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ORE MINERALOGY OF THE RODU-FRASIN AU-AG DEPOSIT, METALIFERI MOUNTAINS, ROMANIA

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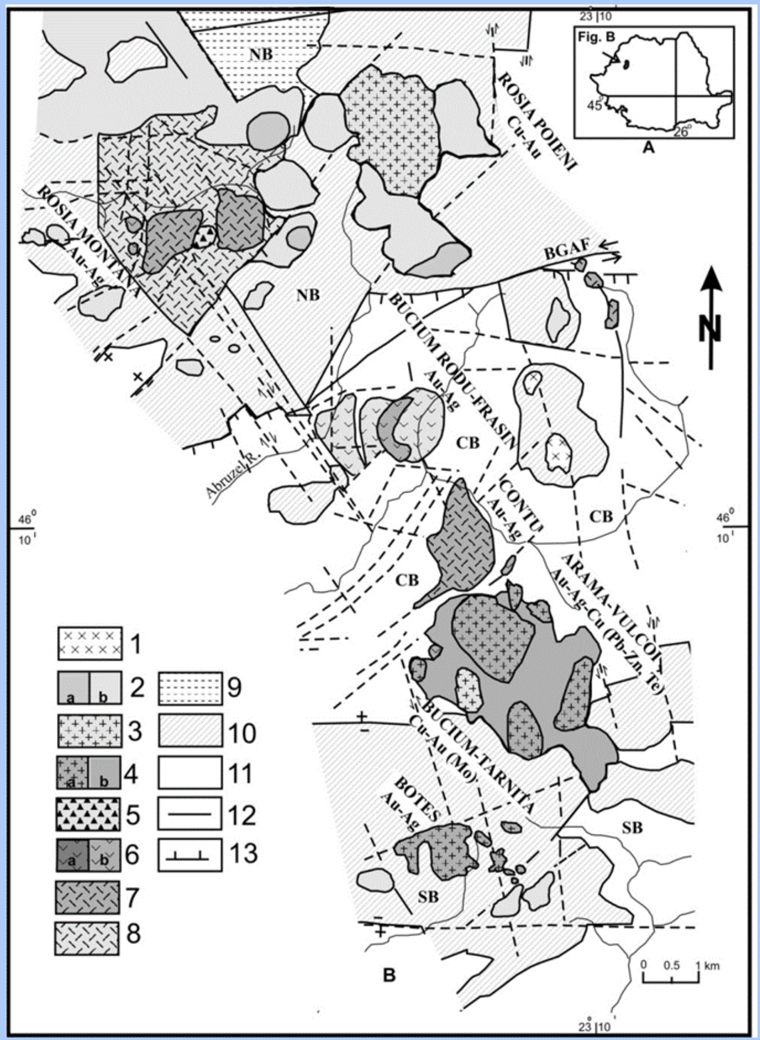
INTRODUCTION

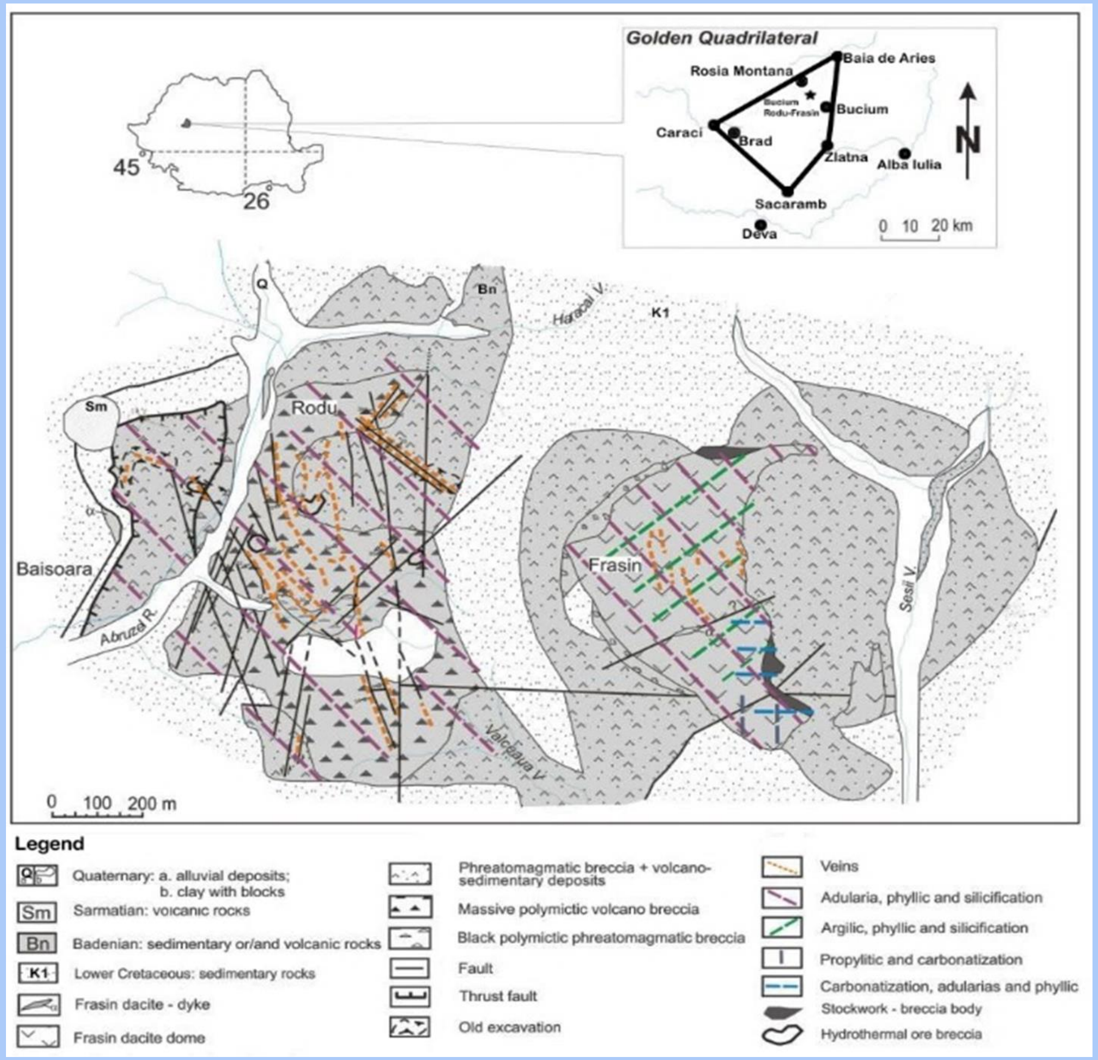
- The Rodu-Frasin Neogene volcanic structure and related Au-Ag deposits are located in the north-eastern part of South Apuseni Mountains, within the so called “Golden Quadrilateral”. They are situated about 10 km east of the Abrud city and 5 km south of the Rosia Montana deposit, being part of the Rosia - Bucium - Baia de Aries metallogenetic district.
- The Au-Ag ore deposits have been exploited from old times, traces of those works being provided by large surface excavations. The total resources for the Rodu and Frasin deposits currently stand 43.3M t with 1.3 g/t Au and 3 g/t Ag, equals 1.8 M oz of gold, and 4.7M oz of silver (Verbeek, 2005, in Hewson et al., 2005).



Generalized structural map of Bucium - Rosia Montana - Rosia Poieni. 1. Detunata basalt-andesite (7.4 ± 0.3 Ma). 2. Undifferentiated Surligata and Pietris - Ruginosu andesites: a. intrusions. b. lavas and pyroclastics. 3. Poieni and Bucium Tarnita quartz andesite-diorite porphyry. 4. Undifferentiated Arama and Vulcoi andesites: a. intrusions. b. lavas and pyroclastics. 5. Black polymictic breccia, 6. Frasin quartz andesites: a. intrusions and b. dominant phreatomagmatic breccias. 7. Montana (13.61 Ma) and Contu dacite intrusions (12.7 ± 1 Ma). 8. Volcaniclastic and epiclastic dacite products. 9. Paleocene marine sediments. 10. Upper Cretaceous flysch. 11. Lower Cretaceous flysch. 12. Certain fault, inferred when dashed. 13. Thrust fault. Abbreviations: BGAF = Bucium – Geamana - Aries Fault. CB = Central Block. NB = North Block and SB = South Block. , modified after Berbeleac et al., 2016).

GEOLOGICAL SETTING

- In Mesozoic-Tertiary times, the Rodu-Frasin area underwent a multi-stage evolution characterized by a strong mobility regime explained, at least partially, by the presence of the north-western segment of an important fault, designated here as Vintu-Aries dextral strike-slip fault.
- Structural interpretation of detailed mappings, mining and exploration drilling works, magnetotelluric sounding data and laboratory studies (Ianovici et al., 1976; Borcoș and Vlad, 1997; Leary et al., 2004; Nadasan and Hewson, 2005) suggest that Bucium Rodu-Frasin area represents a small Upper Cretaceous-Lower Miocene collapse basin and a complex maar-diatreme structure, resulted from normal reactivation of older, steeply dipping fault structures related to the Vintu-Aries Fault (Berbeleac et al., 2016).
- Bucium Rodu-Frasin maar-diatreme complex volcanic structure consists of two separate eruptive craters, each excavated 400-500 m into Cretaceous sediments. One is the Rodu maar-diatreme, dissected by the Abruzel River, and the other one, the Frasin maar - diatreme structure, dissected by Seasa Valley. The Rodu maar-diatreme has an elliptical shape ~ 1500/1000m with its long axis striking N-S and the southern and eastern sides exhibiting an irregular contour. In contrast, the Frasin maar-diatreme is nearly circular in shape with the diameter of about 1100 m.

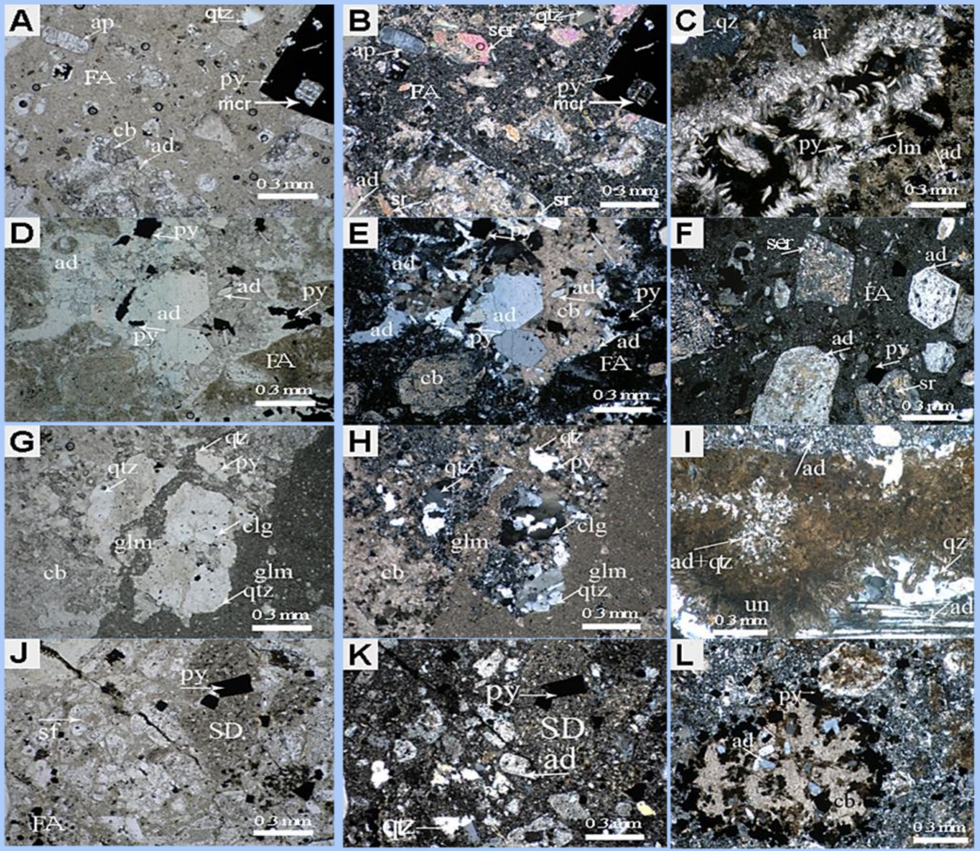


Geological map of Bucium Rodu-Frasin area (after R.M.G.C. data with additions, modified after Berbeleac et al., 2016).

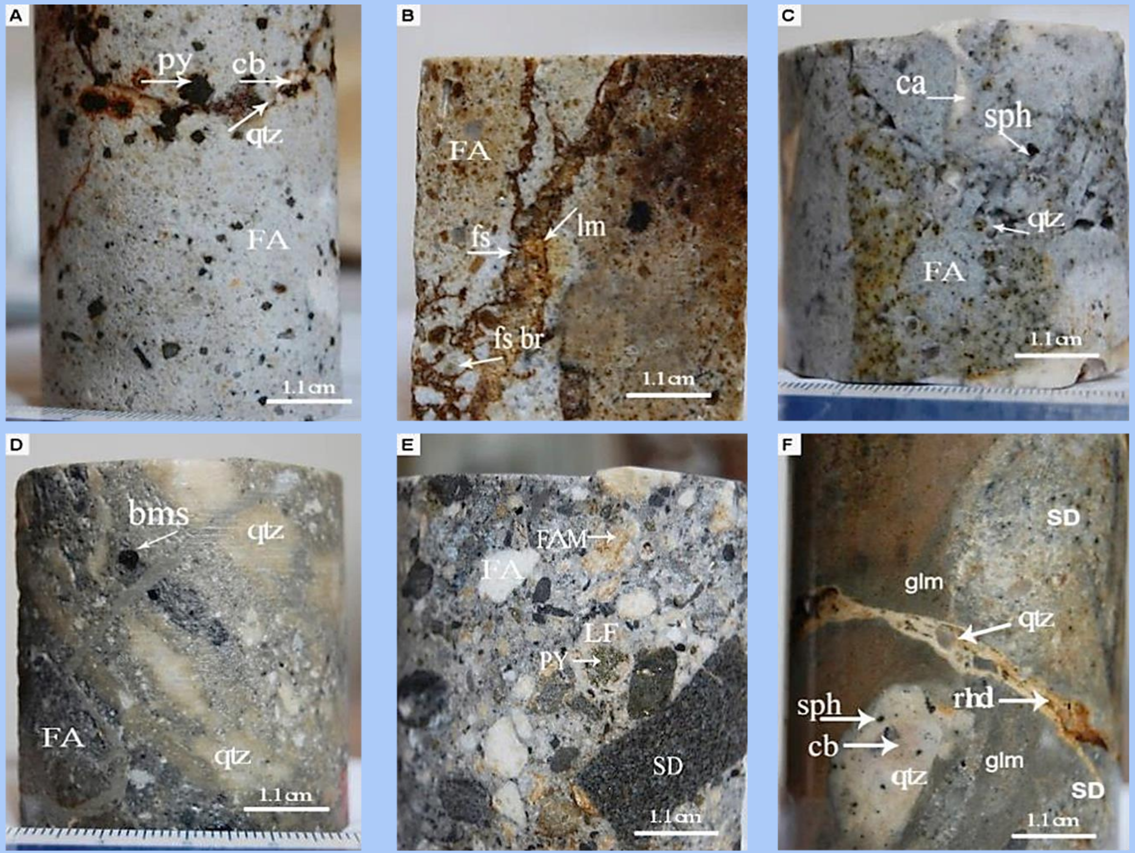
HYDROTHERMAL ALTERATION

- Hydrothermal alteration in Bucium Rodu-Frasin area is pervasive and widespread throughout the volcanic structure and surrounding Cretaceous formations. Altered rocks contain multiple overprinted hydrothermal mineral assemblages, as well as minerals formed by weathering. Five main types of hydrothermal alteration were distinguished:
- **Propylitic alteration** was recognized in the andesite dike on the right side of Abruzel River and in the south-eastern half of the Frasin quartz-andesite flow dome. Its color is greenish and carbonate, chlorite and minor amounts of albite, sericite, epidote, pyrite and rutile are the most common new mineral assemblages. The Ca-plagioclase is replaced by albite ± chlorite, calcite, and epidote. Pyrite, chlorite, calcite, epidote and rutile replaced hornblende and biotite.
- **Potassic (Adularia) alteration** is quite widespread. Its main characteristic is a total or partial replacement of plagioclase and mafic minerals by adularia, sericite and carbonates ± quartz and pyrite - rutile; the initial rock textures are preserved. The adularia processes seem to have evolved in stages II and III of ore deposition, characterized by following major mineral assemblages: arsenopyrite (Au?)-base metal sulfides-quartz-sericite-chlorite-adularia and pyrite (Au)-quartz-adularia in stage II and Au-base metal sulfides-carbonates-quartz-adularia with alabandite-rhodochrosite-quartz-pyrite characteristic for stage III.
- **Phyllic alteration** seems to be younger than adularia alteration. Adularia is overprinted, in various amounts, by sericite. The maximum intensity of this alteration type occurs within mineralized zones situated at the eastern contact of Frasin andesite dome with polymict breccias, as well as in Rodu area.
- **Carbonatization alteration** is subsequent to the adularia and phyllic alterations and in the mineralized zones it is the most widespread. It displays a two stages evolution. Partial replacement took place in the stage II, feldspar and femic minerals of being replaced with fine- to medium-grained carbonates calcite, ankerite and pyrite. The stage III of alteration is recognized by the presence of litophysae, veins and veinlents with fine- to large-grained carbonates (calcite, dolomite, aragonite, rhodochrosite) and ± quartz, precious metals, base metals sulfides, alabandite, rutile, iron and manganese hydroxides.
- **Silicic alteration** displays close relationships to the direct pathways of the ore fluids. Its products consist of amorphous silica as dark-grey small fissures and veins "Chinga" and white-brown fine grained quartz crystals ± adularia, sericite, pyrite and argillic minerals.
- **Argillic alteration** with epigenetic origin, diagenetic and supergene, the clay minerals outlying, in the mineralized zones, the adularia-sericite and phyllic alteration zones.

HYDROTHERMAL ALTERATION



The ore textures and mineralogy of some samples from Rodu and Frasin gold deposits. A. (NII) and B. (N+). Frasin quartz andesite (FA) with porphyritic and cryptocrystalline groundmass textures. Phenocrysts replaced by ad, ser, clm, cb and py; C. (N+). FA with glassy groundmass and fissure partially filled with ar, clm and py; D. (NII) and E. (N+) Vug of jigsaw-fit andesite filled up by qtz, cb, py and ad II; F. (N+). Glassy FA with phenocrysts replaced by ad, ser and py; G. (NII) and H. (N+): Polymict lithoclast breccias with ash clasts. Conglomeratic clast (cgl) consisting of qtz, glassy ash clasts and elongate cylindrical glassy vesicles (gvs) filled with qtz, cross-cut by a "glam" fissure (glm). Cb, qtz and py replace clasts and breccia matrix. I. (N+) Polymict reworking breccia with a fissure filled with kutnahorite, qtz and adII; J. (NII) Polymict breccia with interclast relict classical vesicles–sferulites (sf). K. (N+) ad vesicles-spherulites and phenocrystals of glassy ash, marginal volcanic sandstone clast (SD); L. (N+). Lithophysae filled with cb, ad and py in porphyritic quartz andesite clast matrix. Abbreviations: ad-adularia, cb-carbonates, clm-clay minerals, py-pyrite, ser-sericite, qtz-quartz.

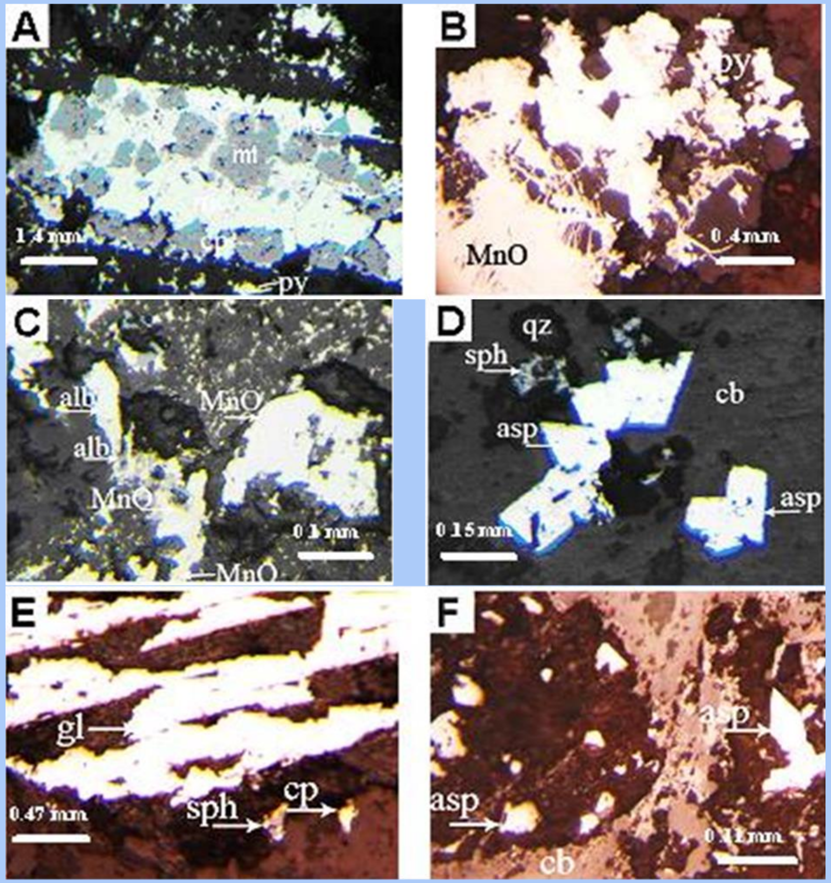


Photographs of some representative core slabs showing the alteration - mineralization stages: A. F1, D 019, m 453.72-473.80. Fissure filled with oxidized pyrite (py), quartz (qtz) and carbonates (cb) in porphyritic (FA) (stage II); B. D 030, m 94.40-94.45. Fissure (fs) with breccia (br) texture cemented by limonite (lm) in Frasin quartz andesite (FA) (Stage I); C. D 039, m. 107.32-107.37. Stockwork mineralization: sphalerite (sph), quartz (qtz) and carbonates (cb) in vugs of jigsaw-fit texture in fine, moderately porphyritic (FA) (Stage II); D. D 023, m. 105.85-105.90. A fracture with reworking breccia and bedded texture mineralized with (bms) and quartz (qtz), cut by a (glm) fissure (Stage II + I). E. D 053 A. m. 226-226.05. Massive reworking hydrothermal polimictic breccia with subangular and rounded (FA) clasts altered and mineralized (FAM). Pyrite (py) in lithophysae and angular sandstone (SD) in lithic supported matrix (Stage I?). F. D 005, m. 186.90-186.95. An older" glam" vein and younger vein filled with (qtz), (cb) and (sph) (Stage II), both cut by (rd) and (qtz) fissure (Stage III).

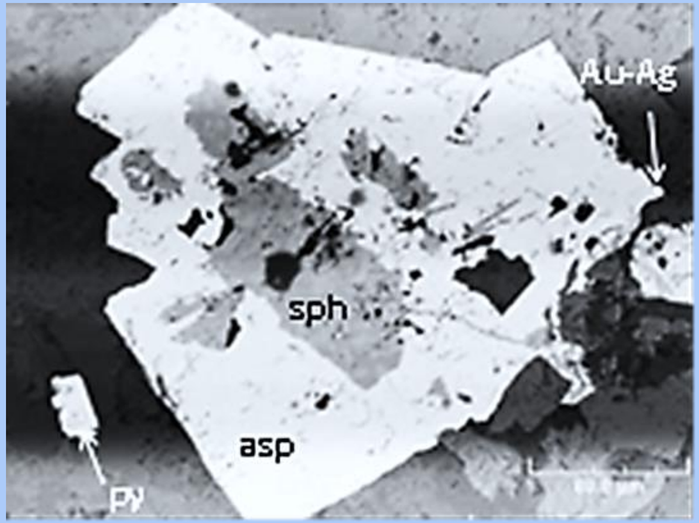
MINERALIZATION

- In Rodu-Frasin area the Au-Ag-base metals mineralization occurs in close genetic relationships with the hydrothermal breccias and phreatomagmatic fracturing. The high-grade mineralization was present mainly in gently dipping veins. The veins include carbonates, quartz, along with minor pyrite, sphalerite, galena, chalcopyrite, tetrahedrite and gold. Magnetite with little hematite and sulfides mineralization, probably formed in the mesothermal conditions (?) has been recognized only as metasomatic substitutions of a probable Cretaceous limestone clasts braked from the depth.
- The mineralization has been considered by White (2003, in Leary et al., 2004) and Szentesy et al., (2004) as LS epithermal style; we think that it probably passes, at larger depths, into the mesothermal domain, or even into skarn in Cretaceous limestone.
- The mineralization can be classified, according to the deposition forms, in the following styles: 1) veins which cut the Frasin quartz-andesite dome and volcaniclastic breccias in the Rodu maar-diatreme and Cretaceous sediments; 2) disseminations and hydrothermal breccia in maar-diatreme breccias, quartz-andesite bodies and Cretaceous sediments and 3) stockworks in the Frasin quartz-andesite dome and the contact breccias.
- The ore deposition had a pulsating character with the evolution occurring, probably, in three stages to which the following mineral assemblages were associated: a. magnetite hematite - pyrite marcasite -quartz and pyrite - quartz ± base metal sulfides in the first stage (mesothermal?); b arsenopyrite Au - -base metal sulfides - quartz - adularia, “chinga” pyrite Au - quartz - adularia and base metal sulfides - carbonates calcite, aragonite, dolomite, ankerite, ± rhodochrosite ± kutnahorite - quartz - adularia, in the epithermal low sulfidation-second II stage and quartz - pyrite –marcasite – carbonates dominant rhodochrosite - Au and alabandite - rhodochrosite - quartz in the third III, epithermal low sulfidation stage.
- The gold is present in various proportions, either as small grains or as sub-microscopic occurrences, within all Rodu-Frasin mineralization styles. The individual gold grains in native state have been observed as thin sheets on pyrite, sphalerite and quartz grains or as short wires, and sheets in geodes. Local gold concentrations are also common at the intersection zones of the so called “chairs” (“scaune”) veins with “crosses” (“cruci”) veins. According to White (2003, in Larry et al., 2004) and confirmed by our study the gold has been petrographically identified as electrum.

MINERALIZATION



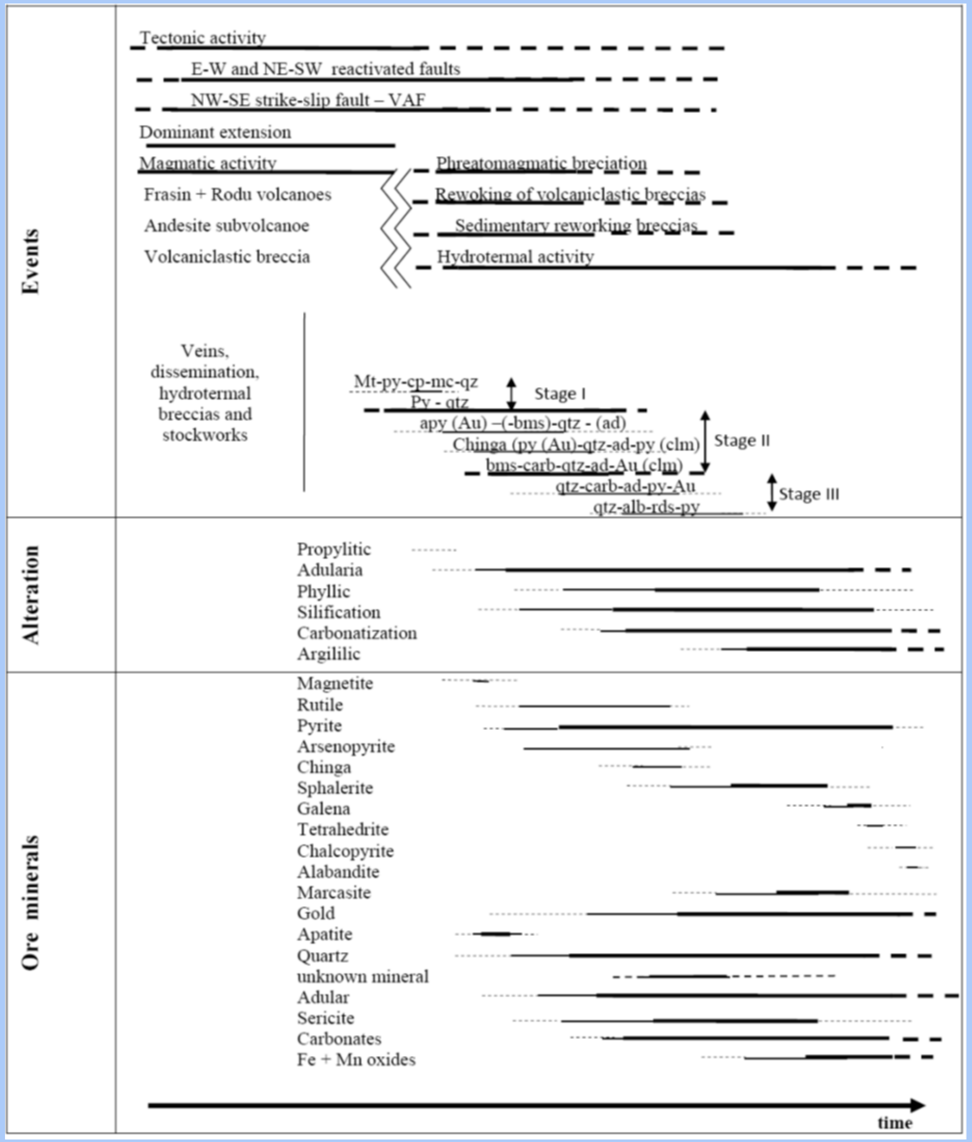
Reflected light photomicrographs of some ore minerals from Rodu and Frasin deposits. A. (N+) FA replaced by euhedral and subhedral coarse-grained magnetite (mt), less substituted by hematite and cemented by marcasite aggregates (mc) and py (stage I); B. (N+) A vug in FA filled with manganese and iron oxides, pyrite and hydrothermal quartz (qtz) (Stage III); C. (N+). Alabandite (alb) near total replaced by manganese oxides (MnO) (Stage III); D. (N +) Fissure filled with arsenopyrite (asp), carbonates (cb), quartz (qtz) and sphalerite (Stage II); E. (N+) Galena (gl), chalcopyrite (cp) and sphalerite (sph) grains, disseminated in polymictic breccia (Stage II). F. (N+) Arsenopyrite (asp) euhedral crystals within lithophysae clast (Stage II).



Mineral	Zn (Wt%)	As (Wt%)	Fe (Wt%)	S (Wt%)	Au (Wt%)	Ag (Wt%)	Sum (Wt%)
Sphalerite	34.20	0.00	2.30	62.12	0.80	2.30	99.42
Pyrite	2.97	0.23	31.06	62.55	2.85	0.00	99.66
Pyrite	2.74	0.27	29.45	63.42	3.94	0.00	99.82
Arsenopyrite	3.55	15.84	36.19	42.59	1.10	0.00	99.26
Arsenopyrite	2.05	16.20	36.91	42.86	1.65	0.00	99.67
Electrum	0.11	0.00	0.22	0.00	72.62	26.62	99.57

SEM image and SEM-EDS analisys of electrum (Au-Ag)-arsenopyrite (asp)-sphalerite (sph)-pyrite (py) assembleage

MINERALIZATION



The temporal relationship between tectonic, magmatic and hydrothermal activities in Rodu-Frasin, showing the styles of alteration and mineralization. Dashed and thin lines mark minor or uncertain occurrence, the thick lines indicate main occurrences. Abbreviations: ad -adularia, alb-alabandite, apy-arsenopyrite, bms-base metal sulfides, cab-carbonates, cp-chalcopyrite, he-hematite, mc-marcasite, mt-magnetite, qtz-quartz, rds-rhodochrosite, (-) minor or uncertain participation, (Au)-associated gold.

CONCLUSIONS

- The Neocene geologic evolution of the Rodu - Frasin magmatic-hydrothermal system took place in close relationships with the tectonic, magmatic and metallogenetic activity of the Bucium - Rosia Montana - Baia de Aries district.
- The ore occurs in a structurally complex environment, typically with some generations of faults or fractures oriented in two or more directions.
- Ore minerals consist roughly of sulfides, gold, carbonates, adularia and quartz. They have been prevalently emplaced as veins, breccia bodies and disseminations in open fractures and breccias in the Rodu diatreme, and as stockworks, veins and disseminations in relationship to the Frasin dome structure.
- The main mineral assemblages are: 1) magnetite (hematite) - pyrite (marcasite) - quartz; 2) arsenopyrite (Au) - base metal sulfides - quartz, “Chinga” (pyrite (Au) - quartz - adularia - carbonates (calcite, aragonite, dolomite, ankerite, ± rhodochrosite ± kutnahorite); 3) pyrite - marcasite - carbonates - quartz, (Au) - carbonates (dominant rhodochrosite) adularia and alabandite - rhodochrosite - quartz.
- The mineralizing hydrothermal fluids had near neutral pH and gold was probably transported as a bisulfide complex; boiling seems to be the main way of gold precipitation.
- Alterations as adularia, phyllic and carbonatizations show close relationships with the gold mineralization.

REFERENCES

- Balintoni I. (1994) Structure of the Apuseni Mountains: Rom. J. of Tectonics and Regional Geology, 72, 51-58, Bucuresti
- Berbeleac I., Nutu-Dragomir Maria-Lidia Udubasa S. (2016) Miocene maar and flow dome complex structures from Bucium Rodu and Frasin, Metaliferi Mountains, Romania. Rom.J.Mineral Deposits, vol. 89(2016), nr. 1-2, p. 59-64
- Borcoş M., Vlad S. (1997) Late Tertiary epithermal systems in the Romanian Carpathians. IGCP Project no. 356 – Stip, Macedonia
- Cioflica Gr., Jude R., Berbeleac I., Jude R., Udubasa S. (2002) Types of gold mineralization in Romania. In: Geologica Carpathica, 53, CD-R, Bhatislava
- Ghitulescu T. P., Socolescu M. (1941) Étude géologique et minière des Monts Metallifères: An. Inst. Geol. XXI, 181-464, Bucuresti
- Hewson N., Leary S., Feier Nicoleta (2005) Tarina and Rodu: Gold mineralization hosted in maar-diatreme contact environments in the Apuseni. Mountains, Romania: Bulgarian Academy of Sciences Geochemistry, Mineralogy and Petrology, 43, 2, 94-101, Sofia, Au-Ag-Te-Se deposits, IGCP Project 486, 2005, Field Workshop, Kiten, Bulgaria, 14-19 Sept 2005, Kiten
- Ianovici V., Borcos M., Bleahu M., Patrulius D., Lupu M., Dimitrescu R., Savu H. (1976) Geologia Muntilor Apuseni: Ed. Acad. Republici Socialiste. Romania, 1- 631, Bucuresti
- Leary S. F., O’Connor G. V., Howie K., Nădăsan L. (2004) The Rodu-Frasin Deposit. In: Cook, N.J., Ciobanu, C.L. (Eds.), Gold-Silver-Telluride Deposits of the Golden Quadrilateral, South Apuseni Mts., and Romania. IAGOD Guidebook, Series 12, 99-104
- Nadasan L., Hewson J. N. (2005) Relogging of the Rodu vent breccia. RMGC Internal Tehnical Memorandum
- Rosu E., Pécskay Z., Stefan A., Popescu G., Panaiotu C., Panaiotu, C.E. (1997) The evolution of the Neogene volcanism in the Apuseni Mountains Romania: Constraints from new K - Ar data: Geologica Carpathica 48, 6, 353-359
- Sandulescu M. (1984) Geotectonica Romaniei, Ed. Tehnica, 366 p., Bucuresti
- Seghedi I., Downes H. (2011) Geochemistry and tectonic development of Cenozoic magmata's in the Carpathian-Pannonian region: Gondwana Research 202011 655-672
- Szentesy C., Minut A., O’Connor G. (2004) Exploration progress on Bucium Rodu Frasin gold deposit: Fourth National Symposium on Economic Geology “Gold in Metaliferi Mountains”3rd-5th September 2004, Alba Iulia, in: Rom. J. of Mineral Deposits, v. 81, p. 186-187, Alba Iulia

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