AN INTEGRATED GEOPHYSICAL TOOL FOR LOCATING Au-Ag DEPOSITS IN NEOGENE VOLCANICS IN ROMANIA

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Abstract: Gravity and ground & airborne magnetics have been widely used in the last decades in Romania covering large areas with Neogene volcanics aiming at revealing their main structural and petrographic features. The main targets were represented by fault/fracture systems and intrusive magmatic bodies hidden to direct geological observation. Sectors of metallogenic interest, such as hydrothermal haloes, breccia bodies or mineralized veins were generally surveyed using electrometry or/and geochemistry.

Airborne and ground gamma ray spectrometry measurements, originally performed for U and Th accumulations, have been used in studying Neogene volcanic and subvolcanic structures, due to the close spatial association of hydrothermal minerals rich in potassium (K^{40}) (sericite, adularia) with metallogenic features (veins or mineralised breccias). Adularia proved to be associated in most cases with gold, pyrite and quartz.

Mercurometry (Hg spectrometry), as a method based on the high volatility and mobility of Hg, that is able to migrate vertically through thick sequences of rocks and overburden, is considered to represent a direct indicator for hydrothermal Au-Ag accumulations. The migration of Hg toward the surface is continuous, enabling this method to reveal even the presence of "blind" ore deposits, buried beneath younger geological formations or simply Quaternary deposits.

These methods have been lately integrated in an exploration tool (Ioane, 1999), designed to perform a complete study of Neogene magmatic structures and locate Au-Ag hydrothermal accumulations.

Geological setting of Neogene volcanics in Romania

Neogene volcanism developed on large areas in the East Carpathians and Apuseni Mountains, this magmatic activity being considered as a result of subduction processes (Radulescu, Sandulescu, 1973), of tectonic compressions following a continent-continent collision, or of a discontinuous subduction, that generated a volcanic arc during Neogene-Quaternary (Seghedi et al., 1995).

In the Apuseni Mountains, Neogene volcanics (Badenian-Pliocene) outcrop in the Metaliferi, Drocea and Codru Mts., the magmatic processes developing mainly along NW-SE tectonic lineaments north of an E-W crustal fault (Mures Valley), that is considered to represent a subduction plane (Borcos et al., 1980). The volcanic activity started in the Lower Badenian, these processes resuming during Pontian-Upper Pliocene. The magmatic products are represented by volcanic edifices, necks, lava flows, breccias and subvolcanic bodies, most of them intensely eroded. The hydrothermal alterations of the Neogene magmatic rocks have been controlled by intrusive bodies and tectono-magmatic fracture systems. The most important mineralizations are associated with the hydrothermal haloes developed within the "Golden Quadrilateral" in the Metaliferi Mts., and contain Au-Ag and base metal sulphides.

The north-western end of East Carpathians in Romania includes important areas with Neogene volcanics within the Oas-Gutai-Tibles Mts. The magmatic rocks are considered to result from subduction processes (Bleahu et al., 1973) and develop along two crustal fractures, trending E-W and NW-SE. The volcanism migrated in space and time from west to east, and from south to north, during Badenian-Dacian (Seghedi et al., 1995). The magmatic products are quite similar to those emplaced within the Apuseni Mountains, including stratovolcanoes, necks, lava flows, subvolcanic bodies and volcano-sedimentary formations. Due to intense hydrothermal alterations, the structure of the volcanic edifices and tectono-volcanic lineaments can be hardly observed. The metallogenic products (Au-Ag and base metal sulphides) associated with hydrothermal haloes develop mainly in veins trending NNE-SSW, rarely W-E and NW-SE.

Hydrothermal alterations

The hydrothermal alteration processes yielded propylite, chlorite, adularia, sericite, clayey and carbonate rocks, a succession which is not always complete within the transformed magmatic rocks or/and sedimentary formations. The argillization-silicification hydrothermal processes affecting the Neogene magmatic rocks induced the substitution of the accessory magnetite with iron sulphides. The argillization-sericitization process is considered as an important stage of hydrothermal alterations, being controlled by tectono-volcanic fracture systems. Potassium rich solutions involved in these processes determined significant mineralogical modifications within the host rocks, the newly formed minerals including adularia and sericite being closely situated with respect to the fractures, veins or breccia bodies. Considering the relationships noticed between hydrothermal alterations and metallogenic products, many times adularia haloes are associated with epithermal Au-Ag mineralizations, while sericite haloes are correlated mainly with mesothermal base metal sulphides.

Petrophysical and geophysical data

Variations in the rocks density observed within the volcanic products are mainly due to differences in mineralogical composition, structure, type and degree of hydrothermal alterations. They may determine in many cases important density contrasts that enable gravity surveys to locate volcanic and subvolcanic bodies by either high or low gravity anomalies, depending on the specific geological environment. Fault systems that are often involved in metallogenic processes may be also depicted on Bouguer maps as lineaments of rapid variations in gravity. Within the hydrothermal haloes, where the argillization processes affected strongly the magmatic rocks, density may decrease significantly, high accuracy gravity data being able to reveal breccia bodies or important vein systems. In Fig. 1 is displayed such a situation, density measurements on andesitic rocks hosting an Au-Ag vein in the Metaliferi Mts being situated on a profile that crosses half of the associated hydrothermal halo. The density variation of 0.16 g/cm^3 on quite a short distance displays significant differences between unaltered and highly argillized rocks (the latter being sampled in the very vicinity of the auriferous vein) (Ioane, 1999).

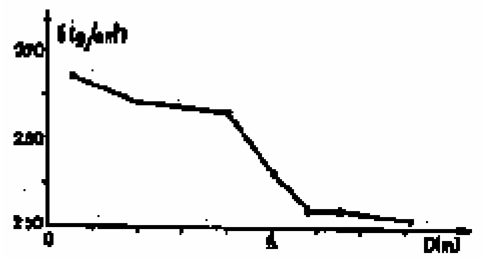
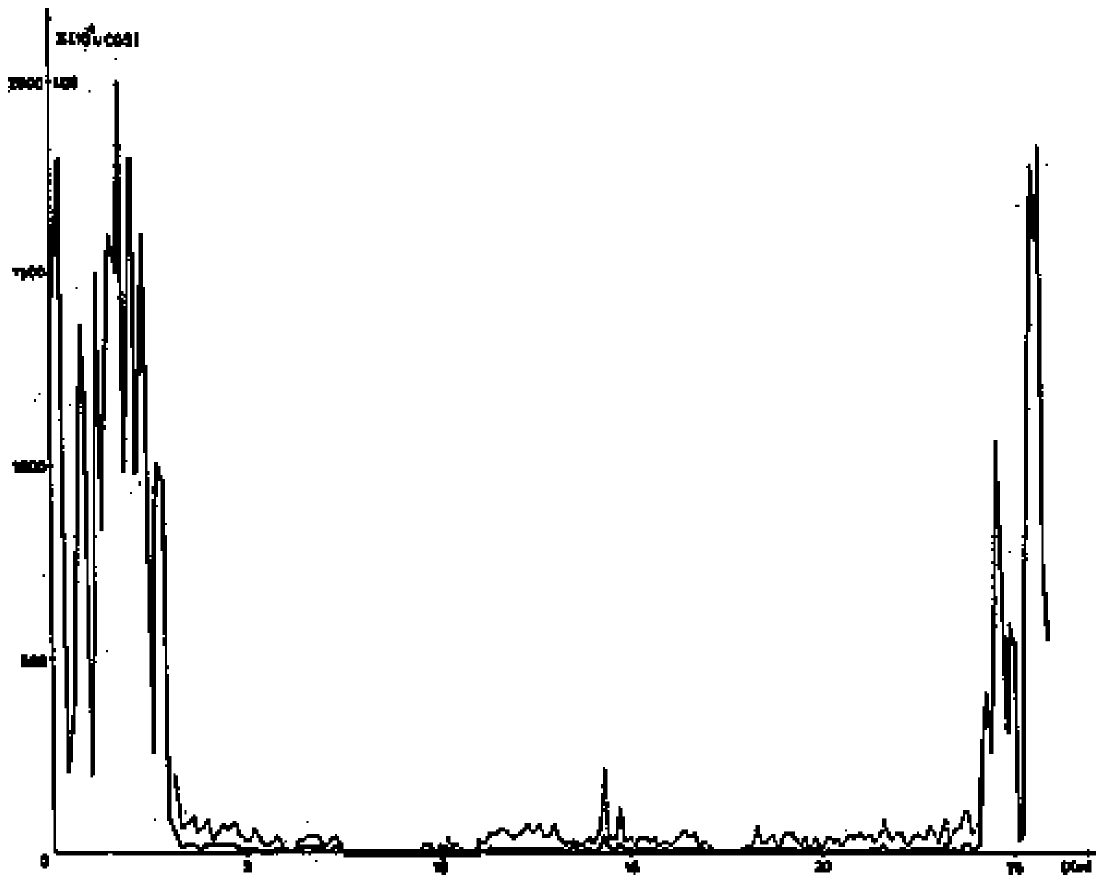


Fig. 1 Density measurements on an Au-Ag vein in the Metaliferi Mts (Romania)

Fig. 2 Magnetic susceptibility measurements across the Au-Ag vein in the Metaliferi Mts (Romania)

The magnetic properties of Neogene volcanics in Romania have been largely investigated, early geophysical studies performed within the Metaliferi Mts (Romanescu, 1963; Calota and Romanescu, 1963) emphasizing good possibilities for magnetic surveys to outline the hydrothermal alteration areas, affected by argillization, sericitization, silicification or pyritization processes. This is due mainly to the substitution of the accessory magnetite with newly formed paramagnetic minerals. Recent petromagnetic and magnetic studies (Ioane and Andrei, 1993; Ioane, 1999) extended such researches in all regions with Neogene volcanism in Romania and found a good applicability for high accuracy magnetic surveys in locating hydrothermal haloes and even metallogenic products, especially when integrated with other geophysical information. In Fig. 2 are displayed the results of continuous measurements of magnetic susceptibility across the studied auriferous vein in the Metaliferi Mts. Two aspects were considered as significant when analysing this picture: a) the abrupt attenuation of the magnetic properties at the outer limits of the hydrothermal halo; b) the absence of any magnetic variations over the mineralized sector. Obviously, in such areas, high accuracy and detailed magnetic maps may



display in good conditions the location and development of fracture systems involved in postmagmatic hydrothermal processes.

The hydrothermal haloes cover large areas in regions characterised by Neogene magmatic rocks and consequently their contouring using gravity and/or magnetic information proved to be not sufficient in many cases when trying to locate Au-Ag accumulations and/or base metal sulphides. Detailed mineralogical studies (Udubasa et al., 1976) showed that hydrothermal mineralizations are closely linked spatially with products of a potassium metasomatosis (adularia, sericite, illite). Laboratory determinations of U, Th and K concentrations on samples of Neogene volcanics displayed significant differences between various petrotypes, enabling gamma ray spectrometry (both ground and airborne) to successfully mapping magmatic structures and/or potassium rich hydrothermal haloes.

Such analyses performed on Neogene andesites and dacites sampled in Romania showed good possibilities of discrimination using information on the U, Th and K contents. For example, amphibole andesites may be characterised by mean values of 1.5 ppm for U and 4.0 ppm for Th, while quartz bearing andesites may contain 1.5 to 3.0 ppm U and 6 to 10 ppm Th. High potassium contents in Neogene volcanics, ranging from 2.5 % to 10.0 %, are many times due to hydrothermal sericite and adularia contents (Ioane and Andrei, 1993; Ioane, 1999).

In Fig. 3 are displayed gamma ray spectrometry data (measurements with shielded detector) and laboratory results on potassium contents in rocks sampled across the same auriferous vein situated in the Metaliferi Mts, Romania (Ioane, 1999). The high potassium anomaly over the sector located closely to the vein is easily observed, both on the geophysical profile and on the K contents obtained on samples of andesitic rocks, affected by variable potassium metasomatosis (adularia, sericite, illite).

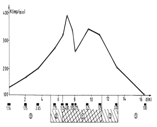


Fig. 3 Potassium anomaly and K content in rocks sampled across the Au-Ag vein (Metaliferi Mts, Romania)

Geophysical tool for locating Au-Ag mineralizations in Neogene volcanics in Romania

The applicability already proved by the geophysical methods considered in this paper (gravity, magnetics, gamma ray spectrometry) in studying Neogene magmatic structures in Romania, as well as some of their valuable metallogenic products (Au-Ag mineralizations), led lately to the integration

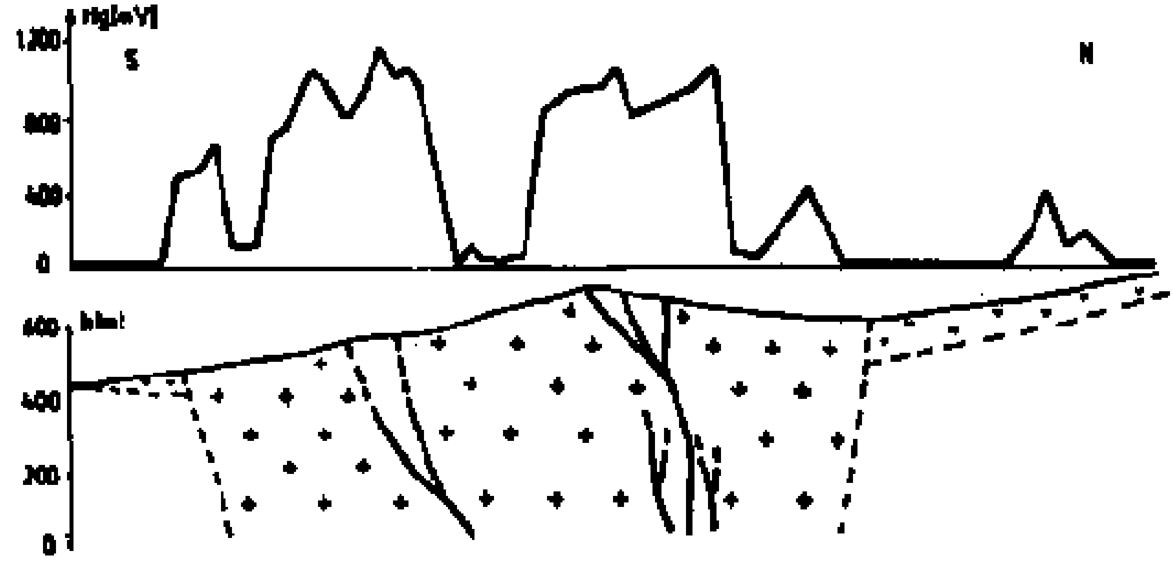


Fig. 4 Mercurometric anomalies across the Baia Sprie Au-Ag ore deposit (Gutai Mts, East Carpathians, Romania)

of their specific capabilities. The following main tasks are envisaged when using these methods:

- the Bouguer gravity data, adequately processed, may be especially exploited for getting information on the structural frame of the studied areas (location of Neogene intrusive bodies, development of fault systems or breccia columns);
- the magnetic data (both ?Z or ?T) may offer two main categories of information: a) location of hidden magmatic bodies, especially when they are unaltered or slightly altered; b) contouring hydrothermal haloes and fracture systems involved in postmagmatic processes;
- the gamma ray spectrometric data, as anomalies of high content in potassium or as high values of the K/Th and K/U ratios, are able to restrict the hydrothermal haloes contoured by magnetics to sectors closely related to the metallogenic features, such as veins or breccias. An important information brought by the radiometric data refers to the main potassium mineral that is developed within the hydrothermal halo. The highest potassium anomalies, corresponding to K content in rocks over 4%, reflect the presence of important adularization processes, many times associated with Au-Ag, quartz and pyrite.

At this stage of the investigation, the processing and interpretation of the above mentioned geophysical data may provide information on the presence of intrusive bodies, hydrothermal haloes, fracture systems that controlled hydrothermal processes and areas rich in potassium minerals (adularia, sericite), closely associated with metallogenic features (veins, breccia bodies). The next important stage of such a study is dedicated to investigations that might provide information on the presence of Au-Ag mineralizations within the magmatic structure. The usual option is represented by electrometric surveys, either induced polarization or electromagnetic. They may prove suitable in numerous situations, but they are quite costly, difficult to perform in rough topography and may lead to ambiguous interpretations when the target mineralizations are enclosed in pyritization haloes. The alternative to electrometry, that is integrated in this geophysical tool, is represented by mercury spectrometry, or mercurometry. This method is based on the association of Hg with low temperature hydrothermal mineralizations (including Au-Ag) and on its high mobility, which enables mercury to penetrate thick sequences of rocks and overburden toward the surface. Such studies that have been carried out in Romania, mainly in Neogene volcanics, showed that mercury anomalies may be related in many cases to the location of the mineralizations, especially epithermal ones. In Fig 4 is presented a mercurometric profile crossing the Baia Sprie Au-Ag ore deposit (Gutai Mts, East Carpathians), the important Hg high content anomalies being nicely correlated with the main veins bearing rich Au-Ag mineralisations (Ioane, 1999).

Conclusions

An integrated geophysical tool for locating Au-Ag mineralizations was tested in Neogene volcanics in Romania. It consists of gravity, magnetics, gamma ray spectrometry and Hg spectrometry, in most cases the measurements being performed in a synergistic mode.

The gravity data provide the structural frame of the studied area, the magnetics being employed to get petrographical and metallogenic information (argillization haloes and fracture systems). The potassium high anomalies may restrict such large haloes to areas closely situated to the mineralized sectors. The mercury high anomalies are usually located within the potassium high haloes, indicating in favourable situations the presence of hydrothermal mineralisations.

Good possibilities of locating Au-Ag mineralizations using this complex geophysical tool are offered by correlating potassium high anomalies determined by zones rich in adularia and mercury high anomalies, determined mostly by epithermal metallogenic products.

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