FIELD TRIP GUIDE

THE ROSIA MONTANA ORE DEPOSIT

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Abstract

The Rosia Montana gold deposit is located in the historical gold mining district known as the Golden Quadrilateral within the Apuseni Mountains of Transylvania in western Romania. Historical gold mining has occurred at Rosia Montana since pre-Roman occupation of the area during the Dacian period over 2000 years ago. Gold at Rosia Montana occurs within n intermediate-sulphidation style epithermal mineralized system, hosted in Tertiary age dacitic intrusions and associated phreato-magmatic breccias. The diatreme is situated within an area dominated by Cretaceous shallow marine and deltaic sediments. Recent exploration of the deposit by Gabriel Resources has outlined a total resource (measured, indicated and inferred) of 400.41 million tonnes at an average grade of 1.3 grams per tonne gold and 6.0 grams per tonne silver for a total contained resource of 16.1 million ounces of gold and 73.3 million ounces of silver.

Regional Geology

Romania includes three major Alpine and older orogens, namely the Carpathian chain that comprises the Southern Carpathians and the Eastern Carpathians, the Apuseni Mountains and the Northern Dobrogea. Tertiary sediments were deposited in the intervening Pannonian and Transylvanian Basins, as well as on the Scythian and Moesian Platforms. Two principal areas of Tertiary volcanic rocks, of predominantly calc alkaline affinity, intrude and overlie these sequences. First one spreads in the Eastern Carpathians from the north in the Baia Mare area (Oas-Gutâi mountains) to the south (Calimani-Gurghiu-Harghita mountains), containing also a subvolcanic median sector (Tibles-Toroiaga-Rodna-Bârgau mountains). The second area with Tertiary volcanic rocks is the Apuseni Mountains in central-western Romania.

The famous mining districts of the Metaliferi Mountains of Transylvania, which represent the southern part of the Apuseni Mountains, comprise a 500km^2 region, immediately to the north of the city of Deva, commonly referred to as the Golden Quadrilateral (Fig. 1). The Golden Quadrilateral has remained Europe's most important centre of gold production for more than 2000 years since Geto-Dacian (pre-Roman) times, with the Roman conquest of Dacia in 105AD-106AD predicated on gaining control over this important goldfield. The district reached peak production during the period of the Austro-Hungarian Empire at the end of the 17th Century to 1918 as well as before World War II.

The Golden Quadrilateral lies within the Apuseni Mountains, which consist of Mesozoic, shallow marine and non-marine sedimentary rocks overlying Palaeozoic and Precambrian sedimentary and metamorphic basement. North-directed thrust faulting during the late Cretaceous resulted in a series of nappes that are unconformably overlain, and intruded, by Tertiary volcanics associated with high-level gold-silver mineralisation and porphyry copper deposits of the Golden Quadrilateral.

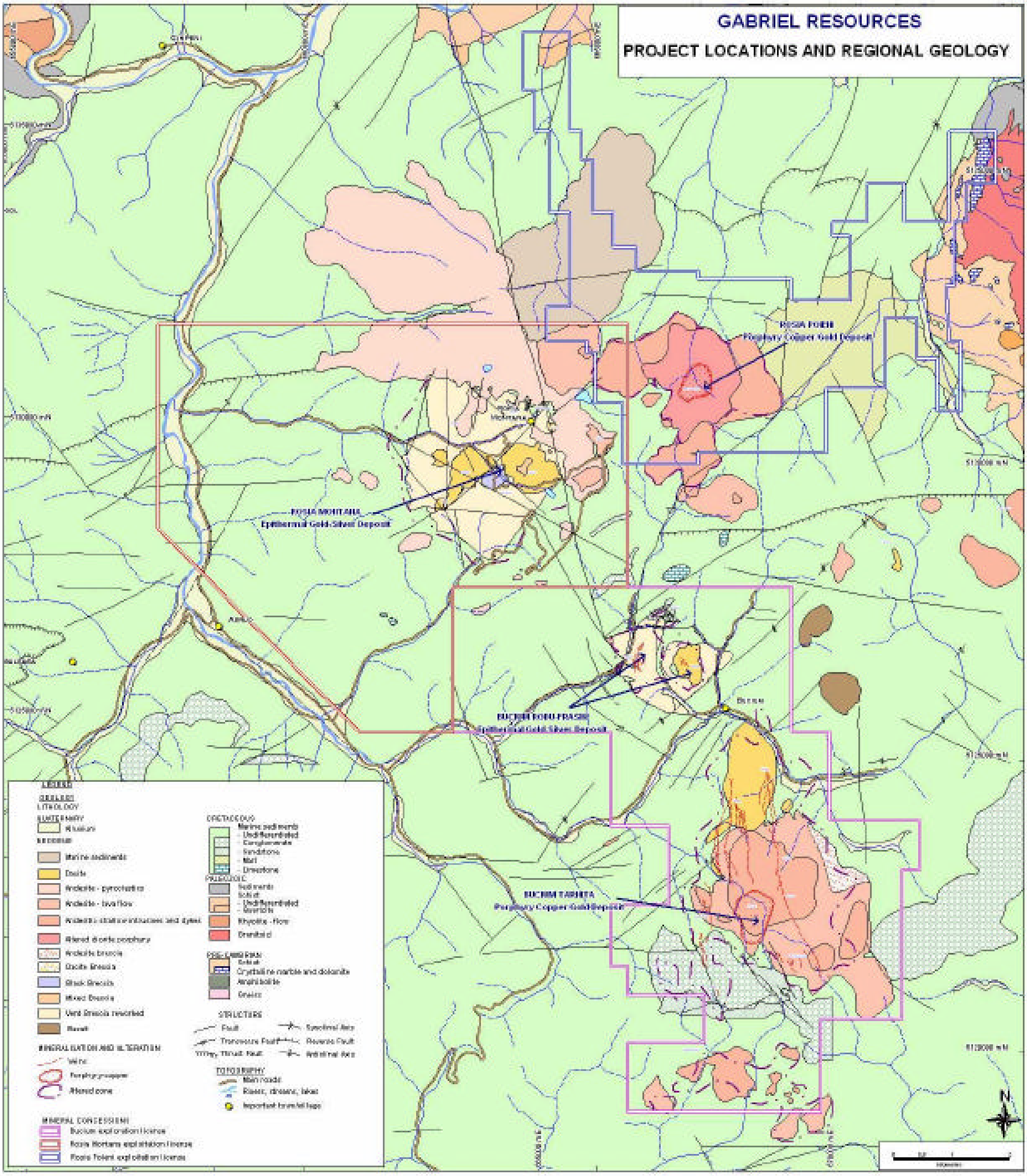

Fig. 1. Rosia Montana regional geology

According to the classical view regarding the Tertiary volcanism from the Apuseni Mountains three cycles has been distinguished (Ianovici et al., 1976). The earliest cycle is interpreted as lower Badenian age and comprises rhyolitic ignimbrite overlain by rhyodacitic and andesitic volcanics. Volcanogenic sediments occur throughout this cycle and widespread hydrothermal alteration overprints all rock types.

The rocks of the second cycle outcrop extensively and are characterised by andesite and dacite overlain by a very thick sequence of quartz andesite that is, in turn, overlain by pyroxene andesite. The sequence is interpreted to be late Badenian – Sarmatian and Pannonian age. The middle (dacite) and upper (quartz andesite) sequence of this cycle represents the principal host to gold-silver mineralisation currently being mined in Romania, as well as significant occurrences of copper, lead, zinc and mercury.

The third and final cycle of volcanism continued into the Quaternary era and is characterised by pyroxene andesite, basaltic andesite and potassic basalt.

According to available K-Ar datings (Pécskay et al., 1995), the main volcanic activity from the Apuseni Mountains range between 14.7 and 7.3 Ma, and ended in Quaternary (1,6 Ma).

Three major northwest-trending belts of volcanism (Brad – Sacarâmb, Zlatna – Stanija, and Rosia Montana-Bucium) and associated mineralisation are identified within the Golden Quadrilateral, with the Rosia Montana Complex representing part of the northernmost belt.

Project Geology

The local Rosia Montana deposit is interpreted as a maar-diatreme complex of Neogene age emplaced into a sequence of Cretaceous sediments, predominantly black shales, sandstones and conglomerates. Mârza et al. (1997) documented the Rosia Montana ore deposit as a low sulphidation epithermal deposit. More recently, Rosia Montana has been interpreted as intermediate sulphidation epithermal (Sillitoe and Hedenquist, 2003).

The three dimensional geometry of the area is well established due to the extensive network of underground development that has been undertaken since the Austro-Hungarian Empire period, and from the extensive surface and underground drilling completed in the last 25 years.

Lithologies within the diatreme complex are dominated by breccias, including magmatic-phreatic and sub-aqueous reworked breccia, intruded by porphyritic dacitic sub-volcanic intrusives. These intrusions are interpreted as Neogene age and are informally named the Cetate dacite (Cetate and Cârnic massifs). The dacite bodies are interpreted to have intruded vertically through the diatreme breccias and to have spread laterally at shallower levels forming surface domes (Fig. 2). An alternative interpretation is that only one major dacite intrusion has occurred and that this has been split into the now separate Cârnic and Cetate dacite bodies by a northeast trending strike-slip fault.

The majority of the Rosia Montana diatreme is made up of a lithology locally referred to as the ‘vent breccia’. This is a diatreme breccia produced by numerous magmatic-phreatic eruptions produced as hot rising dacitic magma interacted with ground water. The vent breccia hosts the dacitic intrusives and, in the case of Cârnic, forms a sub-vertical, ‘ribbon like’ NE-SW oriented structure inside the dacite. This is referred to as the ‘internal vent breccia’ for descriptive statistical and estimation purposes. It is of variable composition with clasts of dacite, Cretaceous sediments and basement schist and gneiss. The clast size, degree of rounding, and the proportion of matrix, vary widely. Texturally it exists as both massive breccia units and sub-aqueous reworked breccia indicating the breccia has erupted into a shallow lake or maar.

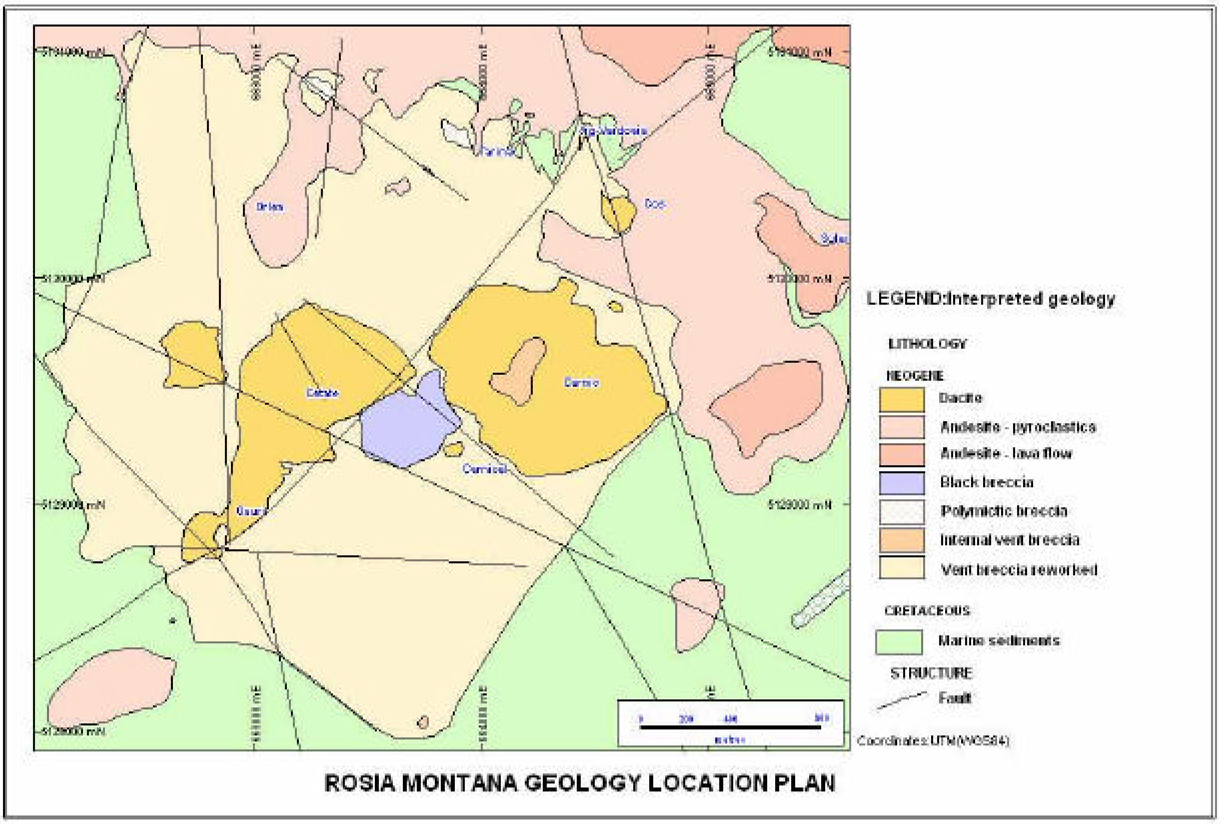

Fig. 2. Rosia Montana geology

This reworked vent breccia is fine to coarsely bedded and varies from clay rich to more common sandy and gravely beds through to beds containing poorly sorted, cobble sized clasts. Graded bedding is common and cross bedding and ripple marks have also been observed.

A breccia, locally termed the 'Black Breccia', forms a sub-vertical pipe within the complex core, emplaced adjacent to the dacitic intrusions. The Black Breccia consists of clasts of Cretaceous black shale from the surrounding sedimentary sequence incorporated into the explosive deposits in the centre of the maar complex, along with clasts of 'basement' lithologies such as garnet-bearing schist and gneiss. The unit only hosts significant gold-silver mineralisation along its northeastern margin. The matrix is dominated by pulverized (rock flour) Cretaceous shale.

A number of intrusive polymictic diatreme breccia bodies that crosscut the reworked vent breccia have been identified between Tarina and Jig. These are composed of matrix-supported breccias with sub-rounded clasts of dacite, Cretaceous sediment and crystalline schists. They vary from poorly sorted to moderately sorted and generally have a uniform maximum clast size (0.5 to 5.0cm) within a specific eruptive unit. The matrix is made up of pulverized sand sized dacite, Cretaceous sediments and schist (rock flour). These are the product of magmatic-phreatic eruptions at depth (within the schist), and have followed steep fault structures to the surface giving them a sub-vertical orientation and are either cylindrical or elongated along the structure in shape. They are up to 150m in width and are generally well mineralised.

In the Igre area dacite and polymictic breccia dykes have also been identified within the Cretaceous sediment. The diatreme breccia dykes are usually 0.5m to 2m in width and are lithological similar to the diatreme breccia described above. These are interpreted to be offshoots of the diatreme breccia material along smaller faults. The dacite dykes are usually 0.5m to 1m in width and are composed of fine-grained, silicic dacite, with coarse sand-sized phenocrysts of quartz. Dykes containing both polymictic breccia and dacite have also been observed.

Andesitic extrusive rocks are mapped mantling the northern and eastern parts of the project area, forming a thin to moderately thick cover over the maar complex. The lowest units within the sequence are pyroclastic block and ash flows, further north and east andesitic lavas overlie the pyroclastics.

Structure

Structure has played an important role at Rosia Montana, firstly supplying dilation for the emplacement of the maar-diatreme complex, and secondly the structural permeability up which the mineralising fluids have flowed.

The Rosia Montana diatreme is interpreted to be emplaced at the intersection of two sub-vertical structures that trend north-northwest and northeast. The north-northwest trend is interpreted to be the earlier and the larger of the two structures. This is a basement structure and of regional scale that has produced the broad zone of fracturing and veining that is seen on the surface within the dacites, vent breccia, Cretaceous sediments and in the andesites at Bucium. It can be traced from Orlea North through Orlea, Cetate and Cirnic and down through the Bucium exploration licence to the south; along this 13 km trend the dominant vein orientation strikes parallel to it and is either sub-vertical or dipping steeply to the west.

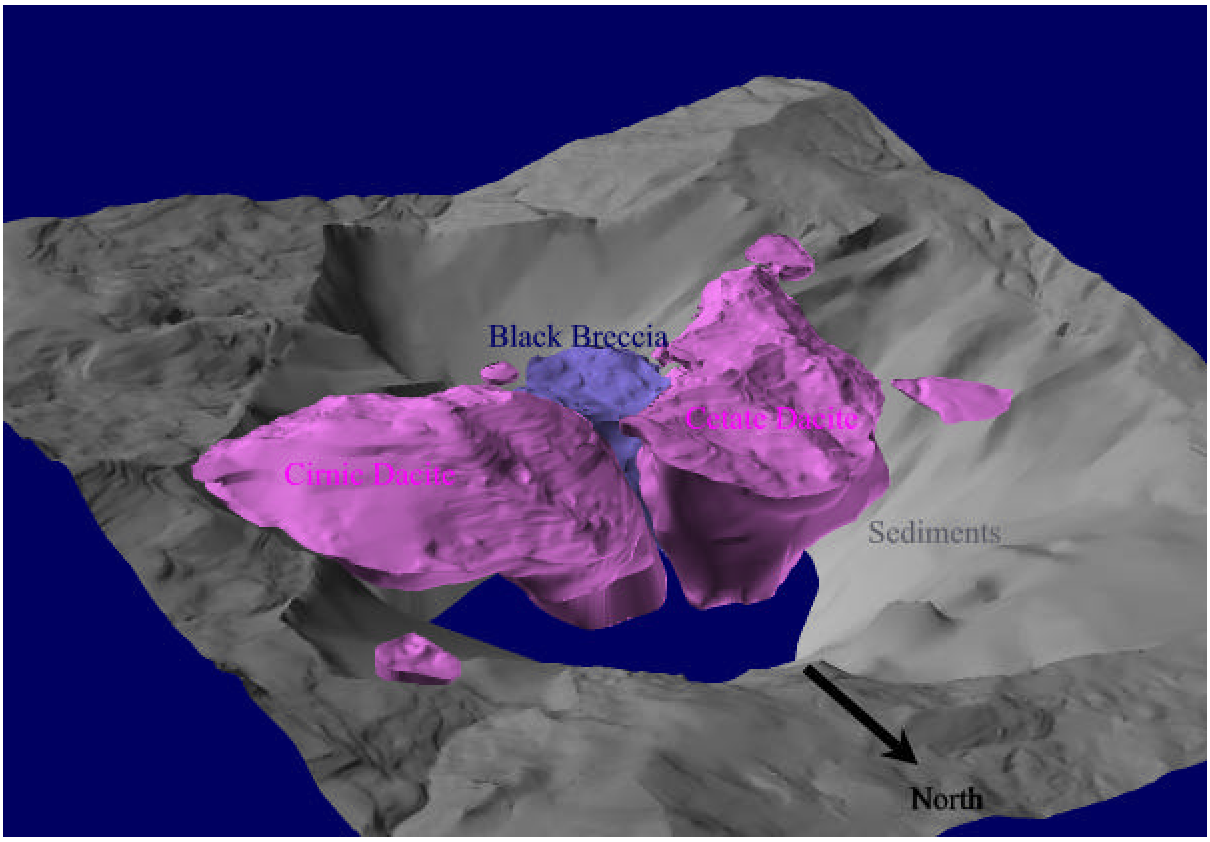

Fig. 3. Perspective view of the geological model.

Across the north-northwest structural trend cuts the northeast trending faults, interpreted to be dominated by left-lateral strike slip movement. The intersection of these regional structures has produced dilation and a focus for the breccias, intrusions and mineralisation at Rosia Montana. Steeply southwest dipping northwest trending structures have also been identified in the Igre area. These are interpreted to have a right lateral sense of movement and may be the conjugate pair to the northeast trending structures.

At Orlea, a large east-west trending clay rich vein (the Crucii vein) dipping at 45º to the south, cuts across the vent breccia. This structure is interpreted to be related to diatreme collapse immediately following eruption of material from the vent. Similar structures have also been interpreted in the Tarina and Igre areas and also tend to dip moderately to steeply towards the centre of the diatreme.

Alteration

An extensive zone of strong hydrothermal alteration hosts the Rosia Montana deposits. The distribution of alteration assemblages is quite complex, however, it can be simplified down to the following groupings (Manske 2004):

i) Chlorite-carbonate-smectite alteration. Peripheral to the resource, there are not many locations where this alteration has been preserved except for a few small outcrops on Cârnic hill. Although a “green” alteration that superficially resembles a propylitic imprint, this zone lacks epidote or appreciable albite (it may preserve relicts of the original igneous plagioclase, andesine-labradorite). It most closely matches the “intermediate argillic” alteration type in the sense of Meyer and Hemley (1967).

ii) Phyllic-argillic alteration. The most widespread alteration at Rosia Montana, creating most of the “bleached” exposures in dacite porphyry. Rocks affected by this alteration show abundant fine-grained sericite (illite) and murky, birefringent clays (smectites) in thin section. XRD analyses and glycolation tests indicate the presence of mixed-layer, illite-smectite minerals as well (*cf*. Tamas, 2002). Supergene argillization certainly exists in the weathering profile over the pyritic orebodies, but the presence of phyllic-argillic altered rock in the sulfide zone shows that much of the clay is hypogene.

iii) QSP (quartz-sericite-pyrite) alteration. QSP appears as a subtype of the general phyllic-argillic imprint, around some quartz veins and also as local zones of more pervasive alteration. It imparts a bluish-gray color to the rock and may be confused with moderate silicification, but may be easily scratched with a knife blade or steel dental pick ($H < 5$). Silica may or may not have been added to QSP rock, as the quartz may be generated by release of SiO_2 during hydrolytic alteration of feldspar (*e.g.*, Barton *et al.*, 1991). This alteration type may destroy much of the primary igneous texture of the rock, except for quartz phenocrysts.

iv) Quartz-adularia replacement. Adularia ± quartz appears in vein halos and as more pervasive alteration in dacite and vent breccia. Fine-grained adularia in some cases effects a wholesale replacement of the dacite matrix and creates a pale rock with ceramic-like texture. In extreme cases, original quartz phenocrysts are attacked and partly replaced with adularia along grain boundaries and micro-cracks. As rock alteration, adularia commonly is partly overprinted by sericite (illite) or clays. As a vein mineral in dacite or a vug-filling phase in breccia, paragenetic studies show that adularia was introduced into the system at two or three distinct stages.

v) Silicification occurs in some quartz vein halos but is not volumetrically widespread in unbrecciated dacite, at least in the Cetate area. Strong silicification is much more characteristic of the margins of breccia zones within or along the edges of the dacite flow-domes. Brecciated dacite but especially the breccia matrix may be densely silicified, replaced by more than 90 vol. % fine-grained quartz as seen in thin section, and much harder than a knife blade in hand sample (H ~ 7).

XRD and TEM analyses (Mârza et al, 1997, Tamas, 2002) confirmed for Rosia Montana the following alterations: potassium silicate assemblages, phyllic assemblages, intermediate argillic, and advanced argillic assemblages.

Mineralisation

Mineralisation within the Golden Quadrilateral district includes porphyry-related gold-silver, copper-gold and copper deposits associated with Badenian-Pliocene (Neogene) andesitic to dacitic volcanic rocks, and associated intrusive rocks. The gold-silver mineralisation outlined at Rosia Montana is interpreted to represent a mid to shallow-level, intermediate sulphidation epithermal system. The mineralisation is dominantly disseminated, with associated stockwork and breccia hosted gold-silver mineralisation.

Gold-silver mineralisation at Rosia Montana is hosted by the following lithologies:

1. Dacite-hosted mineralisation:

Characterised by wide zones of finely disseminated sulphide hosted within dacite porphyry. Silicic-adularia alteration combined with very fine-grained disseminated pyrite are distinctive features of the mineralised dacite and the best indicator of gold and silver grade. Narrow, usually widely spaced stockwork veining is always present but is minor in terms of contained gold and silver. The veins are generally steeply-dipping, discontinuous and less than 1m wide. Significant gold mineralisation of this style occurs at Cetate, Cârnic, Carpeni, Gauri, Lety-Cos and parts of the Vaidoaia zone.

2. Sub-vertical breccia zones cross-cutting dacite intrusive bodies:

Breccias are commonly of mixed lithology and are considered to represent structurally controlled phreato-magmatic breccias. Mineralisation occurs within strongly, to intensely, silicified alteration zones and contain low to moderate amounts of disseminated fine-grained sulphide within both the matrix and breccia clasts. Relevant examples of this type are known in Cetate and Cârnic massifs.

3. Disseminated and vein hosted gold-silver mineralisation within vent breccia:

Significant gold-silver mineralisation is hosted by the vent breccia surrounding the dacitic intrusions. The mineralisation is characterised by silicification and finely disseminated pyrite with veining infrequent, and generally narrow (less than 1m). Examples of this style of mineralisation are at Cârnicel, Vaidoaia, Jig (also known as Lespedari), Igre, Orlea and Tarina.

*4. **Diatreme breccia pipe hosted mineralisation:***

This mineralisation hosted by the sub-vertical diatreme breccia pipes at Igre/Jig. It is characterised by intense, pervasive silicification of both the breccia matrix and the diatreme breccia clasts, disseminated pyrite is also pervasive within the matrix and clasts and will sometimes completely replace the black shale clasts. Zones of rhodochrosite have also been identified, occurring within the matrix of the diatreme breccia.

5. ***Cretaceous sediment hosted mineralisation:***

This mineralisation has been identified at Igre, Gauri and Cos. The mineralisation occurs directly below the vent breccia-Cretaceous sediment contact and is usually hosted by shale, sandstone and less frequently by conglomerate beds. The mineralisation is characterised by both silicification and pervasive fine-grained disseminated pyrite and in some areas (Igre and Gauri) by hydrothermal crackle brecciation that varies from mm-width widely spaced spidery crackle breccia through to more intense mosaic (jigsaw) brecciation. Clasts are always very angular and made up of locally derived sediment. The brecciation can be over 50m thick and tends to be most intense close to the vent breccia-Cretaceous contact. The breccia matrix is typically vuggy and crystalline, some coliform banding has been observed and up to five phases of mineralisation can be present. Mineralisation is dominated by carbonate (both calcite and rhodochrosite), quartz and pyrite with galena and sphalerite not uncommon and rarer chalcopyrite.

Gold has been identified by petrography in numerous samples as electrum. Occurrences were noted as minute (4 µm) inclusions in pyrite, as minute grains (up to 25 µm) intergrown with, and overgrowing Ag-sulphosalts and tellurides. It has also been observed as coarser grains (up to 100 µm) intergrown with carbonate and barite. The electrum is also associated with quartz, galena, and sphalerite. The electrum had a fineness ranging from .537 to .763 (Leach & Hawke 1997).

Fluid inclusion studies indicate that mineralisation was precipitated from a dilute NaCl (0.35 to 7.85 wt. %) hydrothermal solution at temperatures between 200 to 340°C. The lack of vapour-rich inclusions indicates boiling was not the major trigger for gold precipitation. Gold mineralisation may have formed due to the rising mineralising fluid mixing with oxidising CO_2-rich meteoric waters. (Leach & Hawke 1997, Tamas 2002)

Veining

Although veining is secondary to alteration in terms of contained gold and silver, they are important as fluid conduits and therefore control the location and distribution of the gold-silver mineralisation. The veins often contain significantly higher grade gold and were the focus of historical mining.

Multiple phases of mineralisation have been identified at Rosia Montana that can be subdivided into 3 main vein types:

1. 'Chinga' veins

The 'Chinga' is a black, very fine-grained argilic material, intensely silicified. These 'veins' are the earliest phase of veining at Rosia Montana and their textures indicate that the argilic material has been injected into fractures rather than precipitating from a hydrothermal solution. Chinga material can also occur as breccia matrix and the texture is typically massive, veins are often overprinted by later phase mineralisation. This material was probably derived from pulverised Cretaceous black shales and has been emplaced soon after the diatreme eruption. The chinga veins are most common in the upper levels of the Cârnic and Cetate dacites. The grade of chinga material is typically 0.5 to 3g/t Au.

2. Quartz-carbonate-sulphide veins

These veins are associated with the main mineralising phase at Rosia Montana. Veining occurs as multiphase, quartz-carbonate-sulphide (pyrite) $\pm$ adularia and rare base metals, texture varies widely from massive to banded, often vuggy and from very fine grained to coarsely crystalline.

Carbonate dominated veins are interpreted to have been deposited late in this mineralised phase and are often associated with base metal sulphides. Carbonates are predominately calcite and rhodochrosite, with rarer dolomite and siderite. Base metal sulphides are dominated by galena, low Fe sphalerite and chalcopyrite. The veins are typically narrow (up to 30cm) and more common in the deeper levels at Cârnic and Cetate. This also appears to be the main mineralising phase in the Igre Cretaceous sediments and also the commonest vein type around the margins of the Black Breccia. Textures are typically banded and vuggy, sometimes massive. The very last phase is dominated by calcite with marcasite and very little gold or silver mineralisation. Two tellurides occurrences in rhodochrosite-rhodonite high grade silver veins were recently made (Tamas et al., 2004, Cook et al., this volume).

3. Clay veins

These ‘veins’ are generally considered late stage, possibly retrograde. Locally referred to as veins as they contain some gold-silver mineralisation many of these could be classified as shear or fault structures. Clays vary from illite-smectite to illite and often occur with pyrite and marcasite. They usually display a massive or sheared texture.

Veins are usually discontinuous, widely spaced and only millimetres to centimetres in width, but have been observed up to 1m wide. They generally become less frequent, but thicker and more continuous at depth.

Resources and Reserves

Recent exploration of the deposit by Gabriel Resources has outlined a measured and indicated resource of 352.27 million tonnes at an average grade of 1.3 grams per tonne gold and 6.0 grams per tonne silver for 14.6 million ounces of gold and 82 million ounces of silver. The total resource (measured, indicated and inferred) is 400.41 million tonnes for a total contained resource of 16.1 million ounces of gold and 73.3 million ounces of silver (using a 0.6g/t Au cut-off) (Gossage 2003). Proven and probable reserves total 217.96 million tonnes at an average grade of 1.52 grams per tonne gold and 7.5 grams per tonne silver for total reserves of 10.6 million ounces of gold and 52.3 million ounces of silver (using a 0.6g/t Au cut-off).

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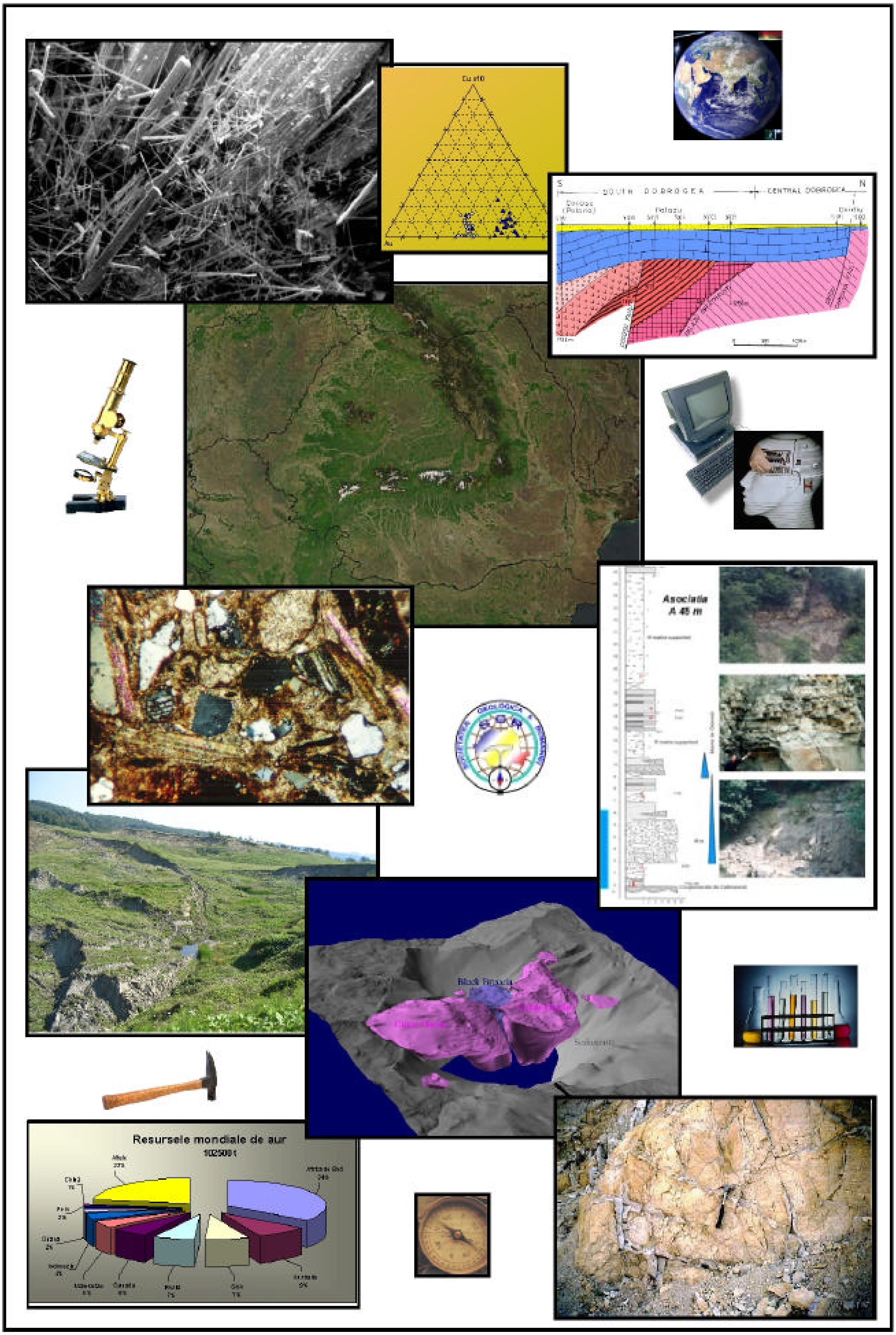

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