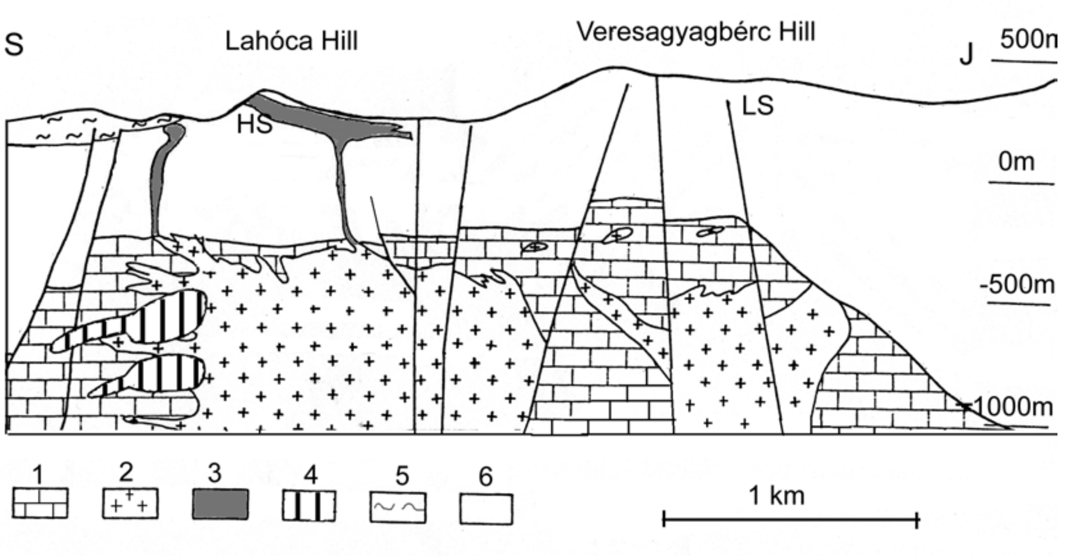

Fig.1. Schematic cross section of the Recsk mineralized complex. 1: Mesozoic basement, 2: mineralized copper porphyry, 3: HS epithermal mineralization, 4: skarn mineralization, 5: oligocene clastics, 6: Upper Eocene andesite and pyroclasts.

The porphyry Cu mineralization shows chalcopyrite-pyrite disseminations and stockworks. In the central parts molybdenite occurs in siliceous-anhydrite veins. In the skarn mineralization the basic Cu-bearing mineral is chalcopyrite accompanied by pyrite, pyrrhotite, magnetite and hematite at the deeper horizons. In the skarnous polymetallic deposit, sphalerite is essential, associated by pyrite, chalcopyrite, galena and magnetite. In the zones of the hydrothermal-metasomatic alterations the polymetallic ore deposits contain dominantly sphalerite, pyrite, galena and chalcopyrite (Csongrádi, 1975). The deep-seated ore was opened by two shafts at 900m and 1200m. These shafts were abandoned in 1999.

The deep-seated porphyry Cu deposit has spatial and probably genetic association with the epithermal Cu-Au deposits (Fig. 1). The epithermal mineralization appears on the surface at Parádfürdő and on the Lahóca Hill. At the Parádfürdő area the mineralization occurs in second-stage dacites and third-stage andesites and pyroclasts. The altered bodies are strongly silicified flat lenses and vein-like forms, surrounded by argillic alteration zones of kaolinite-alunite-pyrophyllite-smectite. A part of the lenses display a vuggy silica character. South of Parádfürdő polimict breccia dykes show K-metasomatic alteration, as an overprint, with adularia and sericite. The ore minerals are galena, sphalerite, less pyrite, Pb-Se- and Ag-Sb sulfosalts, fahlores and rare Au-Ag-Bi-Te-Sb minerals as disseminations and veinlets in the argillic zones; then tetrahedrite and less pyrite dissemination and veinlets in the siliceous bodies as a following phase. Younger, pyrite-rich dissemination occurs in the altered andesitic-dacitic rocks with minor complex sulfosalts. Gold appears both as tellurides and in native form (Nagy, 1983). Gold enrichment (1-10 g/t) is related to the adularia-bearing zones. According to the alteration mineral assemblages the Parádfürdő area can be considered as an early high-sulfidation deposit. As in the late veins cross-cutting breccia bodies adularia and calcite also occur, and galena and sphalerite are present, low-sulfidation activity must have overprinted the high sulfidation mineralization (Molnár and Gatter, 1997).

The Lahóca HS epithermal deposit

The Lahóca Hill includes three mineralization centers: (1) central brecciated zone, (2) northern brecciated zone, (3) Lejtakna breccia pipe. Brecciation could form in three ways. A part of the breccias are syngenetic tuff-breccias. The second type of brecciation was due to the intrusion of a subvolcanic andesitic body into the older stratovolcanic series (crackle and mosaic breccias in the apical part of the intrusion). The third - and youngest - type of brecciation is related to the hydrothermal vapor explosion, which affected both the stratovolcanic- and subvolcanic rocks (rotational and fluidized breccias).

There are several Au-ore bodies in the Lahóca system. The horizontal extent of the largest one that contains 95 % of the ore reserves is 500x900m. This flat, brecciated body slightly dips southward, its thickness varies between 30-100 meters. The gold content is higher near the top and decreases toward depth. Beside the central breccia zone, the Lejtakna "breccia pipe" and the northern breccia zone also show significant gold anomalies. The highest Au grade in the examined samples is 10.9 g/t (the formerly mentioned 180-300 g/t Au ore bodies

(Vitális, 1933) were exploited in the twenties). The reserves of the Lahóca and Lejtakna areas are 35.8 mt ore with 1.47 g/t average gold content, at 0.5 g/t cut-off (Földessy, 1997).

The Lahóca deposit can be considered as a typical high sulfidation epithermal system. The basic features show close similarities to the general characteristics of this type of deposits. These features can be assumed as follows (according to Földessy 1997, Gatter et al. 1999, Seres-Hartai & Földessy 2000):

- The host rock of the deposit is a part of a volcanic arc
- The mineralization is located above a diorite porphyry intrusion and related to an andesitic series.
- The main part of ore appears in brecciated rocks, multiply brecciation frequently occurs.
- The central mineralized core is characterized by pervasive silicification, "vuggy silica" is also present.
- Around the silicified parts advanced argillic alteration developed with kaolinite, dickite, pyrophyllite, alunite, illite and smectite. Propilitization occurs in the peripheral areas.
- Ore minerals are pyrite, enargite luzonite, native gold, complex sulfosalts, tetrahedrite; subordinately galenite and sphalerite.

Methods of studies

The basic aim of the study was to reveal the habitat and morphological and chemical characteristics of gold and the genetic interpretation of the examination results. The examined samples represent all the rock types in Lahóca that host the gold mineralization. 34 samples were collected from the following drillholes: R 368, R 370, R 371, R 372, R 377, R 378, R 390, R 396, R 404, R 408, R 416, R 417, R 421.

The microscopic characteristics were studied both in transmitted and reflected light by an AXIOLAB A-type polarization microscope with MC 80 DX camera.

The scanning electron microscopic and microprobe analysis was carried out by an AMRAY 1830 I scanning electron microscope with EDAX EDS detecting unit pv9700/36, (20 kV, SiLi detector, W cathod) at the Institute of Material Science, University of Miskolc. The analysis was done on the same thin sections that were subjected to the microscopic examinations.

The XRD analysis was carried out at the Hungarian Geological Institute, by P. Kovács-Pálffy. The instrument is a computer-controlled and evaluated Philips PW 1730 diffractometer, with Cu anticathode, 40 kV, 30 mA, graphite monochromator, goniometer-velocity 2º/min. The derivatograph examination also took place at the Hungarian Geological Institute by M. Földvári. The instrument is a computer-controlled and evaluated Derivatograph PC with simultaneous TG, DTG, and DTA appliances (ceramic and corundum pot, 10 Cº/min heating rate and Al_2O_3 inert material).

Complex chemical analysis was made at the Hungarian Geological Institute by A. Bartha. The AAS gold assay results were provided by ANALABS, Perth, Australia.

Rock alteration and mineralization

Rock types

According to the examination results, five rock types were distinguished in the Lahóca area, related to the gold mineralization: (1) stratovolcanic andesite and pyroclasts, (2) late (overlying) andesite and pyroclasts, (3) "blueschist", (4) subvolcanic andesite, (5) hydrothermal breccia:

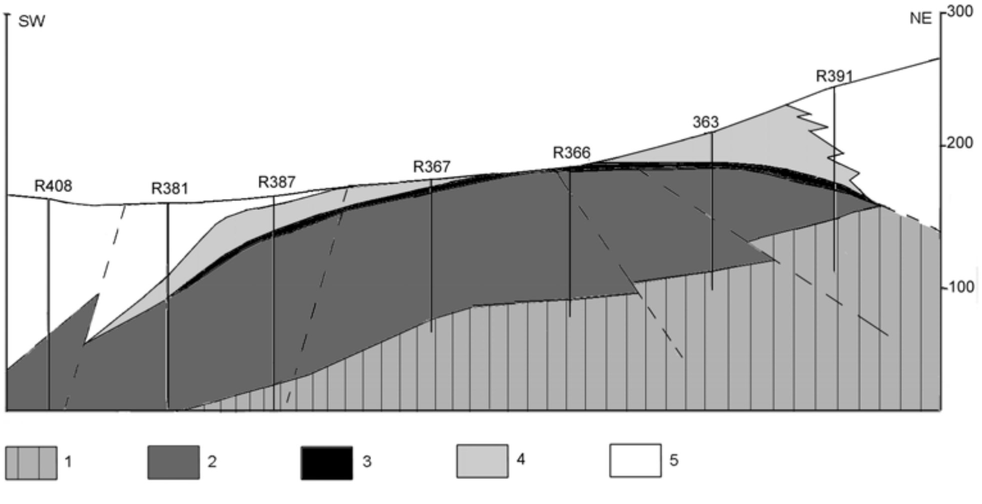

Fig.2. Section across Lahóca Hill showing the lithological units related to the gold mineralization. 1: subvolcanic andesite, 2: hydrothermal breccia and stratovolcanic andesite, 3: "blueschist", 4: late andesitic pyroclasts, 5: late andesite extrusives. Horizontal scale = vertical scale.

The genetic frame of these rock types is as follows (Földessy, 1997):

The stratovolcanic andesite and pyroclasts formed the oldest unit in the area. As a following event, the late andesite and pyroclasts extruded and overlaid the former stratovolcanic sequence. The formation of this unit started by pyroclasts. In the early phase the pyroclasts were deposited in subaquaous environment, and the "blueschist" (it was named after the dark, bluish-gray color of the clayey rock) was formed by the halmyrolytic decomposition of the volcanic fragments (Baksa, 1975). This rock occurs along the contact with the stratovolcanic series. Next, a subvolcanic andesitic body intruded the stratovolcanic sequence, and intrusive breccias formed in the apical part of the subvolcanic intrusion. Related to this event, hydrothermal explosions produced hydrothermal breccias both in the stratovolcanic sequence and in the subvolcanic andesite. The "blueschist" can be considered as the upper limit of the hydrothermal explosion as it formed an impermeable layer above the stratovolcanic and subvolcanic complex (Fig. 2). Gold mineralization appears in all rock types. Above the impermeable "blueschist", in the late andesite only a few, local ore veinlets could form as secondary enrichment.

Hydrothermal alteration

Except the late andesite, all the examined rock types are silicified (Fig. 3). Silicification is most intensive in the central part of the main ore body. The hydrothermal breccias frequently show multiply brecciation and multiply silicification. The first silicification displays colloidal or fine-grained quartz with slurred contours. The second and the following generations of quartz, which rim earlier, colloidal silica fragments or appear in form of younger fragments, have mosaic-patterned texture, with definite grain contours. Pyrite is more abundant in the matrix silica than in the following quartz generations.

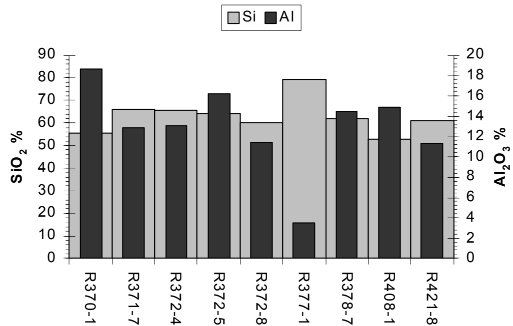

Fig.3. Relation of Si and Al, representing the grade of silicification in contrast with the argillic alteration. The sample R370-101m and R408-14m are unaltered late andesites, in which Al belongs to plagioclases. Sample R377-104 (hydrothermal breccia) shows the strongest silicification and the highest gold content.

Outward from the central part argillic alteration becomes dominant. It is special mainly in the pyroclastic rocks. The strongest argillization was observed in some parts of the blueschist. Montmorillonite in the blueschist is probably a result of the halmyrolytic decomposition, while dickite in the same rock was formed by hydrothermal alteration. The argillization displays a zonality: closer to the strongly silicified hydrothermal center dickite and kaolinite are dominant, outward they are followed by illite/montmorillonit-bearing zones (Table 1). In the stratovolcanic pyroclasts the argillized plagioclases are free of pyrite, while the matrix is frequently strongly pyritized. It can be generally stated that gold (and pyrite) content decreases with the increasing argillization.

Table.1. Results of the XRD analysis, Lahóca deposit. Analyst: P. Kovács-Pálffy, Hungarian Geological Institute. Amounts of minerals are given in percentage.

Rock type	**sample**	**mont.**	**ill/mm**	**illite**	**kaolinte**	**chlorite**	**quartz**	**K-feldspar**	**plagioclase**	**pyroxene**	**pyrite**	**gypsum**	**calcite**	**amorphous**
Late andesite	R408-14	-	16	-	-	6	27	9	9	7	20	1	2	3
Blueschist	R372-6.5	11	-	-	71*	-	-	-	-	-	15	-	-	3
	R417-34.1	-	18	3	23	-	27	-	10	-	16	1	-	2
Stratovolc. and+pyrocl.	R372-99	-	11	-	9	-	56	4	-	-	17	-	-	3
	R390-58	-	18	-	3	3	25	4	25	-	6	2	11	3
subvolcanic andesite	R368-103	-	-	2	23*	-	54	-	-	-	21	-	-	-
	R372-121	-	15	-	1	-	60	5	-	-	15	1	-	3
Hydrotherm. breccia	R372-16.5	-	19	-	9	-	48	8	-	-	11	-	-	4

*dickite

Calcite was found only in a few samples of the subvolcanic andesite and stratovolcanic tuffs, as replacement of porphyric minerals connected by fissures. It represents the latest, post-ore phase of alteration as it cuts enargite and is free of pyrite.

Ore minerals associated with gold

The main sulfide mineral is pyrite (about 95 % of ore minerals). The rest is mostly enargite and luzonite, subordinately galena, sphalerite, terahedrite and complex sulfosalts. According to the morphological characteristics three generations of pyrite can be distinguished: (1) 100-300 microns large, euhedral or corroded crystals; (2) fine dissemination in the silica matrix (2-20 microns); (3) collomorph, spherical or banded structures. Marcasite is even a later phase, following colloidal pyrite. Gold precipitation is related mostly to the second pyrite generation. Enargite and luzonite form 50-500 microns large subhedral to ahedral crystals. They occur as vein fillings, replacements of the porphyric minerals in the silicified andesites, or in breccia fragments. The matrix is free of enargite and luzonite.

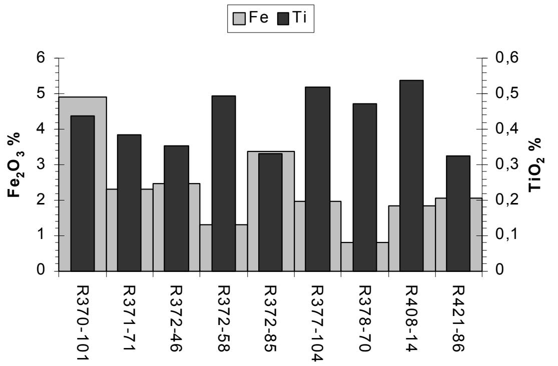

Fig.4. Fe-Ti relation indicating that Ti : Fe ratio becomes higher with the progressive mineralization. The ore-free R370-101m late andesite contains ilmenite. In the other samples Ti belongs mostly to rutile and Fe represents mostly pyrite.

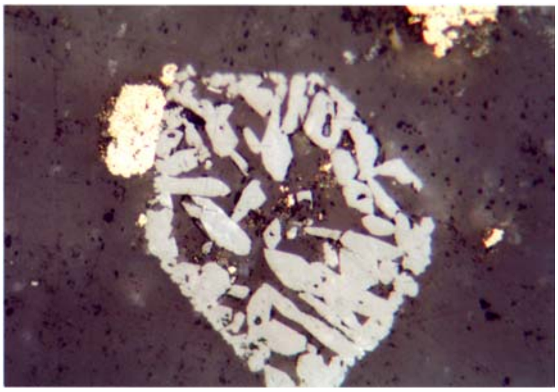

Fig.5. Prismatic and elongated rutile crystals after ilmenite, sub-hedral pyrite. Au: 10.9 g/t. R377-104m, hydrothermal breccia. Reflected light, 1N.

Rutile is a relatively frequent mineral. It formed by the decomposition of Ti-rich accessory minerals (ilmenite) or amphiboles. It reflects the rate of alteration. The unaltered late andesite is free of rutile, but contains ilmenite crystals. On the other hand, the altered rocks display extremely fine, dispersed rutile in the silica matrix and concentrated rutile crystals after ilmenite or amphibole. In the latter case euhedral pyrite crystals often rim the rutile-cluster. These pyrites probably utilized Fe produced by the decomposition of the original crystals. During the hydrothermal processes, the multiply leaching and mineralization could have contributed to the enrichment of titanium (Fig. 4). This is also reflected by the fact that the highest Au-grade samples contain the largest, well-developed rutile crystals (Fig. 5), and are usually more abundant in Ti, although the correlation between Au and Ti is not always definite (Fig. 6).

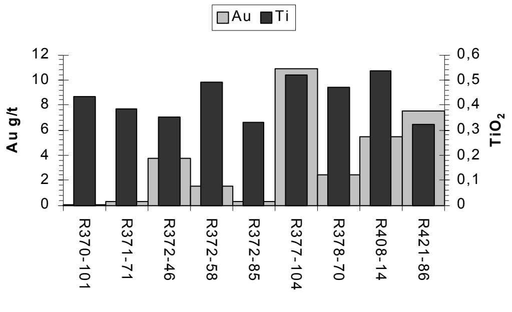

Fig.6. Relation of Au and Ti indicating that the higher-Au-grade samples are more abundant in rutile. Sample R371-101m is unaltered, late andesite, in which Ti belongs to ilmenite. R377-104m hydrothermal breccia contains the largest, well-developed rutile crystals.

Mineralogy and genetic aspects of gold

The gold is concentrated in the highly silicified zones. Gold enrichment is the highest along the contact with the blueshist. In the argillic alteration zones the gold content is 0.1-0.2 g/t. The average silver content is quite low, merely 1-5 g/t.

In the examined Lahóca area gold is present in all rock types. Even in the samples with low Au grade it could be examined by electron microscope. It occurs in native form, in high fineness. In a few cases, a very little amount of tellurium was detected in gold grains. The native gold appears both related to pyrite and in the silicified matrix, as “free” gold.

The "free" gold in the silicified matrix occurs in form of 10-30 microns large aggregates (Fig. 7, 8) or cloud-like structures (Fig. 9). It always appears in silicified environment, either in the strongly silicifed, glassy matrix of the volcanic rocks or in the breccia matrix.

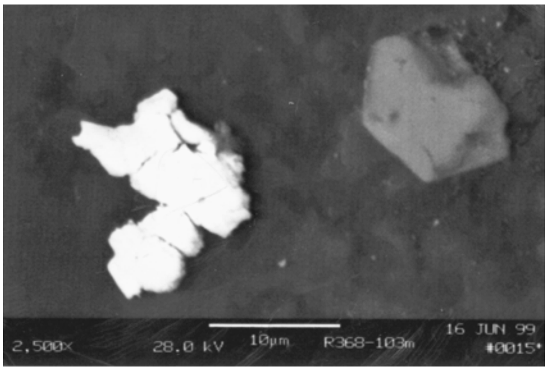

Fig.7. Native gold with aggregate-like structure (white) and euhedral, second-generation pyrite (gray) in silicified matrix. Au: 0.237 g/t. R368-103m, subvolcanic andesite. BSE image.

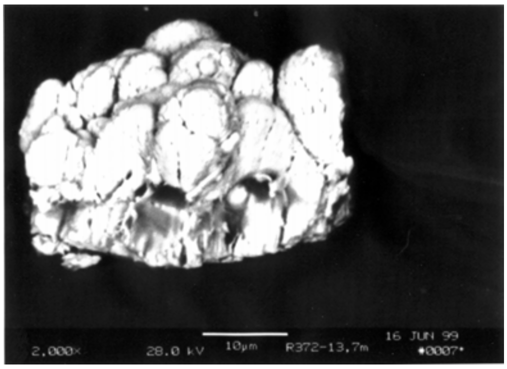

Fig.8. Native gold with aggregate-like structure in silicifed matrix. Au: 2.33 g/t. R372-13.5m, hydrothermal breccia. BSE image.

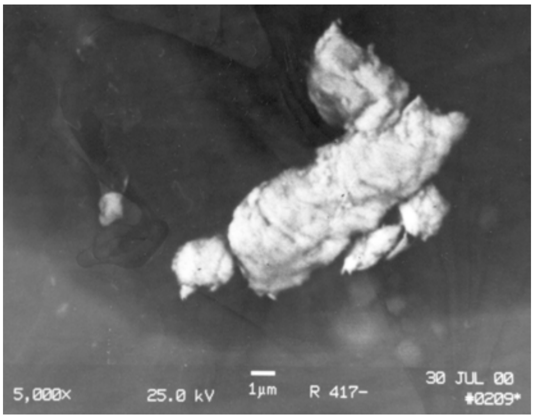

Fig.9. Native gold with cloud-like structure in silicified matrix. Au: 4.14 g/t. R417-68m, stratovolcanic andesite. BSE image.

The pyrite-related gold is more frequent, but these gold grains are smaller than those in the silicified matrix. Their average size is a few microns. It is the second-generation pyrite that is mostly associated with gold (Fig. 10, 11). These pyrites are euhedral-subhedral crystals, a few microns to 20 microns across, and form dissemination in the breccia matrix or in the silicified rocks. The larger, corroded, first-generation pyrite that also occurs in breccia fragments is usually free of gold. Similarly, the third-generation collomorph pyrite and the marcasite are not associated with pyrite. Gold was not found in- or related to enargite, luzonite or any other ore minerals.

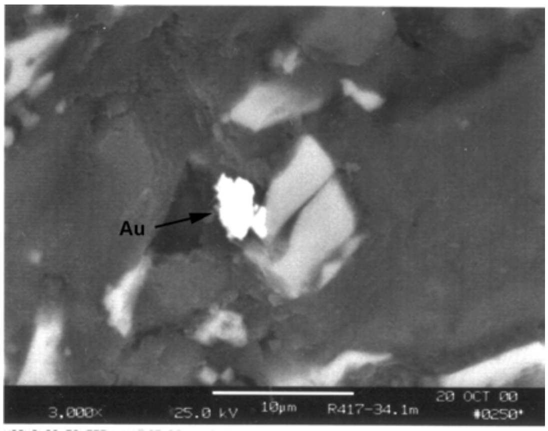

Fig.10. Irregular native gold grown to the edge of a second-generation, subhedral pyrite crystal in the silicified matrix. Au:4.79 g/t. R417-34.1m, blueschist. BSE image.

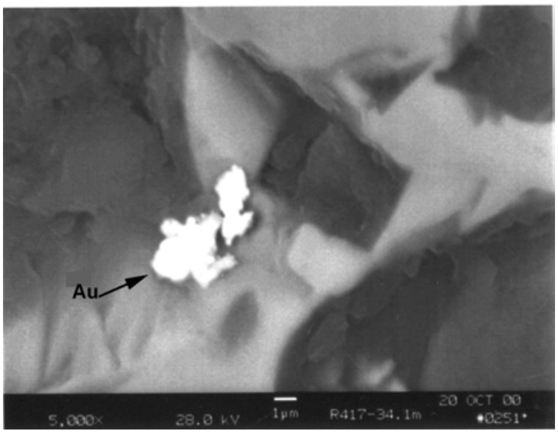

Fig.11. Irregular gold grains on pyrite. Au: 4.79 g/t. R417-34.1m, blueschist. BSE image.

Opposite to the former descriptions, the native gold never occurs as inclusions in pyrite. It inevitably shows affinity to pyrite, but always grows on the crystals, either in small cavities or attached to any part of the pyrites, indicating a separate mineralization phase (Fig. 12, 13).

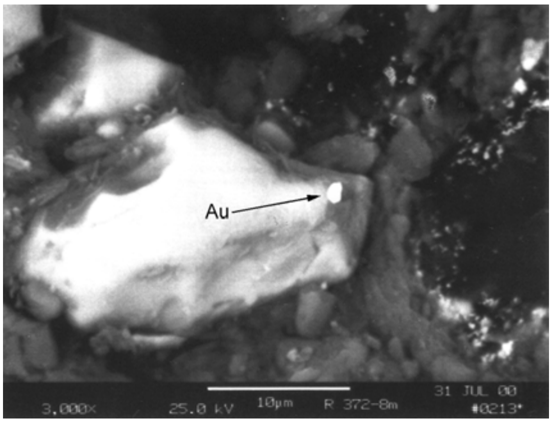

Fig.12. Native gold on pyrite, silicified matrix. Au: 1.57 g/t. R372-8m, blueschist. BSE image.

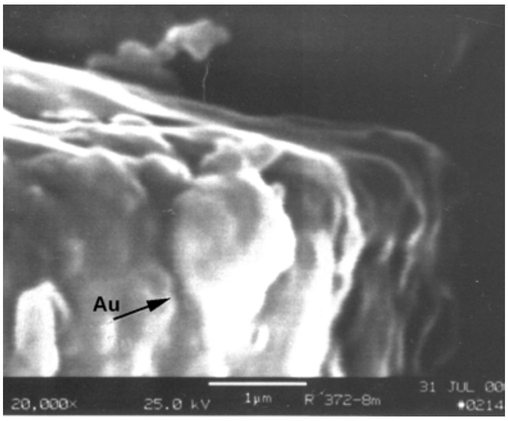

Fig.13. SEM morphological image of the native gold grain visible in Pict. 12 indicating that native gold grow on the surface of the pyrite. Au: 1.57 g/t. R372-8m, blueschist.

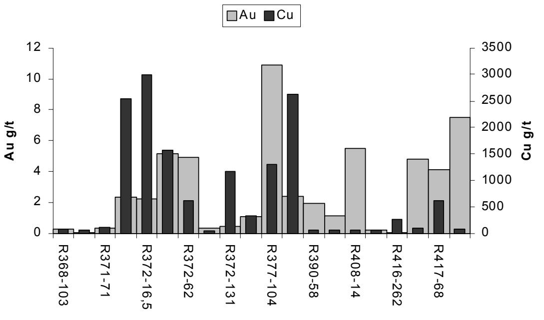

Fig.14. Relation of the Cu and Au content in the examined samples showing no correlation between the two elements.

The Lahóca deposit that was mined for its copper proved to have a significant gold mineralization as well. The formation of the Cu-As and Au ores took place in different stages, and there is no correlation between the Cu and Au content (Fig. 14). According to the textural characteristics of the examined rocks and minerals, considering the paragenetic sequence and the development of hydrothermal fluids the followings can be summarized:

In the early phase of the Lahóca HS mineralization the fluids had strongly acid character that is represented by the advanced argillic alteration and the formation of enargite and luzonite. Probably a slight increase in the pH of fluids resulted the formation of first-generation pyrite and the free gold in the matrix. These pyrites are corroded by the later mineralization phases. Explosive brecciation followed the formation of enargite, luzonite and first-generation pyrite. The second-generation pyrite occurs mainly in the breccia matrix. Shortly after the second-generation pyrite, the main gold mineralization took place. The correlation between pyrite and gold content is definite. These pyrites promoted the formation of gold providing a surface for the precipitation. By the formation of the third-generation pyrite and the marcasite the fluids lost their gold content. The thin, ore-bearing veinlets in the late andesite were produced by the secondary mobilization of the gold in the main ore body.

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