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# NEW GEOLOGICAL DATA ON ORLEA MINING FIELD, ROŞIA MONTANĂ AU-AG EPITHERMAL DEPOSIT, APUSENI MOUNTAINS, ROMANIA

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**Abstract:** New geological data on the Orlea mining field, Roșia Montană ore deposit, Romania were obtained by fieldwork carried out in the underground level +730 m, where three types of mineralized structures hosted by the Vent Breccia formation were studied, i.e., (*i*) flatly dipping vein with rhodochrosite gangue, (*ii*) steeply dipping tectonic breccia dyke, and (*iii*) steeply dipping base metal vein, respectively. The Vent Breccia is a polymictic matrix-supported breccia with sedimentary (clay, sandstone), volcanic (dacite), and metamorphic (quartzite, garnet micaschist) clasts. Four types of hydrothermal alterations were identified, i.e., (*i*) K-metasomatosis (adularia I); (*ii*) phyllic alteration (sericite); (*iii*) silicification; and (*iv*) potassic alteration (adularia II). The ore mineral assemblage consists of electrum, pyrite, chalcopyrite, sphalerite, galena, and minor arsenopyrite and pyrrhotite. The higher-grade ore body is the intermediate-sulfidation flatly dipping vein with rhodochrosite gangue grading up to 101g/t Au. The tectonic breccia dyke is a low-sulfidation ore body illustrating the evolution from early banded vein structure to late/final open-space clast supported tectonic breccia dyke.

**Keywords**: tectonic breccia, intermediate-sulfidation, low-sulfidation, Roșia Montană

## 1. INTRODUCTION

Roșia Montană is the largest European Au deposit with over 400 Mt identified resources at 1.3 g/t Au and 6 g/t Ag (Manske et al., 2006) being situated in the Golden Quadrilateral within the Apuseni Mountains, which is the most important gold-mining region in Romania. Roșia Montană is Au-Ag low- to intermediate-sulfidation maar-diatreme breccia hosted deposit with disseminated mineralization, veins, and hydrothermal breccia ore bodies (Leary et al., 2004, Manske et al., 2006, Tămaş, 2010).

The ore deposit consists of several ore fields, *i.e.*, Cetate, Cârnicel and Cârnic in the south; Coș, and Văidoaia in the east; and Jig, Țarina, Orlea and Păru-Carpeni in the north (Fig. 1a). The present contribution is focused on the Orlea mining field, +730 m level (Fig. 1b).

In June 2006 the open pit operations carried out in Roșia Montană by the Romanian state mining company MINVEST Deva were closed. However, S.C. Roșia Montană Gold Corporation S.A., a joint venture between Gabriel Resources Ltd. (Canada) and MINVEST Deva owns since 1999 a mining license for the same perimeter.

The Roșia Montană Gold Corporation's exploration drilling program, surface and underground geological mapping in the Orlea mining field revealed economic mineralizations, and accordingly the Company planned an open pit operation in that part of the deposit based on measured and indicated resources of about 55 Mt at 1.14 g/t Au and 2 g/t Ag and metal reserves of over 2 Moz Au and 3.8 Moz Ag (Armitage, 2012).

The previous studies on the Orlea mining field belong to Petrulian (1934), which investigated several samples from the underground level +714 m, also known as *Sfânta Cruce din Orlea*. More recently, Iatan & Bilal (2016) made optical microscopy, SEM, and EPMA investigations on 50 samples from the Orlea mining field and described three types of Au-Ag alloy.

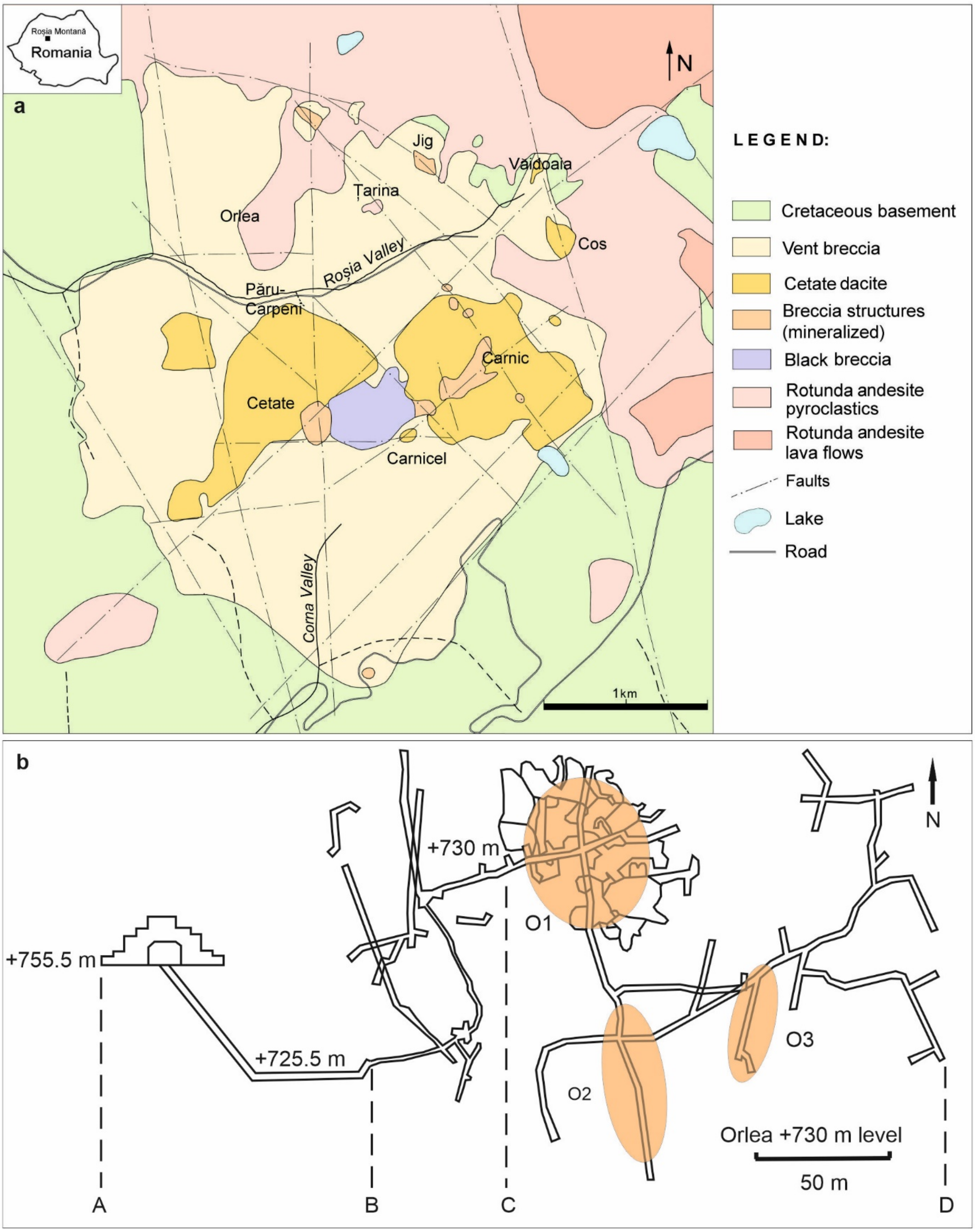


Figure 1. Geology and example of mining developments in Roșia Montană. a) The geology map of Roșia Montană ore deposit (RMGC courtesy, with changes from Tămaș et al., 2014); b) simplified map of the underground mining works of +730 level, Orlea mining field, including the access from the surface (RMGC courtesy) with A-B: schematic and not to scale vertical cross-section of the modern workings that allow the access from the surface (Benea & Tămaș 2010); B-C: plan view of the Roman Adits Museum; C-D: plan view of the +730 level, Orlea with the location of the sampling areas - the shaded zones (Drăgușanu 2017, with changes).

## 2. GEOLOGICAL SETTING

The Roșia Montană ore deposit belongs to the Transylvanides (South Apuseni Mountains - SAM), which together with the Apusenides (North Apuseni Mountains - NAM) constitute from tectonic point of view the Apuseni Mountains (Săndulescu, 1984; Balintoni, 1994, 1997; Dallmeyer et al., 1999, Pană et al., 2002). The Transylvanides consist of pre-Palaeozoic/Palaeozoic metamorphic basement covered by Middle Jurassic ophiolitic complex, Upper Jurassic-Lower Cretaceous Island arc volcanic rocks, Jurassic and Cretaceous sedimentary rocks, Upper Cretaceous-Paleogene magmatic rocks, and Neogene volcanics (Săndulescu, 1984).

The Neogene volcanism in the South Apuseni Mountains was active between 14.8 Ma and 7.4 Ma, with the final pulse at 1.6 Ma (Roșu et al., 2004). The volcanic activity occurs as two spots in the northern and the southern edge of SAM at Baia de Arieș and Deva, respectively, and is largely developed along three extensional alignments known as *i*) Săcărâmb-Brad-Zarand, ii) Zlatna-Stănija, and iii) Bucium-Roșia Montană volcanic districts/basins (Ghițulescu & Socolescu, 1941; Borcoș et al., 1984). The Neogene volcanism controlled the formation of porphyry Cu-Au/Au-Cu deposits (Roșia Poieni, Deva, Bolcana, etc.), epithermal deposits, *e.g.* high-sulfidation (Pârâul lui Avram, Larga - Horia level), intermediate-sulfidation (Breaza, Fața Băii, etc.), low-sulfidation (Brădișor, Rodu, etc.), carbonate replacement (Baia de Arieș - Ambru), sediment hosted (Hărăcăi), and transitional intermediate-sulfidation to Carlin type (Certej). The Roșia Montană Au-Ag ore deposit is located in the north-eastern part of the Golden Quadrilateral at approximately 2 km west-south-west of Roșia Poieni open pit.

## 3. SAMPLES AND METHODS

The present study is based on fieldwork carried out in mining works from the underground level +730 m, Orlea mining field. The access in the underground was possible by the inclined plane allowing easy access to the Roman Adits Museum. The fieldwork focuses on three ore bodies identified during the preliminary underground exploration and labeled O1 to O3 (Fig. 1b). A number of 145 samples were collected for further investigations. Thin and polished sections were used to study the host rocks, the hydrothermal alterations, and ore minerals assemblages. Gold grade analyses were carried out at ALS Global, Gura Roșiei, Alba County, Romania. The commercially analytical method used is labelled *Au-AA26* and provides the Au grade by fire assay and atomic absorption on 50 g nominal sample, with the range of the detection limit from 0.01 to 100.0 ppm. One overrange value was measured using the analytical method labeled *Au-GRA22*, which provides the Au grade by fire assay and gravimetric finish on 50 g nominal sample, with the detection limit ranging from 0.05 to 10,000 ppm.

## 4. RESULTS

The Orlea mining field is entirely located within the Roșia Montană diatreme/Vent Breccia formation (Leary et al., 2004; Tămaș, 2010). At the surface, this unit is partially covered by Rotunda-type andesite lava flows and pyroclastics (Fig. 1a).

### 4.1. Host rock: diatreme/vent breccia

The vent breccia is bedded and is built up of coarse and fine-grained sequences showing normal and reverse grading (Fig. 2a). The individual sequences are usually cm-sized thick; however, thicker sequences measuring tens of centimeters also occur. Post-depositional faulting, plastic deformation, and bomb sag structures (Fig. 2b) were also observed within the vent breccia.

The vent breccia in the Orlea mining field shows a large textural variation according to the clasts and the matrix composition, and the relative proportion of these two components. Additionally, the flow of the hydrothermal fluids through this breccia unit contributed to the formation of the alteration minerals by replacement of the primary minerals (e.g. feldspars) and by deposition from the fluids as filling within the available open spaces (quartz, adularia, pyrite, etc.). The clasts show a great lithology variability, *i.e.* Cretaceous sedimentary rocks (sandstones and shales), volcanic rocks (dacite), metamorphic rocks (quartzite, garnet micaschist), and breccia fragments formed during previous brecciation events. Additionally, crystal fragments, e.g. magmatic quartz and feldspar phenocrysts from the dacite also occur in the matrix of the vent breccia. The dimension of the clasts ranges in size from millimeters to several centimeters. The shape of the rock fragments ranges from angular to rounded. The vent breccia has a rock-flour matrix formed by comminuted country rocks, e.g., dacite, shales, sandstones. Overall, the vent breccia from the Orlea mining field is matrix-supported, however, clast-supported breccias locally exist.

The macroscopic observations in the field and the slices cut from representative samples revealed several varieties of vent breccia in respect to their fresh/altered state and the clast composition:

- *i)* fresh/unaltered polymictic matrix-supported breccia (Fig. 2c, d);
- *ii)* silicified polymictic matrix-supported breccia (Fig. 2e);
- *iii)* fresh polymictic matrix-supported breccia with fresh breccia clasts (Fig. 2f);
- *iv)* fresh polymictic matrix-supported breccia with silicified breccia clasts (Fig. 2g);

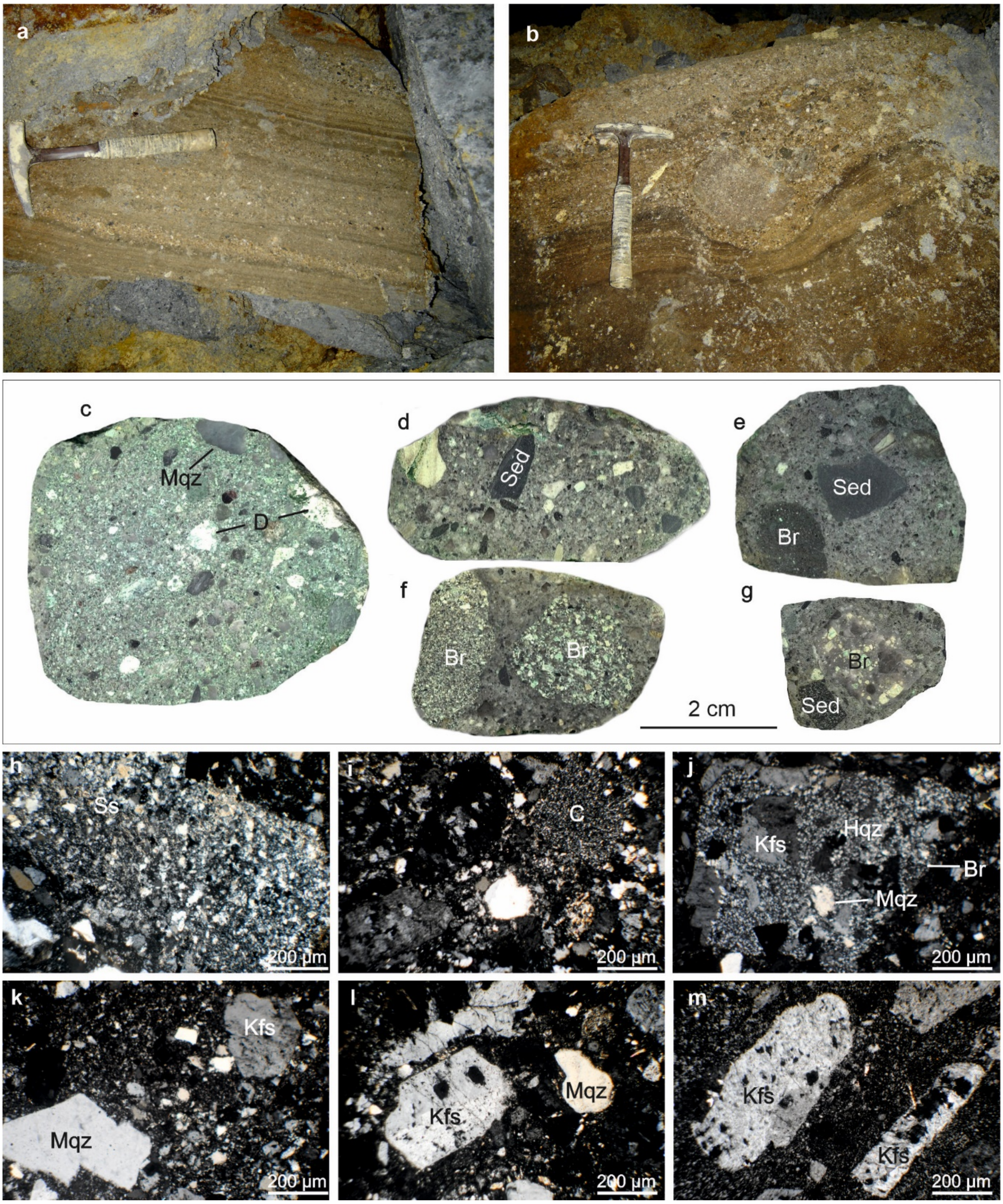

Figure 2. Vent breccia from Orlea mining field, illustrated by macroscopic views in the underground (a-b), polished slabs (c-g), and microphotographs in plane-polarized transmitted light (h-m). The brown color of the vent breccia in (a) and (b) is due to surficial oxidation of the walls of the mining works that masks the grayish to bluish-gray true color of the breccia. a) Bedded vent breccia with fine-grained and medium-grained thin sequences; b) bomb sag structure formed by a rounded vent breccia fragment that landed on wet vent breccia (underwater) and deformed it at the impact; c) and d) fresh polymictic matrix-supported breccia with dacite clasts (whitish clasts) and magmatic quartz crystals; e) silicified polymictic matrix-supported breccia with sedimentary clasts; f) fresh polymictic matrix-supported breccia with fresh breccia clasts; g) fresh polymictic matrix-supported breccia with sedimentary clasts and silicified breccia clasts; h) sub-rounded sandstone clast; i) claystone clast; j) breccia clast with feldspar phenocryst fragments, affected by potassic alteration, and magmatic quartz phenocrysts held together by silicified matrix; k) angular magmatic quartz crystal fragment; l) K-alteration on feldspar phenocryst (adularia I) and magmatic quartz phenocryst fragment; m) feldspar phenocrysts replaced by adularia I (K-alteration). Abbreviations: Br - breccia; C - claystone; D - dacite; Hqz - hydrothermal quartz; Kfs - potassic feldspar; Mqz - magmatic quartz phenocryst; Sed - sedimentary; Ss - sandstone (c-m from Drăgușanu 2017, with changes).

The optical microscopy study confirmed the macroscopic observations on the composition of the clasts and offered more details on the hydrothermal alterations. The thin sections study confirms the occurrence of sedimentary clasts, e.g. sandstones (Fig. 2h) and clays (Fig. 2i), breccia clasts (Fig 2j), and dacite clasts, from which locally were preserved only the magmatic quartz crystals (Fig. 2k, l) and the K-feldspar phenocrysts (Fig. 2k, l, m).

Several hydrothermal alterations were confirmed at microscopic scale, i.e., silicification of the matrix of the breccia clasts (Fig. 2j), and potassic alteration with adularia formed on the primary feldspar phenocrysts in the dacite clasts (Fig. 2j). All the feldspar phenocrysts identified in thin sections were replaced by adularia (Fig. 2k, l, m) through K-metasomatism. This type of adularia is noted as adularia I and is differentiated by the adularia that occurs as euhedral crystals deposited in open spaces and associated frequently with hydrothermal quartz, which is noted as adularia II.

## 4.2. Mineralization

The bulk mineralization in Orlea mining field that yield the mineable ore reserve reported by Armitage (2012) is given by disseminated Au and Ag. However, tabular higher-grade mineralization is also known, and a selection of three ore bodies labeled here O1 to O3 hosted by the vent breccia in the Orlea mining field, level +730 m are further presented. They consist of *i*) flatly dipping vein with rhodochrosite gangue - O1; *ii*) steeply dipping tectonic breccia dyke - O2; and *iii*) steeply dipping sulfide vein - O3 (Fig. 1b).

### *4.2.1. Flatly dipping vein with rhodochrosite gangue*

This type of ore body is an example of high-grade vein mined out since Roman times and known in the local mining slang as "*scaune*", or seats. The grade analysis of a representative grab sample from this vein structure yields 101 g/t Au. The rhodochrosite vein is up to 5 cm thick and has a dip of 10° to the south. The underground mining of the vein was conducted by room and pillar method with several rooms with vertical safety pillars still accessible nowadays.

The flatly dipping vein was followed horizontally on approximately 1,500 m² being preserved in the safety pillars (Fig. 3a). The vein is banded being composed mostly of rhodochrosite and hydrothermal quartz. The ore minerals including native gold occur as thin sequences interbedded with the rhodochrosite bands and as infilling of the open spaces (Fig. 3b, c, d). Small hydrothermal breccia pockets occur locally along the vein being cemented by the gangue minerals. The thin sections study revealed the presence of euhedral adularia crystals (adularia II) deposited within the open spaces as well as associated to rhodochrosite and hydrothermal quartz within the vein (Fig. 3e, f).

The ore microscopy facilitated the identification of the ore mineral assemblage that consists of electrum, pyrite, chalcopyrite, sphalerite, and galena (Fig. 3g-m). The pyrite appears frequently as euhedral crystals up to 250 µm in size. The sphalerite systematically contains small inclusions of chalcopyrite, which suggests a copper concentration within sphalerite between 2 and 15.8 wt.% (Udubașa et al., 1974; Cook et al., 2009). Generally, irregular sphalerite patches cover euhedral to subhedral pyrite crystals and may host smaller pyrite inclusions (Fig. 3g). At its turn, galena covers the pyrite or may infill the open spaces formed within the pyrite crystals and controlled by small cracks. The relationship between sphalerite and galena was not clearly identified. Native gold was identified in association with pyrite (most often) and sphalerite. The gold grains range in size from 20 to 150 µm (Fig. 3h-m) and are deposited on pyrite crystals (Fig. 3h,l,m), and locally enveloped small pyrite crystals (Fig. 3k). Gold grains were also identified within pyrite crystals being controlled by small cracks and voids (Fig. 3i). Gold occurs as grains hosted by rhodochrosite gangue (Fig. 3j) and along the border of sphalerite large grains (Fig. 3k).

### *4.2.2. Tectonic breccia dyke structure*

The studied tectonic breccia dyke structure from Orlea is hosted by the vent breccia as well. The breccia dyke has 15 - 20 cm in width (Fig. 4a-c) and is visible in the ceiling of the mining works on approximately 25 m along strike.

The breccia dyke structure is heading north and is dipping approximately 80° to the east. The contact between the tectonic breccia dyke and the vent breccia host rock is sharp and quite linear, and the breccia dyke has no significant branches. Overall, the grade of the breccia ranges between 8 and 12 g/t Au. The clasts of the breccia structure are mostly angular and consist mainly of banded quartz vein and hydrothermal cement fragments (Fig. 4d-h). The size of the clasts ranges from millimeters up to 20 cm and are cemented by white-gray hydrothermal quartz and gray hydrothermal cement. The silicification and the adularization are the only hydrothermal alterations identified at microscopic scale. The hydrothermal quartz crusts that cover the clasts and the thin hydrothermal quartz veinlets that cross the vent breccia fragments created locally intense silicification halos

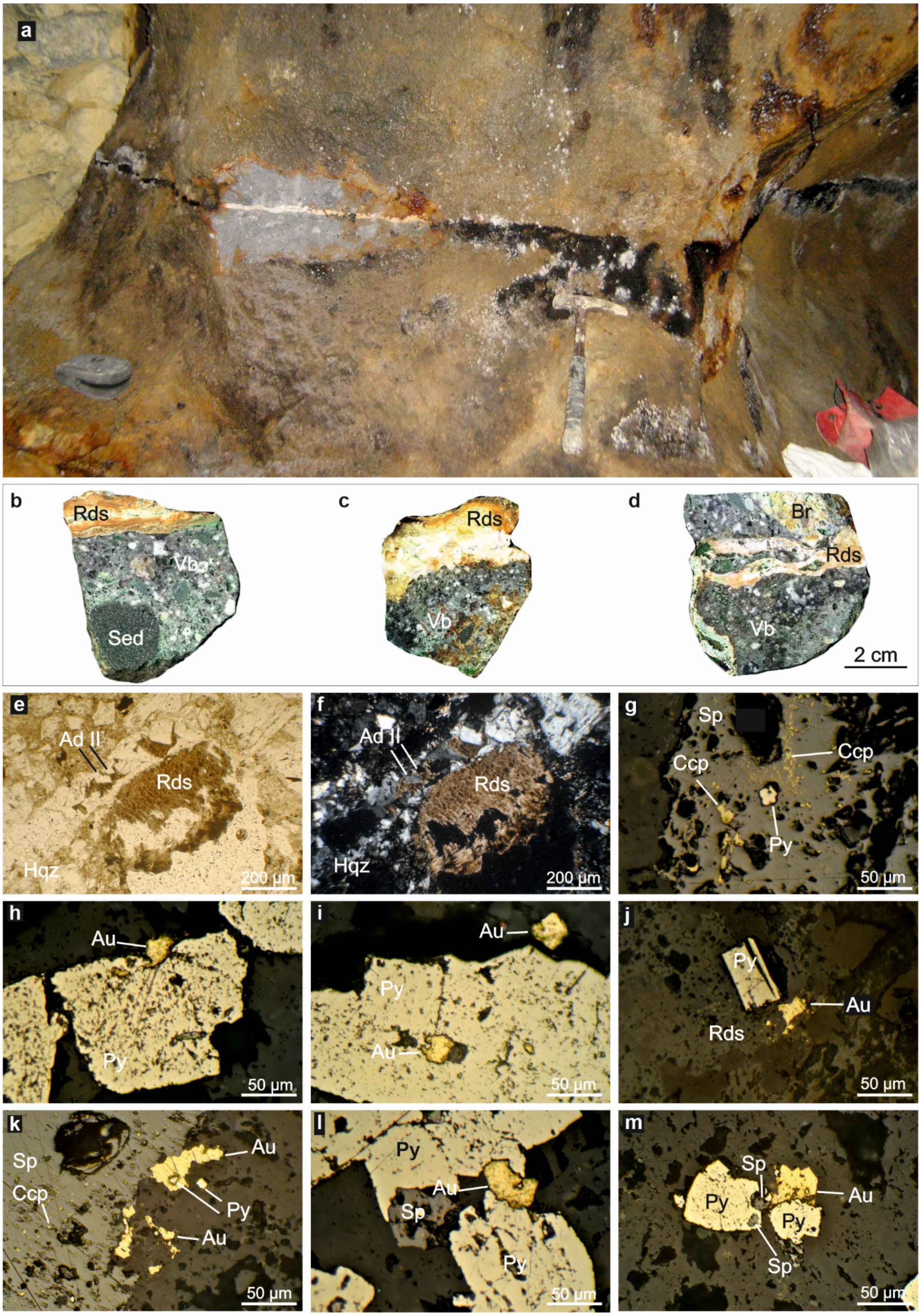


Figure 3. Flatly dipping rhodochrosite vein from the +730 m level, Orlea mining field illustrated by macroscopic image in the underground (a), polished slabs (b-d), microphotograph in plane-polarized transmitted light with one polarizing filter (e) and two polarizing filters (f), respectively, and microphotographs in plane-polarized reflected light (h-m). a) Flatly dipping rhodochrosite vein exposed on a vertical safety pillar; the image is showing the sampling zone grading 101

g/t Au; b-d) details of the banded rhodochrosite vein hosted by the vent breccia; e-f) adularia-hydrothermal quartz-rhodochrosite mineral assemblage within the vein; g) sphalerite with chalcopyrite disease and pyrite inclusions; h) gold deposited on and within pyrite crystal; i) gold grain located close to the border of a pyrite crystal and within pyrite being controlled by small cracks; j) gold in rhodochrosite gangue; k) gold concentrated at the border of sphalerite with chalcopyrite inclusions; l) pyrite covered by gold and sphalerite; m) gold deposited on pyrite crystals; sphalerite is also deposited on pyrite and seems to be at its turn covered by gold. Abbreviations: Ad II - adularia II, Au -gold, Br - breccia clast, Ccp - chalcopyrite, Hqz - hydrothermal quartz, Py - pyrite, Rds - rhodochrosite, Sed - sedimentary rock fragment, Sp - sphalerite, Vb - vent breccia (Drăgușanu 2017, with changes).

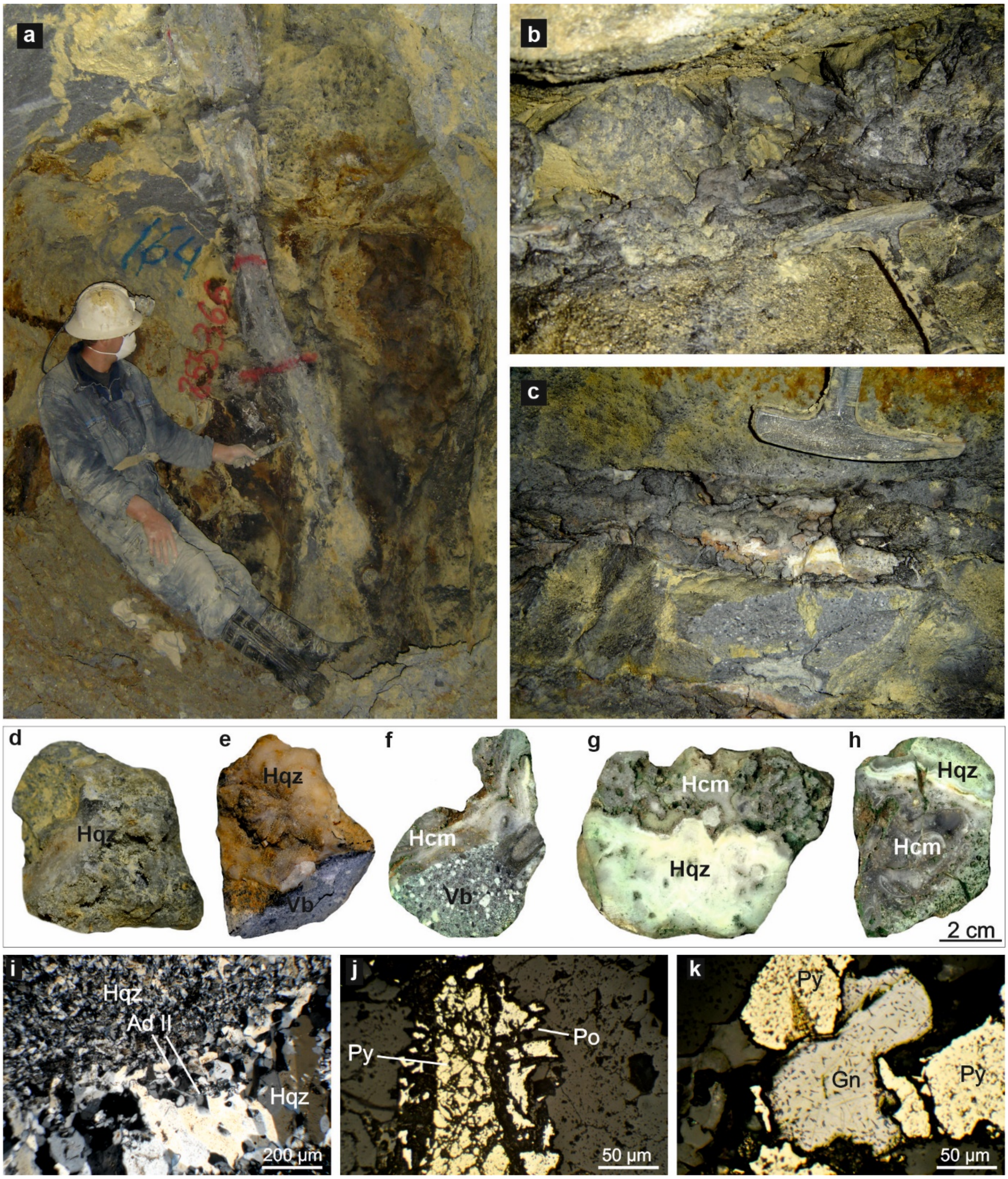


Figure 4. Tectonic breccia dyke structure hosted by the vent breccia, underground level +730 m, Orlea mining field illustrated by underground images (a-c), polished slabs (d-h), microphotographs in plane-polarized transmitted light (i) and reflected light (j,k). a) The breccia dyke structure exposed on the face line of an exploration adit; b) detail of the tectonic breccia dyke showing the walls of the structure, the abundance of the open spaces, and the grayish color of the hydrothermal cement that envelops the clasts; c) detail of the tectonic breccia dyke - typically clast supported, with white and banded quartz vein

fragments covered by thin sequence of hydrothermal cement; note the vent breccia host rock; d) sub-angular fragment of hydrothermal quartz; e) vent breccia host rock at the contact with tectonic breccia dyke; f-h) polished slabs of clasts formed of banded hydrothermal quartz and grey hydrothermal cement; i) quartz veinlet and related adularia II euhedral crystals within a vent breccia fragment from the tectonic breccia; j) pyrite covered by pyrrhotite; k) euhedral - subhedral pyrite grains covered by galena. Abbreviations: AdII - adularia II, Br - breccia clast, Gn - galena, Hcm - hydrothermal cement, Hqz - hydrothermal quartz, Po - pyrrhotite, Py - pyrite, Vb - vent breccia (d-k from Drăgușanu 2017, with changes).

where euhedral adularia crystals also occur (Fig. 4i). Additionally, widespread less-intense silicification occurs within the matrix of the vent breccia fragments. The occurrence of euhedral adularia deposited from the hydrothermal fluids in open spaces represents a mineralogy key indicator of gold mineralization. The ore microscopy study carried out on samples from the tectonic breccia dyke body revealed the presence of pyrite, chalcopyrite, galena, and pyrrhotite. Pyrite is surrounded by pyrrhotite (Fig. 4j) and is covered by galena (Fig. 4k). It appears that the pyrite was deposited first, however, the relationships between pyrrhotite and galena are unclear. The gangue consists of hydrothermal quartz (± adularia) and hydrothermal cement.

#### *4.2.3. Base metal vein*

A base metal vein with hydrothermal cement gangue heading north was studied in another adit from the south-eastern part of the +730 m underground level from the Orlea mining field, indicated by the O3 label in Fig. 1b. The vein is easily visible in the underground being highlighted by the oxidation formed on the abundant pyrite (Fig. 5a).

The vein structure has about 10 cm in width and is accessible along strike on 15 m. The vein is hosted by the vent-breccia and is opened along the wall of the adit. Macroscopically, millimeter sized quartz veins are associated with the base metal vein. Apart from pyrite and quartz, galena also occurs as euhedral millimeter-sized crystals (Fig 5b, c). The transmitted light microscopy study revealed three types of hydrothermal alteration products: *i*) hydrothermal quartz veins that cut and split apart the sulfides from the base metal vein (Fig. 5d), with the quartz veins having the same strike as the sulfide vein; *ii*) sericite within the matrix of the breccia clasts, and *iii*) K-alteration with adularia (Ad I) formed on feldspar phenocryst fragments (Fig. 5e). The ore minerals assemblage in the base metal vein revealed by ore microscopy consists of pyrite, chalcopyrite, arsenopyrite, galena, and pyrrhotite (Fig. 5f-i). Galena is covering completely or partially euhedral-subhedral chalcopyrite (Fig. 5f) and pyrite crystals (Fig. 5g). Pyrrhotite was deposited on the border of pyrite (Fig. 5h) or associated with arsenopyrite (Fig. 5i). According to cross-cutting relationships observed at microscopic scale, the order of crystallization is pyrite, chalcopyrite, galena, pyrrhotite, and arsenopyrite. The ore minerals are accompanied by minor hydrothermal quartz gangue.

## 5. DISCUSSION

The diatreme/vent breccia formation, which is the host rock in the Orlea mining field is a polymictic breccia that contains sedimentary (clay, sandstone), volcanic (dacite), and metamorphic (quartzite, garnet micaschist) clasts. Besides these clasts from the country rocks, there are also fresh and silicified vent breccia clasts. The clasts of the breccia are held together by a rock-flour matrix. The matrix composition is heterogeneous and reflects the composition of the clasts, being similar to the matrix of the vent breccia in Țarina mining field, where Hewson et al., (2005), defined the vent breccia as clay-rich matrix-supported. Overall, the vent breccia formation is mainly fresh being only locally silicified close to the ore bodies where a silicification halo is always present. According to the silicified/unsilicified character of the vent breccia whole rock and the silicified/unsilicified vent breccia clasts, four breccia types were identified, precisely fresh or silicified vent breccia containing fresh or silicified breccia clasts, respectively. These vent breccia types suggest the existence of several brecciation and silicification/hydrothermal events. As such, silicified vent breccia clasts in fresh/unsilicified vent breccia suggest that the brecciation event responsible for the formation of that vent breccia sequence took place after a hydrothermal event that silicified those respective rock fragments. The existence of unsilicified rock fragments held by silicified matrix could be explained by the more porous character of the breccia matrix as compared to the rock fragments, which consequently better drained the hydrothermal fluids and preferentially silicified the matrix.

The main hydrothermal alterations within the vent breccia in the Orlea mining field are the potassic alteration with adularia and the silicification, and a subordinate phyllic alteration (sericitization). Two types of potassic alteration were observed, i.e., *i*) replacement of primary feldspar phenocrysts from dacite and vent breccia clasts containing dacite rock fragments by K-feldspar, or K-metasomatosis - adularia I, and *ii*) deposition of euhedral adularia crystals associated with hydrothermal quartz in open spaces and veins - adularia II. The adularia I seems to be a mining field/ore deposit scale event, while the adularia II is strictly localized and controlled by a given hydrothermal conduit that allowed the flow of the hydrothermal fluids and the deposition of the precious-metals ores being thus a mineralogical clue for the proximity of low-sulfidation Au-Ag mineralization/ore body. As concerns the timing of adularia I and adularia II formation, Mârza & Ghergari (1992) and Tămaș (2002, 2007) show that

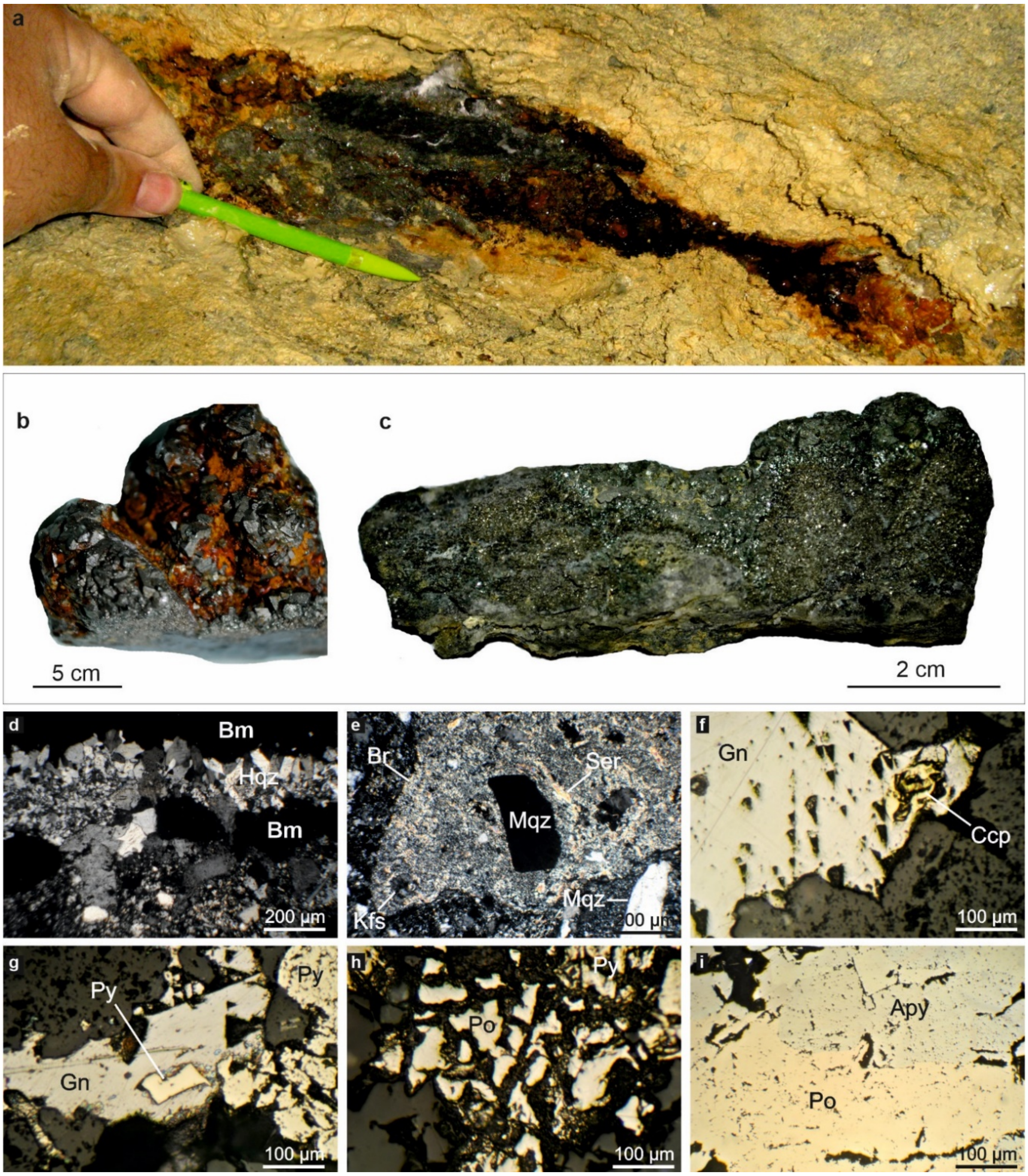


Figure 5. Base metal vein from the+730 m level, Orlea mining field, illustrated by macroscopic images (a-c), and microphotographs in plane-polarized transmitted (d,e), and reflected light (f-i). a) The sulfide vein masked by the oxidation of pyrite, which is the most abundant sulfide (detail); b-c) hand samples from the sulfides vein; note the oxidation of the sulfides in the image (b); d) base metal vein cut by hydrothermal quartz veinlet; e) vent breccia clast with magmatic quartz phenocryst and pervasive sericite in the matrix and adularia (Ad I) formed on feldspar crystal fragment; f) chalcopyrite inclusion in galena; g) pyrite grain enveloped by galena; h) pyrrhotite deposited on the border of pyrite; i) arsenopyrite and pyrrhotite association; note the presence of subhedral rhombic arsenopyrite crystals and the weak bireflectance of arsenopyrite (bluish tint locally). Abbreviations: Apy - arsenopyrite, Bm - base metal veins, Br - breccia clast, Ccp - chalcopyrite, Gn - galena, Hqz - hydrothermal quartz; Kfs - potassic feldspar; Mqz - magmatic quartz; Po - pyrrhotite, Py - pyrite, Ser – sericite, (Drăgușanu 2017, with changes).

adularia I is cut by adularia II - hydrothermal quartz veinlets, indicating that adularia II formed after adularia I. The ore bodies are enveloped by a silicification halo with hydrothermal quartz closely related to adularia II. Within the Roșia Montană ore deposit, Tămaș (2002) noticed that the silicification is clearly indicating the proximity of low-sulfidation precious-metals ore bodies. According to Cauuet & Tămaș (2012), the increasing rock hardness of the rocks guided the Roman miners towards the unknown ore bodies. The sericitization occurs sporadically and at low intensity. It occurs within the clay matrix of the vent breccia and locally developed on K-feldspar replaced by adularia. The adularia II crystals show no traces of sericitization. Accordingly, the timing of the hydrothermal alterations within the Orlea mining field is as follows, (*i*) K-metasomatosis (adularia I); (*ii*) phyllic alteration (sericite), (*iii*) silicification and deposition of the hydrothermal quartz, and (*iv*) potassic alteration (adularia II). The ore minerals are associated with silicification/hydrothermal quartz and adularia II deposition.

Three ore bodies were identified during this study, a flatly dipping vein with rhodochrosite gangue, a sub-vertical tectonic breccia dyke structure, and a sub-vertical base metal vein. The rhodochrosite vein is by far the most important from economic point of view carrying high Au grade. This type of ore body was previously described by Ghițulescu & Socolescu (1941) and Bordea et al., (1979), with the "Filonul Crucii" (Cross Vein) as the better-developed structure. According to these authors this major vein is hosted by the vent breccia in the northern part of the deposit, is heading W-E and has a dip of 45° towards the south. The same authors highlight the importance of the intersections between Crucii Vein and the N-heading vein structures due to their extremely high gold grades and consequently, were particularly followed by the miners.

The field observation on tectonic breccia dyke structure coupled with microscopic study suggests that this ore body is the result of two hydrothermal events and a tectonic reworking of a vein structure. This evolution, which is supported by the available evidence is summarized by the following steps:

(1) set up of a N-S fault, controlled by the regional tectonic setting;

(2) the fault channelized the hydrothermal fluids flow and controlled the deposition of the hydrothermal quartz and the associated ore minerals as a banded vein structure, which we consider here the early-vein structure (Fig. 6a);

(3) the early-vein structure was affected by faulting that created angular fragments composed essentially of banded hydrothermal quartz; the faulting of the early-vein structure is interpreted as a tectonic brecciation event (Fig. 6b);

(4) following the tectonic brecciation of the early-vein structure, another hydrothermal pulse took place with the deposition of thin rims of hydrothermal quartz and hydrothermal cement on newly created fragments and on their contacts consolidating thus the clast-supported tectonic breccia structure (Fig. 6c).

The depositions of the ore minerals took place during two hydrothermal events, i.e. pre- and post-tectonic brecciation. However, the tectonic brecciation created more open spaces and enhanced the subsequent deposition of new gangue and ore minerals sequences.

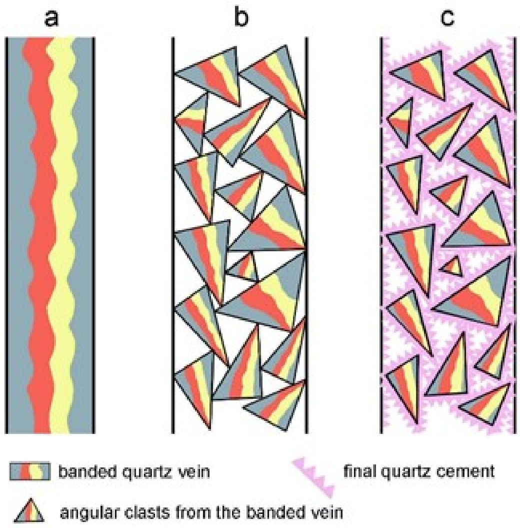


Figure 6. Evolution of the tectonic breccia dyke from +730 m level, Orlea mining field. a) Banded vein with quartz and gray hydrothermal cement sequences formed on N-S fault; b) angular fragments formed due to tectonic movements/brecciation along the early-vein/fault; c) deposition of hydrothermal quartz rims on the angular fragments during the last hydrothermal pulse.

The ore mineral assemblage from the investigated ore bodies in Orlea mining field consists of electrum, pyrite, chalcopyrite, sphalerite, galena, and, subordinately arsenopyrite and pyrrhotite. The dominant gangue mineral is the rhodochrosite in the flatly dipping vein, and the hydrothermal quartz in the sub-vertical tectonic breccia dyke and the base metal vein. According to the ore and gangue mineral assemblage, the mineralization style of the flatly dipping vein is similar to the intermediate sulfidation vein structures hosted by the Black Breccia in the Cetate mining field and the Cârnicel Vein from the Cârnic mining field (Ciobanu et al., 2004; Tămaș et al., 2004; Bailly et al., 2005; and Tămaș et al., 2006). However, the argyrodite, the tellurides, *i.e.*, hessite, altaite, sylvanite, and the sulfotellurides, *i.e.* cervelleite and alburnite described by the above-mentioned authors and Tămaș et al., (2014) were not identified so far in the flatly dipping vein with rhodochrosite from the Orlea mining field. The mineralization style of the sub-vertical tectonic breccia dyke structure and the sub-vertical base metal vein is typical low-sulfidation as other ore bodies from the Văidoaia mining field (Drăgușanu & Tămaș, 2017). It is worth mentioning that Tămaș et al., (2006) noticed that at least in the southern part of the Roșia Montană ore deposit the low-sulfidation mineralization was followed by the intermediate-sulfidation mineralization style. Similarly, the low-sulfidation steeply-dipping vein and breccia dyke structures from the Orlea mining field are more likely cut by the intermediate-sulfidation rhodochrosite flatly-dipping vein. However, the spatial relationships between these ore bodies is no more available due to the extensive underground mining focused on these high-grade ore shoots.

The high-grade gold intermediate-sulfidation rhodochrosite vein from the +730 m level, Orlea mining field represents the first evidence of the potential of the intermediate-sulfidation ore bodies from the Roșia Montană ore deposit to be important Au ore bodies contrasting to the previous image (Ciobanu et al., 2004 and Tămaș et al., 2006) suggesting that this type of ore body in Roșia Montană is mainly Ag-carrier, with lower Au grade ranging from 1 to maximum 5 g/t Au. However, Tămaș et al., (2021) reported the occurrence of a hydrothermal breccia dyke cut by quartz veins showing transitional character from low-sulfidation to intermediate-sulfidation in Cârnic Massif, Roșia Montană with native gold, tetrahedrite, polybasite, acanthite, sphalerite, chalcopyrite, galena and pyrite, with the gold grade ranging from approximatively 8 to 97 g/t.

## 6. CONCLUSIONS

The presence of the low-sulfidation and the intermediate-sulfidation mineralization styles in the underground level +730 m, Orlea mining field from Roșia Montană Au-Ag ore deposit was confirmed by the occurrence of a tectonic breccia dyke and a base metal vein, and by a rhodochrosite flatly dipping vein, respectively. Two types of K-alteration (adularia I and adularia II) were observed, besides the silicification and the sericitization. The silicification and the adularia II represents key alteration/mineralogy controls of Au-mineralization with native gold/electrum, pyrite, sphalerite, chalcopyrite, and galena, while adularia I is a hydrothermal event developed at the ore deposit scale having no tight spatial connection to the ore bodies.

The tectonic breccia dyke suggests a long-term relationship between the regional and local structural control and the hydrothermal activity. Similarly, the vent breccia alteration peculiarities suggest recurrent phreatomagmatic and hydrothermal events.

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