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Au-Ag TELLURIDE DEPOSITS IN THE METALIFERI MTS.: EFFECTS OF LOCAL GEOLOGY OR OF A "HYDROTHERMAL ICHOR"

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ABSTRACT: *The Metaliferi Mountains are located in the southern area of the Apuseni Mountains. In these mountains there are the most important gold and silver deposits in Romania and Europe. An unusual feature of the gold-silver mineralization is the presence of gold and silver tellures, discovered for the first time in the deposits in the "golden quadrangle" Brad - Săcărmb - Roşia Montană - Baia de Arieş. In this study there are some clarifications regarding the genesis of these mineralizations and the effects of local tectonics and geology on the formation of gold and silver deposits.*

Keywords: *telluride; tectonic; petrochemical features; gold-silver deposits;*

1. Introduction

The "Golden Quadrangle" (or Quadrilateral) (GQ) in the Metaliferi Mts. (MM), Romania, is well known worldwide especially due to the richness in Au-Ag tellurides (AAT) of several ore deposits in the area. In addition, the GQ is unique in the Carpathians both as a "gold spot" of prime importance in Europe and as occurrences with an unusual high frequency of AAT.

Attempts were made to explain this gold and AAT "anomaly" within the GQ, although the analytical proofs are not always available. Udubasa et al. (2001) pointed out to the peculiarities of the local geology and tectonic setting and invoked the role of the basement as a supplementary source of Au and Te.

Alternately, Cook et al. (2003) "believe the answer lies in the evolution of individual hydrothermal systems, rather than in basement sources". What evolution is meant remains unknown and the arguments presented by Udubasa et al. are thus replaced by a "hydrothermal ichor".

2. Tectonic setting and some petrochemical features

The most striking feature of the magmatism in the MM is its generation in a transtensional regime, by adiabatic decompression and partial melting of the reactivating Upper Cretaceous – Paleogene enriched lithospheric mantle. The resulting graben structure was a consequence of eastward translation and clockwise rotation of the Tisia-Dacia or Tisia-Getia terrane (Seghedi et al., 1998). In this area the evidences of contemporaneous subduction are lacking, as opposite to the other segments of Neogene magmatism in the Carpathians. The same authors invoked a possible relation of the Neogene magma generation to an earlier subduction-related mantle metasomatism event (Late Cretaceous to Early Paleogene magmatism). Thus, the subduction signature of the Neogene magmatism in the MM is inherited from earlier events.

A further feature of the Neogene magmatites in the MM is their distribution along two “alignments” (roughly NW and SE) (Rosu et al., 2001). Between the two alignments is an angle of about 60-70˚. Perhaps it is not a pure coincidence that the clockwise rotation of the MM during Eocene-Miocene was first of 20˚ and then of 60˚.

The rotation started around 14 Ma and progressively diminished (28˚) at 13 Ma and ceased at around 12 Ma (Rosu et al., 1998). It is perhaps not a pure coincidence that the age of the Sacaramb magmatites is “post-rotational”, i.e. of 10-11 Ma.

A transition from normal calc-alkaline to calc-alkaline adakite-like magmas was depicted in some rocks of the MM (Sacaramb area included) and no significant contamination and fractional crystallisation of rapidly ascending magmas could be proved (Rosu et al., 2001). Formally, these facts seem to contradict any influence of the basement in featuring the MM magmatic and metallogenetic events/activity.

3. Historical and computation background

The Metaliferi Mts. (MM) in Romania, the historical “siebenbürgisches Erzgebirge”, contain by far the richest gold deposits related to the Neogene magmatic activity in the whole Carpathians. The AAT ores represent also a unique feature of the area. The Sacaramb AAT ore deposit is situated in the southern part of the MM and is the largest among the AAT ore deposits. Its exploitation began some 250 years ago. The Sacaramb mine produced some 30 t Au, 55 t Ag and 60 t Te from veins located mostly in the volcanic (andesitic) structure. Five main mining horizons exist here, covering a vertical extent of about 450 m. The opening years and their altitude are given below.

Maria	1746	784 m
Bernat	1757	723 m
Josephi (Ferdinand)	1765	637 m
Franz (Carol)	1824	494 m
Franz Joseph (Nicolae)	1898	335 m

The average content of gold was of about 90 g/t at the beginning and of about 3 g/t in the last 50 years, which roughly gives a general figure of 10 g/t Au. Ghitulescu & Socolescu (1941) gave a total output of Au+Ag of 85,000 kg, i.e. about 30,000 kg Au and 55,000 kg Ag.

No data seem to exist concerning the Te content of the ores, which can be only estimated by assuming a Au:Te ratio of 1:2, as in the most important gold tellurides, i.e. nagyagite and sylvanite. From such estimations it results an average content of 20 g/t Te and about 60 t Te (only partly processed and used).

The “closely packed” vein array of Sacaramb shows a garland-like distribution within the volcanic structure. The veins have an average thickness of 0.3 m and a total length estimated at about 300 km (Udubasa et al., 1992).

The Sacaramb volcanic structure is of a moderate size, looking as an inverse cone some 1 km in length, 1 km in diameter at the upper part and less than 100 m at the lowest part known (160 m below the Nicolae horizon). The AAT ore-bearing andesite volume was thus probably of about 0.25 km3 (eroded part included). The ore veins and the related altered host rocks make about 5 % of the volcano volume, i.e. 0.0125 km3, roughly 50 mil. t of “useful material”.

By assuming that the volume of the magmatic chamber producing the Sacaramb volcano was 5 times larger than the volume of the volcanic rocks now exposed (underground and at surface), the volume of the magma and the related magmatic fluids can be estimated at about 1.25 km3.

Taking into consideration the amount of 60 t of Te produced at Sacaramb an average content of 0.058 g/t Te in the magma and the related hydrothermal fluids can be computed. This figure is about 10 times larger than the average value of Te in the earth crust (0.006 g/t). If such an amount of Te can be accommodated by a normal andesitic magma is doubtful or at least should be proved.

4. Discussion; Origin of Tellurium

Due to the lack of data concerning the geochemistry of tellurium, the formation of the AAT ore deposits and especially of the Sacaramb deposit is hardly difficult to be convincingly explained. The Sacaramb deposit remains at least a big anomaly within the Carpathians volcanic chain of Neogene age.

First of all, the comparison of geochemistry of Neogene magmatites does not suggest major differences among the different segments of the Carpathian volcanic chain (Seghedi et al., 1998), except the adakite tendency of some andesites in the MM (Rosu et al., 2001). It is true, the Neogene magmatites in the MM have formed under special conditions, i.e. transtensional regime by adiabatic decompression and partial melting of the reactivating Upper Cretaceous – Paleogene enriched lithospheric mantle (Seghedi et al., 1998). This the first point to be highlighted: inheritance of an earlier subduction event.

Such peculiarities as concern the geochemistry and magma generation, are not sufficient to explain the huge concentration of Au and Te, at least at Sacaramb. Cook et al. (2003) suggest the evolution of hydrothermal system, without giving any data upon this special evolution. The recent review paper of Heinrich & Neubauer (2003) does not bring many novelties concerning the matter under discussion. Based on oxygen isotope analyses Alderton et al. (1998) and Alderton & Fallick (2000) suggest however a metasedimentary signature of the altered rocks. This is the second point in disturbing the role of a special hydrothermal "ichor" promoted by Cook et al. (2003).

Even if the contamination and fractional crystallisation processes cannot be traced from other isotopic data, e.g. Sr, at least for the younger magmatic stages (including the Sacaramb andesites) (Rosu et al., 2001, p. 17), contamination in shallow magma chambers cannot be excluded (the same authors, p. 19).

The role of the basement in the Te (and Au) enrichment cannot be totally ruled out, as there are several arguments, which should be "destroyed" prior to favoring a hydrothermal, undefined "ichor". The arguments are of different kinds:

• *General:*

1) As compared to the Baia Mare area (Pb Zn Cu dominated, with subordinate Au ores) the MM area is Au (Cu) dominated with a special Te signature. In the Baia Mare area there are only traces of basic rocks (scarcely developed Pienides, as a part of the Main Tethysian Suture, Sandulescu, 1984) whereas in the MM the ophiolitic basement is largely developed. In the Baia Mare area the adakite tendency has not been depicted (yet?).

2) No other parts of the Neogene volcanic chain in the Carpathians show such a varied basement as the MM has: Mesozoic ophiolites and sedimentary rocks, banatitic rocks and younger magmatic rocks of Eocene age, as well as sedimentary Mn ores.

• *Specific:*

3) Several magmatic events succeeded and spatially partly overlapped on a large area of the MM terrane:

a) Ophiolites, ~140 Ma;
b) Lower Cretaceous granitoids, ~80 Ma;
c) Upper Cretaceous - Paleogene banatites, 60 Ma;
d) Acidic rocks (scarcely developed), ~40 Ma;
e) Neogene andesites, 15-8 Ma
f) Basaltic and shoshonitic rocks, 1.6 Ma.

Fluid circulation can be traced in every of the above mentioned events, suggesting a repeated heating and cooling of a large area, as well as circulation of fluids of different composition and temperature (Udubasa et al., 2001) and also mixing of fluids of different ages, which could have brought leachates from different sources, some of them uncommonly rich in Te (and Au and Mn).

4) The geochemical triad Au-Te-Mn is very typical, especially for the Sacaramb ores, a feature not encountered in other parts of the Carpathian Neogene chain. However, Popescu (1978) advocated the role of the stratiform Mn ores from Preluca Mts. in explaining the abundance of rhodochrosite at Cavnic, Baia Mare area.

- *Particular:*

5) In a pure Pb-Zn-Au ore deposit (Coranda Hondol) AAT were found exclusively within altered ophiolites (and Cretaceous sedimentary rocks).

6) The Sacaramb AAT ore deposit is situated near the Major Tethysian Suture (Figure 1) and at the same time at the "intersection" of the two alignments with Neogene magmatites (Figure 2), representing thus the "pivot" of the Miocene rotation (?).

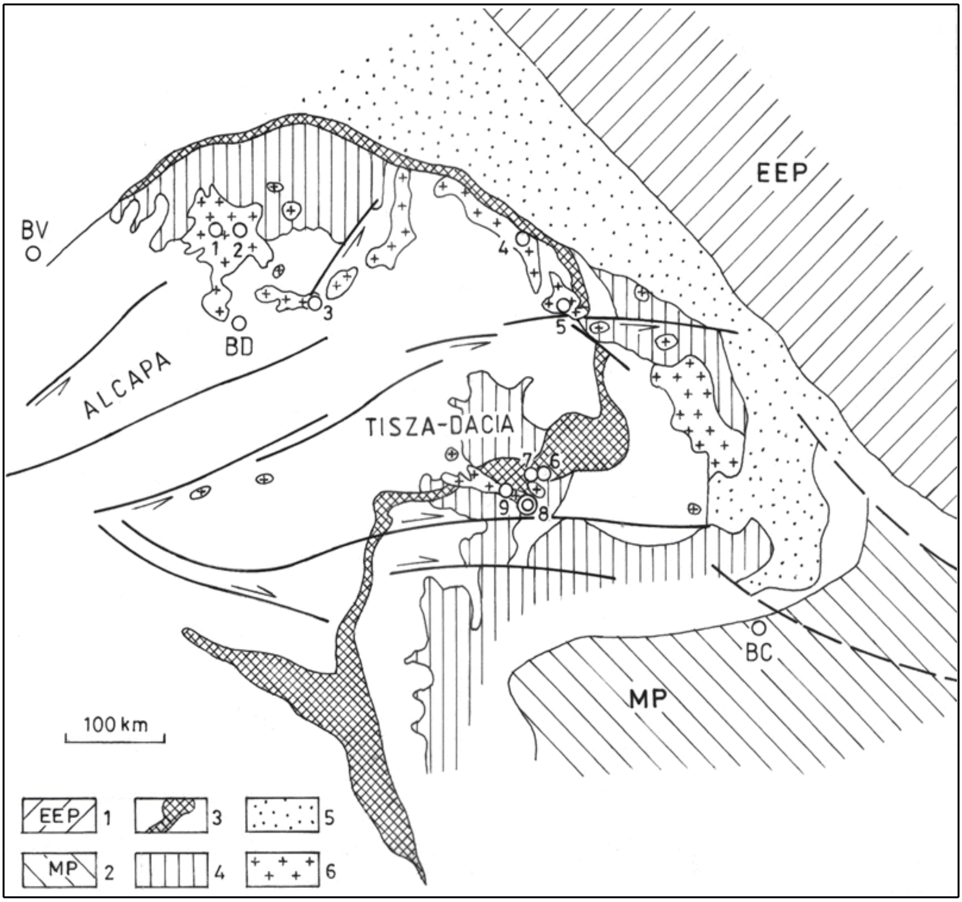

Fig. 1. Structural sketch of the Carpathians showing the distribution the Tertiary volcanic rocks and the location of the 9 major ore deposits related to them

(1. Kremnitsa (Au), 2. Banska Stiavnica (PbZnCu); 3. Recsk (Cu); 4. Vyshkovo (Hg); 5. Baia Sprie (PbZnCu); 6. Rosia Poieni (6); 7. Rosia Montana (Au); 8. Sacaramb (AuAgTe); 9. Brad (Au). EEP (1)-East European plate; MP (2) Moesian Plate; 3-Major Tethysian Suture; 4-Pre-Neogene rocks; 5. Carpathian Flysch Belt; 6- Tertiary calc-alkaline and alkaline volcanics. The Miocene kinematics (simplified) acc to Royden et al.(1982), Csontos et al. (1991) and Fodor et al.(1996) – from Hippolyte et al.(1999). Abbreviations: BV-Bratislava; BD-Budapest; BC-Bucuresti. (simplified, acc. To Sandulescu, 1984; Seghedi et al., 1998; Hippolyte et al., 1999)

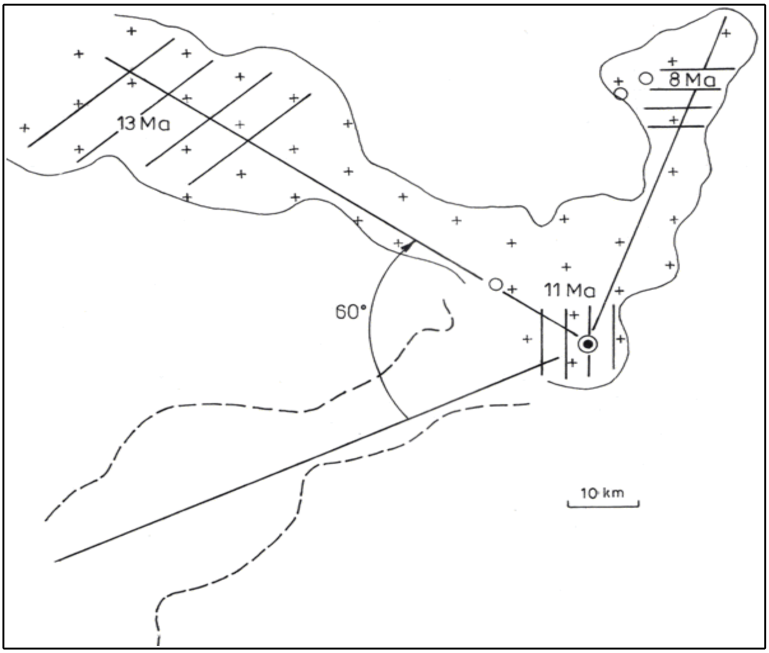

Fig. 2. Cartoon showing the position of the western alignment with Neogene magmatites (crosses) before the rotation (14-12 Ma). The Sacaramb AAT ore deposit might be regarded as a "spindle" of the two alignments.

- *Computational:*

7) The magmatic chamber producing the Sacaramb volcanic structure should have contained ten times more Te (0.058 ppm) than the average content in the earth crust (0.006 ppm).

This figure was computed in order to obtain the amount of Te (about 60 t) produced by the Sacaramb mine. If an andesitic magma with related fluids can accommodate such large amounts of Te (and Au: 30 t and Ag: 55 t) remains to be proved.

8) The so far highest Te contents in terrestrial materials were determined in some limestones and shales (Beaty & Manuel, 1973).

Amazingly enough, the cosmic abundance of Te and its abundance in biosphere is higher than in the lithospheric materials (Cohen, 1981). The average content in meteorites is of about 1 ppm (Greenland, 1967).

5. Final conclusion

Instead of promoting a hydrothermal "ichor" (a special evolution of hydrothermal systems) it would be more realistic to take into consideration the above mentioned arguments, most of them not obvious at the first glance and not easily to be overlooked.

In addition, one conclusion released by Afifi et al. (1988) from their experimental study of telluride stabilities is as follows: "The deposition of tellurides in ore deposits is due to a short-lived increase in Te fugacity, probably reflecting a finite supply or an abbreviated release mechanism for tellurium at the source" (p. 402). No further comments are needed. Just remember: "short-lived increase in Te fugacity" and "finite supply … for tellurium" should be accommodated to a hydrothermal model before the effects of local geology will be totally refuted.

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Appendix

1. Some data on geochemistry of Te (average values, ppm)

Crustal abundance	0.005	(Cohen, 1984)
Earth crust	0.006	(Rosler & Lange, 1972)
Meteorites	0.1	(Goldschmidt, 1937)
	1.02	(Greenland, 1967)
Rocks	0.0018	(Goldschmidt, 1937)
Igneous rocks	0.0082	(Beaty & Manuel, 1973)
Carbonates rocks	1-2	(Beaty & Manuel, 1973)
Human body	560mg	(Beaty & Manuel, 1973)

2. Enrichment factors for Sacaramb ores

Te	3,333x (20ppm, av.ores: 0.006)
Au	2,500x (10ppm, av.ores: 0.004)

3. Computation of the total amount of Te produced by Sacaramb mine (Te content of the ore never measured) by using three different methods:

I. By assuming a double amount of Te as compared to Au (30t)	60t
II. By considering 200 Km of mining workings on veins (1.8Mil.t)	52t
III. By considering the waste dumps (about 40 Mil.t) and giving about five per cent therefrom for the ores extracted	60t