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Metal Anomaly Prospection at Cerrado. Example for the use of Si-Phytoliths as anomaly indicators at Riacho dos Machado Region, Minas Gerais, Brazil

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RESUMO

O alvo deste trabalho é uma anomalia de metais pesados nos arredores de uma mina de ouro em uma mineração de chumbo. Este estudo investigou a distribuição dos elementos pesados selecionados em amostras de solo e em Si-Fitólitos de plantas. O objetivo foi verificar se o conteúdo de metais nos Si-Fitólitos é indicativo para anomalias destes metal no solo ou substrato. Plantas e amostras de solo foram coletadas em perfis de solos sobre rochas gnáissico-graníticas, que formam o embasamento e que estão em contato tectônico com as unidades sedimentares superiores, pertencentes ao Grupo Riacho dos Machados, parte do Supergrupo Espinhaço. O embasamento é coberto por solos lateríticos a areniticos, com profundidades de exposição diferente. Fluido rico em metal invadiu estas unidades, formando anomalias de metais que chegaram a depósitos econômicos de Pb-Zn-Au, como o de Salobre-Porteirinha e Riacho dos Machados. Após a preparação adequada, as amostras foram, analisadas por ICP-OES (amostras de Si-Phytoliths) e FRX (amostras de solo). Anomalias no perfil investigado são indicadas pelo alto conteúdo de metal na Si-Phytoliths das espécies selecionadas. A concentração de metal em diferentes profundidades usando diferentes espécies pode ser simples e fácilmente executada. As concentrações de Si-Phytolith parecem reproduzir melhor as anomalias metálicas do substrato de rocha do que as amostras de solo.

Palavras Chave: Si-Fitólitos; prospecção de metais; Cerrado; Savannah; plantas

ABSTRACT

The target area of this work is a heavy metal anomaly in the surroundings of a gold mine and a lead mining complex. This work investigated the distribution of selected heavy elements in soil samples and Si-Phytoliths from plants. The aim was to verify if metal contents are indicative for metal anomalies in the soil. Plants and soil samples were collected in profiles over granitic-gneissic rocks, which form the basement, in tectonized contact with the overlaying sedimentary units belonging to the Riacho dos Machados Group, part of the Espinhaço Super Group. The whole rock substrate is covered by lateritic to arenitic soils with different exposure depths. Metal-rich fluid invaded these units, forming metal anomalies culming in Zn-Pb-Au deposits, like that of Salobre-Porteirinha. After appropriate preparation, the samples were, analyzed by ICP-OES (Si-Phytoliths) and FRX (soil). Anomalies in the investigated profile are indicated by high metal contents in the Si-Phytoliths of the selected species. Using different species the metal concentration in different depths can be determined in a simple and easy way. The Si-Phytolith concentrations seem to reproduce better the rock metal anomalies than the soil samples.

Key words: Si-Phytoliths; Metal prospection; Cerrado; Savannah; Plants

1. INTRODUCTION

Weathering and transport processes of rock substrates creates sedimentary or soil covers with element concentrations in function of their primary composition in the disaggregated rocks. Plant takes up the necessary element for their metabolism and may deposit some in special structures inside, called Phytolith (Sendulsky &Labouriau, 1966; Runge, 1999). Plants take up silica and can deposit it in Si-Phytoliths, small opal corps in the plant organism, which help to maintain their structure and also enforce the resistance against herbivores. A large number of native plants from Cerrado are accumulators of this opal structures (Korndörfer *et al*.,1999). According to Wilding & Drees (1971) these Phytoliths are also able to concentrate significant quantities of heavy metals in compatible magnitude to their distribution in the soil. Jaffre *et al.* (1976), Raven (1983) and Rossini-Oliva *et al.* (2009) show the processes of uptake and deposition of heavy metal in selected plants.

Plant uses the ions concentrated in soil to obtain their nutrients. In this process, all ions present are transported into the plant, heavy metals included. The excess of these elements, which are dangerous for the organism, is refused by the plant, which fixes them in Phytoliths of opal or oxalate composition. These fixed elements are trapped and permanently retained from the bio circuit. The knowledge about the physical and chemical composition of the soil is important to know the adaptation and resistance of these plants at the existent conditions (Accioly & Siqueira, 2000). These concentrations remain nearly uninfluenced by the changes of the external factors such as climatic changes or rainfall. Contrary to this the organic parts of plants show these changes in their metabolism and composition (Fig. 1).

Prospecting new mineral occurrences is a very expensive and extensive but necessary process. Many direct and indirect methods are in use. We are showing here a new possibility of biological prospection using native plants to obtain information about metal concentration in subsoil by surface - soil evaluation of metal leaching during weathering. Many authors such as Raven (1993), Turnau (2007) and Wuana & Okieimen (2011) describe the transport and the enrichment processes of ions in plants.

The objective of this work is to suggest a method of prospecting heavy metals that can be applied in a simple, rapid and cheap way without the problems of conventional methods caused by anthropogenic alteration of the surface.

2. STUDIED AREA

The studied area is located southwestern of the village of Riacho dos Machados and northeastern of the mining plant of the Ouro Fino Mine, today operated by Carpathian Gold. Inc. The area is limited by the coordinates UTM 702600E-702300E and 8230750N-8230350N. The access is made from Montes Claros, by the highway BR-251 (68km), then by the State Highway MG-120 (37 km away), covering a distance of 10.5 km in total to the city of Riacho dos Machados. From that point, secondary roads make access to the headquarters of Fazenda Tião Amaral (Figures 2 and 3).

The rocks of the region are of Precambrian age, formed by a granitic-gneissic basement, with meta-sedimentary rocks, like diverse schists and mafic intrusions. Hydrothermalism deposited higher metal concentrations in the contact region from the basement into the over layered schists. The map and stratigraphic profile (Crocco et al., 2006) show the geological situation of the investigated region (Fig. 2), with a distribution of the metal bearing units.

Within the target region, anomalies of three elements were selected (Cu, Zn, and Pb) to test the methodology. Sampling was carried out over a region of about 0.5 km^2. Eighteen soil samples were collected as well as 58 plant samples, three of each species, at each point. Figure 3 shows the sampling area and the distribution of nine batches of samples over the anomalies in the target area (Figure 3; Isoline map of Riacho dos Machados Gold Mining group).

The soils in this investigated area are very little thick and formed by argi- and Cambisoils with a lot of outcrops of argillite, arenite and the basement granites and gneisses (Fernandes-Horn et al. 2016). The climate, using the table of Köpen is of Aw type with dry often humid winters and dry and very hot summers, always with temperature above 18°C (Nimmer 1973, Baggio 2002).

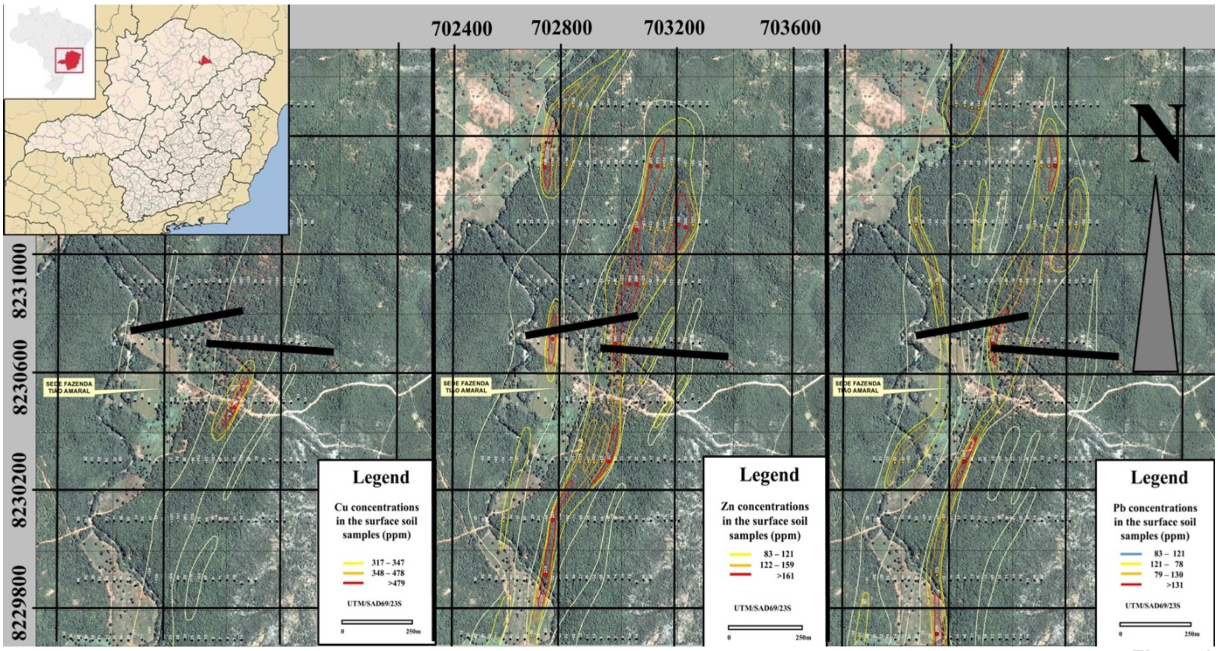

Figure 3

Situation on the investigated site. Maps showing Pb, Cu and Zn distribution in the soil shown as isolines (provided by the Mining Corporation). The samples were taken on two E-W profiles (black lines; unified), cutting the metal-enriched zones.

3. MATERIALS AND METHODS

3.1. SPECIES SELECTION

After a careful field investigation to find the local native species, which produces Phytoliths, 25 were found and determined. Species that are rare or that have seasonal growth with little importance or showing dependence of environmental changes were discarded from the analysis and only five ere selected (Table 1).

Table 1: Selected species for investigation.

Family	Scientific Name	Flowering Period	Fructification Period	Ecologic Importance	Height (m)
Annonaceae	Rollinia leptopetala	November-April	March	Secondary initial	3 - 8
Momosaceae	Piptadenia gonoacantha	November-April	April - August	Secondary initial	6 - 8
Caesalpinioideae	Senna obtusifolia	May - September	October - April	Pioneer	1.5 - 2.5
Malvaceae	Sida sp	Summer	Summer	Pioneer	< 1
Solanaceae	Silanum capsicoides	May - September	October - April	Pioneer	< 3

3.2. SAMPLING

Plants and soil samples were collected following two profiles oriented W-E (1to 4) and NW-SE (5 to 9); they cover all known anomalies. The surface was cleaned of vegetation and every soil sample, 1 to 2 kg weight each, was taken from a depth of 3-10 cm. Five to ten plants of every different species (*Annona leptoptella; Piptadenia gonoacantha; Sida sp*) were collected close to the soil sample locations.

3.3. SAMPLE PREPARATION

The Si-Phytoliths from plants were separated using the method described by Parr *et al.* (2001), those from soil samples were separated using the methodology of COE (2010). Both were dissolved with HF/HNO_3 to dryness, retaken with 10% HNO_3, filtered and stored in a freezer at low temperature. After drying, crushing and sieving to <0,634 mesh, the soil samples were preserved at low temperature.

3.4. ANALYTICAL PROCEDURES

The solutions were analyzed by an ICP-OES spectrometer, type SPECTRA, using internal and international reference standards. The analyses were executed at the NGqA-IGC-UFMG. The soil samples were submitted to FRX-analyses, using a Shimatzu spectrometer, at the Laboratory of LIPEMVALE-Federal University of Jequitinhonha and Mucuri Valleys (UFVJM).

3.5. DATA TREATMENT

The analytical data were submitted to a statistical evaluation, in order to homogenize group data, obtain usable mean values, to detect, and to separate the incorrect data from the set. The analytical soil and Phytoliths data were compared to the anomaly element data obtained from Carpathian Gold Inc.

4. RESULTS

The study consists in an integrated approach, which used field GPS information, analytical data of plants and soil samples and isoline-information from Riacho dos Machados Gold Mine (former: Ouro Fino Mine). The plants accumulate metals in different concentration, in their bio minerals. For this purpose, mean values of whole plant Si-Phytoliths concentrations are used, which are very close to the high contents found only in the leaves.

The analytical data distribution on soils show a good match with the distribution of the isoline data in the maps. In addition to the three main elements (Pb, Zn, Cu) other ones were also evaluated (Mg, Al, Ca, Cr, Fe, Co, Cd, Ti, Mn, Ni, and Ba). Figure 4 shows the correlation between the different concentrations for the selected elements. Elements concentration in Si-Photoliths from plants shows a slightly more complex behavior than that of soil samples, while a correlation between the two data sets were also found. The change of natural factors like rainfall, insolation, and temperature changes influences the Si-Phytoliths less than the whole plant biomass.

The stability of Si-Phytoliths in the soil conditions due to their low solubility do not depend, within a certain range, on climate changes with solute quantity-, temperature-, eH- and pH-changes (Table 2). Using Phytoliths separated from soil instead of those separated from plants the result is nearby the same (Fig. 5) and much better than from total soil sample.

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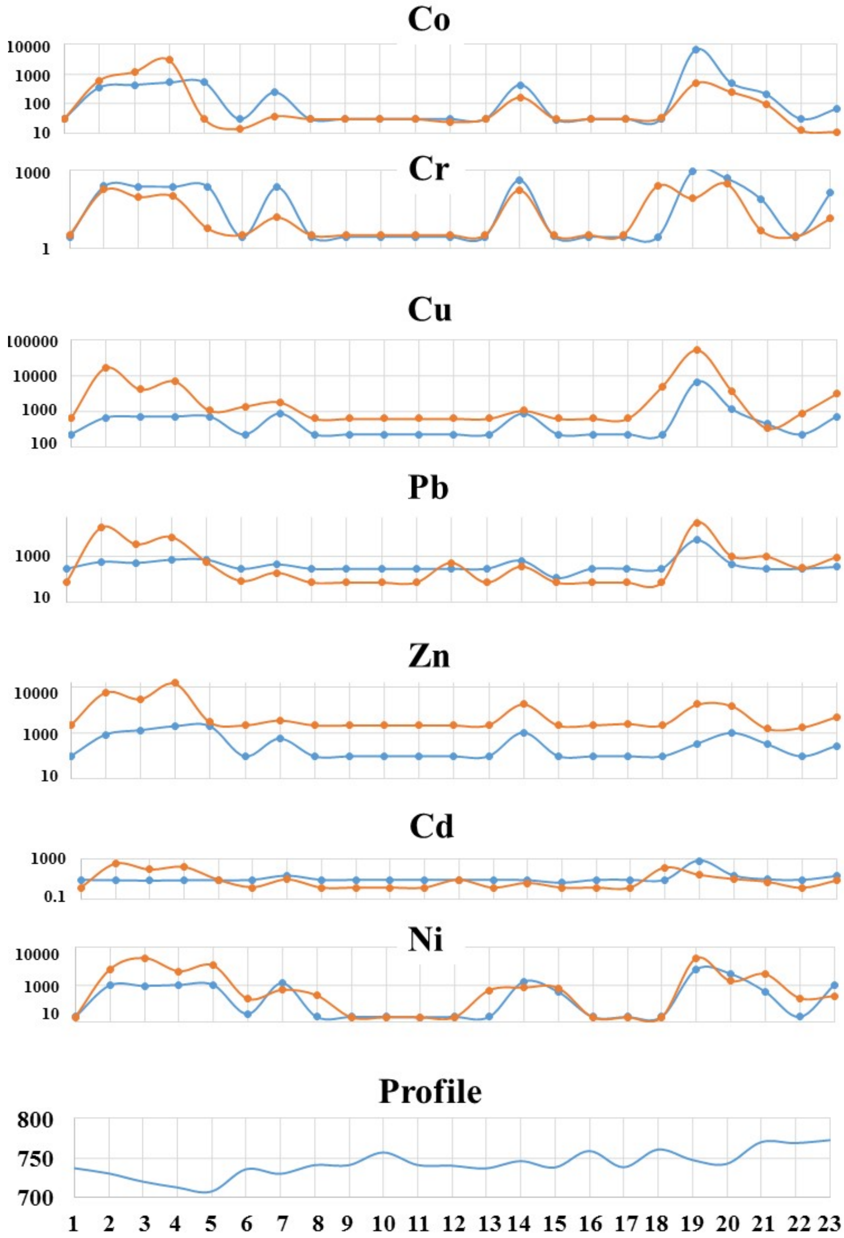

Figure 4
Selected element concentration (ppm) in soils and Si-Phytoliths from plants along an E-W oriented profile (blue: soil samples; brown: Si-Photoliths data). The lowest profile shows the altitude (m). The numbers are the profile sampling points.

Table 2 Solubility and other properties of different SiO_2 species. The solubility under normal soil condition is low and they can take up impurities.

Mineral	Density	Hardness	Impurities (gkg^{-1})	H_2O (gkg^{-1})
Quartz	2.65	7.0	traces	0
Plant opal	1.5 - 2.3	5.5 - 6.5	50 - 150*	40 - 90
Geological opal	1.2 - 2.9	5.5 - 6.5	up to 200**	2 - 10

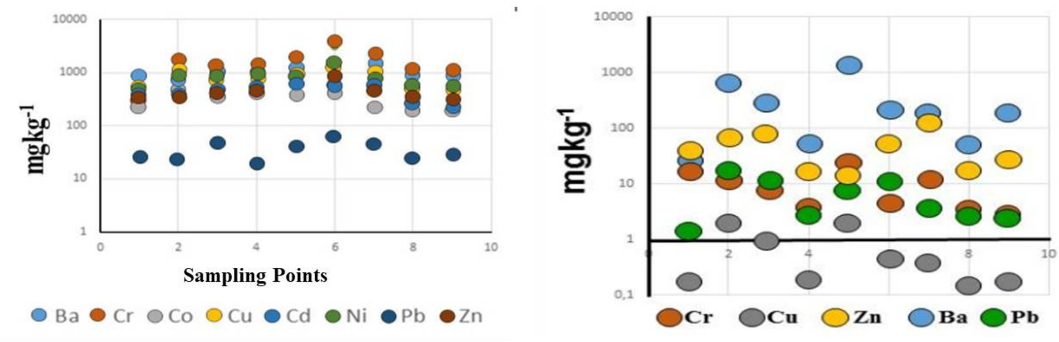

Figure 5
Comparison of metal concentration in Phytolith separated from soil (right) with those from soil samples (left).

4. DISCUSSION AND CONCLUSIONS

The dense distribution of the selected plants and their high Si-Phytoliths production allow their use in the Cerrado/Caatinga region of whole Brazil. This first investigation may stimulate the search for other plants of other biotopes for the same purpose. The information is more exact than the soil sampling method due to the peculiarities of soil evolution and transforming process. The variation of natural factors like rainfall, insolation, and temperature changes influences less the Si-Phytoliths than the whole plant biomass. Si-Phytoliths show metal enrichment correlated with soil metal concentration. The plants can assimilate metals at various concentrations, due to their physiology, the physical-chemical conditions of and the form of the metal compounds. The Si-Phytoliths, due to their inorganic nature, are less sensitive to extreme weather changes, like poor precipitations/lack of rain, insolation or temperature changes.

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