IMPLICATIONS RESULTING FROM THE STUDY OF FLUID INCLUSIONS IN THE SHEAR ZONE-TYPE GOLD MINERALIZATION FROM BOZOVICI (BANAT) AND SOMEȘUL RECE (GILĂ U MOUNTAINS)¹

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In memoriam Prof. Valeriu Lucca

ABSTRACT. The paper presents the results of a study on fluid inclusions (petrography, chemistry, Th, Td) from the gold-containing quartz in the shear zone – type mineralizations from Bozovici (Banat) and Someșul Rece (Gilă u Mountains). Four types of fluid inclusions were identified: **A** – aqueous, **AS** – aqueous with efflorescences and crystals of nahcolite, **C** – monophasic and biphasic containing CO₂, and **AC** – aqueous solutions with CO₂. Microthermometry (Th and Td) indicated homogenisation temperatures of nahcolite between 136-260⁰ C, total homogenisation temperatures of 283-390⁰ C, and a maximum temperature (Td) between 380-420⁰ C. The molar content of the CO₂/H₂O ratio varies between 0.35 – 0.72; salinity ranges between 2 – 14 wt % equivalent. Gold is intimately disseminated in quartz (in both studied occurrences), but also it is associated with sulphides, especially pyrite (Bozovici) and chalcopyrite (Someșul Rece).

Key words: fluid inclusions, shear zones, nahcolite crystals, Th, Td, molar ratios CO₂/H₂O, wt % salinity.

Recently, shear zone-type gold mineralizations associated to metamorphic complexes in the Carpathians of Romania were also studied for their fluid inclusion content. The main goals were to establish the formation temperatures (Întorsureanu et al., 1985), the erosional level of the gold-containing ore bodies (Popescu and Sava, 1994) and the chemistry of the inclusions (Popescu and Predeteanu, 1999; Predeteanu and Popescu, 2000) etc. Among the numerous gold occurrences genetically associated to shear zones structures from the crystalline terrains from the Romanian Carpathians, our study referred only to the ones from Bozovici (Banat) and Someșul Rece (Gilă u Mountains). The paper brings new results concerning geothermometry, without going into the general geological and petrographical aspects of the studied areas, previously presented elsewhere.

¹ Presentation on the occasion of the Anniversary Symposium "Prof. Valeriu Lucca (1901-1969) – 100 years from his birth", 1-2 June 2001, Cluj-Napoca.

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1. The gold-containing mineralization from Slă tinic (Bozovici, Banat).

The gold-containing quartz from Slă tinic Valley (an affluent of Miniș Valley) was first identified in 1922, due to the discovery of a gold-containing quartz block in the Badenian conglomerates outcropping in the region, overlaying crystalline schists (amphibolite, amphibole schist). As a consequence, intensive-prospecting activity started, followed by exploration with mine works located upstream from the confluence of Slă tinic Valley with Miniș Valley (performed by "Mica" Society from Brad). Lucca (1949)⁴ presented a brief description of the mineralization in a geological report, together with a sketch of the mining works showing the lens-shape of the ore associated to the metamorphic schists. The previously mentioned geological report contains also several profiles that illustrate the underground situation. One year later (Lucca, 1950)⁵ the same group of authors proposed that the mining activity should be stopped based on the facts that the mineralised body presented significant discontinuities in the depth and the contents of gold and silver were considered not worthy economically.

The gold mineralization under discussion consists of massive quartz incorporating fine disseminated particles of gold and sulphides; accidentally small calcite geodes were also noticed. Macroscopically, three types of quartz were separated (Întorsureanu et al., 1985):

- white-yellowish quartz with greenish tint (containing gold particles);
- grey-greenish brecciated quartz accompanied by secondary minerals formed along the fissures (chlorite, carbonates, neoformed quartz etc.; gold is present as disseminations);
- white-milky quartz (lacking gold particles).

The gold included in the first two types of quartz is present as fine grains (0.072 - 0.120 mm in size; Pl. III, fig. 1). The white-milky quartz is a metamorphic segregated type of a late generation, that explain the lack of gold. Pyrite occurs sporadically as fine micrometric grains often oxidised (limonite), while chalcopyrite is partly substituted by chalcocite; galena and sphalerite occur only accidentally.

2. The gold-containing mineralization from Someșul Rece (Gilău Mountains)

This occurrence consists of lenses of gold-containing quartz located in the Mieilor Hill, Bă ilor Creek and Seacă Valley areas, that are congruent effluents of Someșul Rece Valley (aligned along a tectonic plane), upstream

⁴ V. Lucca (1949). Raport geologic minier asupra regiunii Bozovici (12 p, 5 schiț e). Arhiv. Naț ion. Deva.

⁵ V. Lucca, Giurgiu C., Haida H., Patriciu V., Belecan G., Kelemen Ș. (1950). Proces verbal asupra lucră rilor din reg. Bozovici (Banat) (fost în Arhiv. Intr. Min. Barza, Brad).

from Someșul Rece village (Pl. I, fig. 1)⁶. From a geological point of view, the Biharia metabasite Series with local dolomitic sequences tectonically overlaying a retromorphous term (mica schistes with garnets) of the Someș Series, probably Someș lithogrupe, is worth to mention; this represents the tectonic setting from Someșul Rece, that concentrated the shear zone – type gold mineralizations. The dolomitic sequences is most probably of a reef – type. The presence of the quartz veins in the dolomite is the result of the tectono – metamorphic mobilization of silica (SiO₂) (Pl. II, fig. 1).

The exploration and mining works were realised during a short interval in the first half of the XIX century and subsequently in several stages (Pl. I, fig. 2). The most recent mining activity was conducted by TRANSGEX – Cluj. The gold mineralization consists of lenses of quartz located in a complex of metamorphic rocks (quartzitic-feldspatic-sericitic schists (Cobârzan and Căpraș, 1997), or in porphyroids and their associated epimetamorphic rocks (Mârza, 1999). The bodies of gold-containing quartz are sometimes aligned parallel or other times discordant to the foliation of the host rock, and they can be isolated or continuous. The length of the continuous vein-like areas varies from several meters to tens of meters, rarely reaching 100 m, while the thickness never exceeds 2.5 m. Within the quartz crystals, gold lamellae (exceptionally visible by naked eye), and sulphides (pyrite, chalcopyrite, sphalerite, galena, tetrahedrite, chalcocite, covellite etc.) are disseminated. Sporadically siderite is also present. Locally, concentrations of sulphides are accompanied by larger amounts of gold.

Genetically, the mineralizations from Someșul Rece were attributed to: older granitic sources (Lucca, 1936), banatites (Hesselman, 1967)⁷, post-banatitic hydrothermalism (Mureșan, 1980), and more recently to the **shear zones - type** (Udubașa and Hann, 1988; Dimitrescu and Mihaela Dimitrescu, 1995; Mârza, 1999).

Fluid inclusions

The samples that were investigated for their fluid inclusion content from both areas were collected from old, but still accessible mines, from waste dumps, from drill cores and from outcrops. Taking into account the similarities between the parameters of the fluid inclusions (petrography, homogenisation temperature, Th, and decrepitation temperature, Td, chemistry) and the conclusions that can be drawn accordingly, below a common presentation is given. However, the specific features will be emphasized.

Four types of fluid inclusions were identified in the studied materials, distinguished by shape, degree of filling of the vacuoles, and phase composition:

⁶ Photos in the field were realized by Lecturer dr. Călin Tămaș (Plates I, II), whom we express our acknowledgments.

⁷ Hesselman A. (1967). Raport geologic asupra lucrărilor cu caracter de prospectivare și referință, executate de ISEM în perioada anilor 1961-1962 în sectoarele: V. Bedeci și Someșul Rece, regiunea Cluj. Arhiv. IGG București.

- A-type consists of biphasic (L+V) aqueous inclusions represented by negative, irregular crystal shapes (Pl. III, figs. 2 and 3);
- AS-type is represented by aqueous (L+V) solution, and efflorescences and aggregates of daughter minerals with a reduced birefringence;
- AC-type, the most frequent one in the gold-containing quartz in both areas; it corresponds to the aqueous solutions of CO₂ (Pl. III, fig. 4 and Pl. IV, figs. 1 and 2). In comparison, an AC-type inclusion in quartz from Tincova, Banat is presented (Pl. IV, fig. 3);
- C-type contains mono- and biphasic fluid inclusions of CO₂ (liquid + vapours) (fig. 1).

Microthermometric data

The C-type inclusions are characterised by homogenisation temperatures (Th) in liquid phase between 18° and 29° C, below the critical value of CO₂ (fig. 1A). For the A-type inclusions temperatures between 90° and 200° C are common, while to AS-type corresponds the range 125° - 250° C. The efflorescences and particles of birefringent **daughter minerals**, are homogenised in liquid phase between 135° and 260° C. AC-type, that characterizes the aqueous CO₂ solutions, shows two distinctive Th intervals: one corresponding to the transformation of CO₂ (gas) into CO₂ (liquid), between 18 – 26° C, and a second one between 283 – 332° C, with a maximum between 300 – 310° C indicating the total homogenisation temperature. (fig. 1 B). The latter values correspond to the transformation of liquid CO₂ into aqueous solution, or to that of aqueous solution into liquid CO₂.

A histogram built on the basis of 95 Th measurements of the AC-type fluid inclusions in the gold-containing quartz from Someşul Rece, indicating the limits and the maximum temperature frequency is presented in fig. 2. Taking into account the abundance of CO₂ in the inclusions one can plead for the gold precipitation from hydrothermal-metamorphic solutions at high pressures and at depth below 5 km. After applying a correction of 17° C/ km according to the thermal gradient (30° C/ km, Savul and Pomârleanu, 1960) the maximum frequency of Th (305 – 310° C) corresponds to the interval between 380 – 390° C. This interval is within the range of temperatures calculated for the metamorphic processes for the sericitic schists of Arada Series (Borcoş and Dimitrescu, 1969).

The intervals corresponding to the decrepitation temperatures (Td) of the fluid inclusions in the first two gold-containing quartz types from Slătină (Bozovici) are represented in the decrepitolgrams (fig. 3). The maximum temperature frequency ranging between 380° and 420° C is close to the values calculated by taking into account the thermal gradient (30° C/km).

Th values for the CO₂-containing inclusions lower than the critical value of CO₂ are due to the presence of CH₄ with T_c = - 83° C and of N₂ with T_c = 147° C, as components easily miscible with CO₂.

A specific feature concerning the chemical composition of the fluid inclusions is represented by the CO₂/HO₂ ratio, ranging between 0.50 and

0.772 for the samples from Slătinic, and between 0.35 and 0.70 for Someșul Rece samples (analysed by using gas chromatography). The molar CO_2/HO_2 ratio in the inclusions from Slătinic samples as compared to that from Someșul Rece samples is also determined by the higher volume of CO_2 .

Fig. 1. **A** - The behaviour of a fluid inclusion of C-type: **a**, at + 19⁰ C and **b**, at + 29⁰ C; **B** – behaviour of an inclusion of a AC-type: at + 19⁰ C three phases can be distinguished - CO₂ vapours (G) + liquid CO₂ (L₁) + aqueous solution (L₂), while at 25⁰ C the triphasic environment turns into a biphasic one.

Fig. 2. Th histogram of the AC-type inclusions in the gold-containing quartz from Someșul Rece.

Fig. 3. Decrepitograms of the gold-containing quartz from Slătinic (Bozovici): **A** – grey-greenish quartz (waste dump), **B** – white-yellowish quartz (vein).

The presence of efflorescences and highly birefringent microcrystals (daughter minerals) in the A and AS-type inclusions, as well as their dissolution in the temperature range 135 – 260° C prove the presence of nahcolithe in these inclusions, as daughter mineral; Samson et al. (1977) identified it in similar mineralizations.

The microthermometric measurements performed at high temperatures and at freezing temperature evidenced specific correlations between Th, Te, and Tm and a variable salinity (2 – 14 wt % NaCl equivalent). The specific parameters obtained from the inclusions in the gold-containing quartz from Slătinic (Bozovici) and Someșul Rece (Gilău) are presented in table 1.

Table 1.

The type, origin, and the specific values of Th and Td for the fluid inclusions in the gold-containing quartz from Slă tnic (Bozovici) and Someșul Rece (Gilă u)

Category	Type	Phases	Origin	Temperature °C	
				Th*	Td
Aqueous	A	L + V*	s	90 - 200	300 - 460
	AS	L+V+nahcolithe**, rarely birefringent crystals	p+s	125-250	300-460
Bicarbonate aqueous	AC	Triphasic, aqueous bicarbonate	p+s	283-332	380-420
Bicarbonate	C	Mono- and biphasic, bicarbonate	p	18 - 28	380-420

* L – liquid, V – vapours; p – primary, s – secondary; Th – homogenisation temperature, Td – decrepitation temperature;

** nahcolithe crystals are dissolved between 140 – 260° C

Conclusions

- Petrographically, the lens-shaped, vein-like body from Slă tnic is located in amphibolites and amphibolite schists corresponding to metabasites (Intorsureanu et al., 1988), while the gold-containing quartz lenses from Someșul Rece are spatially associated mainly to the porphyroids and metabasites of the Biharia or Codru series. Thus, there are similitudes concerning the metamorphic petrometallogeny of the two occurrences.

- Based on the shape, content, origin and geothermometric parameters etc., the studied fluid inclusions of the two occurrences are similar; the specific difference consists in a higher frequency of the CO₂ inclusions, higher values for the molar CO₂/HO₂ ratio and other volatile components such as CH₄, N₂ etc.; the microcrystals (daughter minerals) from the fluid inclusions correspond mineralogically to nahcolithe (NaHCO₃).

-The maximum temperature of formation of gold and the hydrothermal-metamorphic-metallic assemblage in general was determined to be above 350° C.

- Starting from these results, other shear zones enriched in gold and silver might be identified and delimited in the metamorphic terrains of the Romanian Carpathians. This would involve the common research of experts in various fields of geosciences (tectonics, geophysics, petrography, metallogeny, geochemistry, geothermometry etc.)⁸.

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⁸ We express our special thanks to Dr. Dana Pop for the English version of this paper.

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PI. I.

Fig. 1. Mieilor Hill (left side of Someșului Rece river) with the outcrop of dolomites included in Biharia Series.

Fig. 2. Exploration mine in Mieilor Hill.

PI. II.

Fig. 1. Dolomite (Biharia Series) crossed by a dense network of quartz veins.

Fig. 2. Microbended porphyroid rocks (Biharia Series, left side of Someșului Rece river).

PI. III.

Fig. 1. Gold included in quartz (Slătinic, Bozovici; Intorsureanu et al., 1985); N II; 180 x.

Fig. 2. Fluid inclusions of A-type in the gold-containing quartz from Someșul Rece.

Fig. 3. Fluid inclusions of A-type (L+V) in the gold-containing quartz from Slătinic (Bozovici).

Fig. 4 Fluid inclusions of AC-type in the gold-containing quartz from Slătinic (Bozovici).

PI. IV.

Fluid inclusions of AC-type: from Valea Seacă (Someșul Rece, fig. 1, 2) and from Tincova (Banat, fig. 3; for comparison), where CO₂ dominates and a fine pellicle of aqueous solution is also present.

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Pl. I

Pl. II

Pl. III

Pl. IV