Gold in "brown mud"

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My research focuses on high Au anomalies in brown earthy sediments detected by Avala Resources Ltd. along the western margin of the Timok Magmatic Complex (TMC) in the Republic of Serbia. Within the north-south oriented, 80-km-long TMC, there are four differently mineralized metallogenic belts progressing from east to west (Kolb *et al.,* 2012): a Cu-Au porphyry belt, a high sulphidation Au-Cu belt, a diorite porphyry Cu-Au belt, and a sedimentary rock-hosted auriferous belt on the western margin of the TMC. By stream sediment and soil sampling Avala Resources revealed several sedimentary rock-hosted gold deposits (SRHG) in a 20-km-long belt of anomalous Au-As-Sb-Hg-Tl mineralization. These newly discovered gold deposits are Bigar Hill, Korkan and Kraku Pester (van der Toorn *et al*., 2013). The area of my interest, the Bigar Prospect, is located southeast of Bigar Hill. It covers an area of 0.7 km^2 along the contact between a western, marmorized Jurassic-Cretaceous limestone dominated area and an eastern calc-silicate dominated area. The reasons for the contact metamorphic effect are Late Cretaceous intrusive bodies (van der Toorn *et al.,* 2013). Three main fault systems dominate the wider area of the Bigar Prospect (van der Toorn *et al.,* 2013). The oldest system is composed of NW-SE striking structures; a younger is a NNE-SSW striking trend, and the youngest one is an E-W striking system of normal faults. These fault systems have probably been long-lived and have been re-activated several times. Gold mineralization exists both in NW-SE and in NNE-SSW trends but the E-W striking faults lack in it. These E-W striking post-mineralization normal faults have the potential to protect mineralized rocks from erosion by forming graben-like structures.

Geochemical analyses showed that gold is often enriched on limestone and calc-silicate dominated areas. Samples from these areas –both from exploration trenches on the surface and from drillcores– often have a dark-brown, earthy appearance, usually with high gold content (2-10 ppm Au). Due to their weathered appearance it is hard to define their origin. It is also unknown where their high Au, Ag, Pb, Zn and Mn content comes from and to what mineral phases they are connected. The goal of this study is to determine the exact location of gold in the brown earthy material and the nature of the gold concentrating processes.

To answer these questions, complex analytical methods have been used. Mud-like samples were sieved into six different grain size fractions. Each fraction was studied under stereomicroscope to see the appearance of the individual grains. The basic mineralogical composition of the samples (bulk and predominant grain size fractions) was determined by X-ray powder diffraction (XPD). Results of XPD analyses highlighted the connection between different samples, creating a possibility to group them by their mineralogical composition. SEM-EDX measurements were carried out on grain separates and polished sections. 19 samples were selected for ICP-MS and ICP-AAS analysis for 51 elements in the laboratory of SGS Serbia in Bor.

According to XPD results, brown, mud-like samples from drillcores are usually rich in goethite, kaolinite and smectite minerals, have a moderate amount of feldspar and occasionally grossular. Similar, brown earthy samples from exploration trenches are rich in goethite, kaolinite, illite, chlorite, occasionally with high gypsum content and in some cases have moderate feldspar content. Carbonates and quartz are found both in drillcores and in exploration trenches.

The drillcore sample with the highest gold content contains a high amount of brown mud. Upon a closer look, this material can be further divided into three subparts, a creamy white, a rusty brown and a dark brown material. The creamy white part is composed of "detrital grains" in a clayey matrix. The detrital grains are grossular, K-feldspar, quartz, occasionally epidote and titanite, while the matrix is smectite. Kaolinite occurs in patches of distinct contour. Close to the border towards the rusty brown part, 500-µm-size radial groups of idiomorphic cerussite crystals were found. The rusty brown material consists of goethite pseudomorphs after cubic minerals, most probably pyrite. In some cases patchy Mn-Pb-Zn-enrichment is also associated with the pseudomorphs. The third, black part is a very porous, weakly compacted dust. According to the XPD analysis, it contains predominantly goethite. The mineral composition of this subsample is analogous to the highest gold-containing sample according to the observations done so far.

Sieving revealed that the brown mud-like samples are dominated by the <32 µm grain size fraction. This fraction is composed of goethite and clay minerals, such as smectites, kaolinite or illite. In the larger grain size fractions, the most frequent phases were bronze-brown to black, shiny, striated, cubic or cube-like goethite pseudomorphs after pyrite. Another frequent grain type is black, irregular, porous scoria-like clasts. According to SEM-EDX analyses these are likely to be Mn-Pb-Zn oxide or oxyhydroxide phases. These are present in brown muds and their overlying carbonates as well, filling intergranular spaces, cracks and pores, so probably they are the results of late epigenetic processes.

So far, the most valuable ore-related pieces of information from the brown muds seem to be the goethite pseudomorphs, the Mn-Fe-Zn precipitations and the surviving garnets which can be found both in brown muds and in fresh calc-silicate rocks. Therefore, I concentrated on the presence of sulphides and garnets in fresh rocks of calc-silicates –found both in drillcores and on the surface– to mark them as possible source rocks of the brown muds. SEM-EDX analyses revealed that in drillcore samples of fresh skarns, tabular and columnar minerals are replaced by iron-disulphides. Concerning garnets, they are present as andraditic grossulars in brown muds, while skarns in drillcores and on the surface host andradites and grossularic andradites. Based on these results, so far I did not find any direct evidence for a genetic connection between the brown muds and fresh skarns.

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