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A NEW APPROACH TO MAP HOST ROCK FOR GOLD EXPLORATION IN THE RIO DAS VELHAS GREENSTONE BELT, QUADRILÁTERO FERRÍFERO, MINAS GERAIS, BRAZIL

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ABSTRACT

An empirical modeling approach was used to locate zones that are favorable for gold mineralization in Rio das Velhas Greenstone Belt, Quadrilátero Ferrífero (QF). A known spatial coincidence exists between banded iron formation (BIF) host lithology, structures and mineralogy type that are indicative of gold. Quantitative relationships between airborne geophysical and geological data sets with known gold occurrences were determined using probability ratio analysis. Spatial associations between geophysical data and host lithology were combined to produce predictive models to explore for Archean oxide-BIF-hosted deposits. This approach has shown great capability for linking geological and geophysical interpretation. The results of this modeling map areas of exposed and subsurface geologic units that are important to gold exploration in the area.

INTRODUCTION

In several known mining camps, many exploration surveys have been conducted based on surface geological and geochemical mapping. These efforts were the primary tools responsible for many gold discoveries. However, recent technologies have allowed emphasis to be placed on the use of geophysical surveying followed by a combination of all techniques in an expert system and GIS (Geographic Information Systems).
Most mineral deposits are a spatially small part (less than $3km^2$) of a mineralizing system (Jaques *et al*., 1997), which can occur over a scale of tens of kilometers (district scale) or hundreds of kilometers (regional scale). The QF is characterized as one of the biggest producers of gold in the world, especially when it refers to the deposits hosted in banded iron formation of the Algoma type. In the Rio das Velhas Greenstone Belt case, many exploration works have been conducted and the "*obvious*" and important targets have been evaluated. Such deposits commonly have a regional and/or local magnetic and/or radiometric and/or electromagnetic signature, many of which were mapped by Rio das Velhas airborne survey.
Although spatial data integration methods are being used increasingly for mineral resource assessments, the preferred methodology is by no means established. The purpose of making combinations is to identify and describe spatial associations present in the data, and use models for analysis and prediction of spatial phenomena (Bonham-Carter, 1994).
This paper discusses a quantitative data integration project for establishing areas of mineral potential carried out for the Rio das Velhas Greenstone Belt, Quadrilátero Ferrífero, currently an important area for gold exploration. The general goal is to combine information from the known geology; airborne geophysics and radiometrics, and mineral occurrences to map areas favorable for gold on an intermediate regional scale (1:100 000). Emphasis is placed on predicting the distribution of BIF-Archean-hosted-gold mineralization using the probability ratio method (Lee *et al*., 1999) and to evaluate the truthfulness of the resulting models.

GEOLOGIC OVERVIEW

The QF is situated in the southern portion of the São Francisco Craton and is composed of Archean granite-gneissic terrains (GGTs); Archean Greenstone Belt (Rio das Velhas Supergroup); Paleoproterozoic (Minas Supergroup and Itacolomi Group) and Paleoproterozoic-Mesoproterozoic (Espinhaço Supergroup) supracrustal units.
The supracrustal units, namely Minas and Rio das Velhas Supergroups, surround and are surrounded by granite-gneiss domes and each has been named: Bação, Caeté, Bonfim, Belo Horizonte and Santa Rita. These domes consist of poly-deformed gneiss, metatonalites to metagranites, amphibolites, meta-ultramafic rocks, as well as pegmatites formed in amphibolites facies conditions during the Archean and in the Tranzamazonic Eras (Cordani *et al*., 1980). The contact with adjacent supracrustal units is tectonic.

The Rio das Velhas Supergroup (RVSG – 3.0-2.7 Ga) is divided in two groups. The first, Nova Lima Group (NLG) comprises a lower ultramafic unit, an intermediate felsic-mafic unit and a clastic-mafic-felsic unit (Ladeira, 1980). These rocks are overlain by quartzites of Maquiné Group.

THE CONTROLS OF THE MINERALIZATION THAT DRIVEN THE ANALYSIS

(A) Lithological Control:

Banded iron formations are by far the most important hosts of the economically viable gold mineralization. BIFs have contributed 99% of the total gold production, and are associated with differentiated lithotypes. The banded iron formations have different geological and physical properties and can be divided in three types: oxide, carbonate-sulphide and ankerite/ferroan dolomite, quartz and plagioclase (*Lapa Seca*) types. The oxide BIF has significant economic grade-mineralization and has contributed 62% of the deposits in the area. The objective in this paper is to map the likelihood of the oxide-type BIF inside of Rio das Velhas Greenstone Belt (Ribeiro Rodrigues, 1998).

(B) Mineralogical Control:

Usually, the ore is composed of pyrrotite, arsenopyrite, pyrite, sometimes, presenting smaller quantities of calcocite, sfarelite and galene. The quantity of the mineral phases varies from deposit to deposit, it could be bigger or smaller inside the different bodies or inside the same deposit. Gold is associated with sulphides, occurring as inclusions, in fractures or along grain boundaries (Ribeiro Rodrigues, 1998).

(C) Structural Control

The Quadrilátero Ferrífero is marked by a complex multi-phased history, which resulted in the heterogeneous superposition of successive tectonic events and are important factor in controlling and the distribution of the gold. One important feature that characterizes this fact is the remarkable down-plunge continuity of the ore bodies parallel to the stretching lineation (Ribeiro-Rodrigues, 1998).

THE PROBABILITY RATIO METHOD

The purpose of the probability ratio method is to use the airborne geophysical and radiometric data to determine whether or not there exists a characteristic signature over a geologic unit with a known high potential for gold mineralization. Probability ratios are given as weights that describe how strong a spatial association the test data layer (magnetics, electromagnetics, and radiometrics) has with the training area (geologic unit). The larger the weight, the stronger the spatial association. We would infer areas mapped outside the training areas share the same geophysical and radiometric signatures and would be likely candidates to host gold mineralization. The mathematical basis for the probability ratio technique is described in Lee *et al*., 1999).

Different classes of each information layer were considered candidates for this analysis. Some assumptions are considered in these cases:

- The geological map of the study area (8 bits) and the host lithologies are known and used as predictor of mineral potential of oxide BIF-hosted-gold mineralization;
- The location of mineral deposits and occurrences are known. The mines were buffered with 500-meter radius. The goal is to define the geophysical signature around known gold mineralization and then extend this information into unknown areas outside the occurrence.
- The resulting weights represents the measures of the spatial correlation between the host lithology and input data set (geophysical or radiometric data). Values greater than 1 indicate a positive association between the tested class and tested domain; a value less than 1 suggests a negative association and a value equal one implies a random association. For example, a weight of 12 for a class implies that class is 12 times more likely to be found within the reference area as in the other (non-reference) areas in the study area.

THE DATA SETS

A variety of regional data sets from Rio das Velhas Greenstone Belt have been registered and analyzed using a geographic information system (GIS). The data sets include Rio das Velhas Project geological map (reference), Rio das Velhas airborne geophysical survey data (airborne magnetic, radiometric and frequency domain electromagnetics), and terrain.

The data layers in this research were processed, analyzed and interpreted in specific software in order to obtain products that could be used in the probability ratio analysis. The processing steps and description of the derivative products produced from the various data layers in preparation for probability ratio mapping are described in Silva, *in preparation*).

BIF–HOSTED GOLD PREDICTIVE MODELS

Figure 1 shows a predictive model for oxide-BIF geologic units based on the analysis of derivative products calculated from magnetics, 4175Hz-electromagnetic and potassium. Probability ratios were calculated for classes within individual data layers that had overlap with the mapped oxide BIF units (Silva, *in preparation*) and summed. The sum-of-weights model has weights that range from 3 to 25 and represent tracts of ground with favorable conditions to map oxide BIF-host rocks. The modeled areas have the same geophysical and radiometric properties as the known oxide BIF geologic units.

A new target was mapped with this model and was ground truthed with geologic fieldwork in 1998 (Silva, *in preparation*). The extension of the modeled area is larger than the mapped outcrop, inferring the ability of technique to map shallow sub-surface geology. Although drill data is required to verify this inference, the approach shows encouraging potential to identify possible shallow mineral targets.

CONCLUSIONS

The Archean-oxide BIF-hosted gold mineralization, represents a distinctive group with many common characteristics. The prospective nature of banded iron formations in the Rio das Velhas Greenstone Belt has been known since the first works in the area. Most of the discoveries of the actual deposits are the results of geochemical prospecting and drilling in the region. However, applications using geophysical techniques and a combination of all techniques in an expert system and GIS have been seldomly used.
The quantitative relationships between geophysical and geological data sets with known gold occurrences have shown great capability for linking geological and geophysical interpretations. The results map areas of exposed and subsurface geologic units and can direct new ways for gold prospecting at the Rio das Velhas Greenstone Belt.

REFERENCES

BONHAM-CARTER, G.F.; 1994. Geographic information system for geocientists – Modeling with GIS. Pergamon, 398p.

CORDANI, U.G.; KAWASHITA, K.; MUELLER, G.; QUADE, H.; REIMER, V.; ROESER, H.P. 1980. Interpretação tectônica e petrológica de dados geocronológicos do embasamento do bordo sudeste do Quadrilátero Ferrífero, Minas Gerais. Acad. Bras. Cienc., Anais...Rio de Janeiro, 52:785-799.

JAQUES, A.L.; WELLMAN, P. and WYBORN, D. 1997. High resolution geophysics in modern geologic mapping. ASGO Journal of Australian Geology & Geophysics, 17 (2): 159-173.

LADEIRA, E.A. 1980. Metallogenesis of Gold at the Morro Velho Mine, and in Nova Lima District, Quadrilátero Ferrífero, Minas Gerais, Brazil. London. 272p. (Ph.D. thesis, University of Western Ontario).

LEE, G.K., McCAFFERTY, A.E., ALMINAS, H.V., BANKEY, VIKI, ELLIOTT, J.E., FRISHMAN, D., KNEPPER, D. H. JR., KULIK, D.M., MARSH, S.P., PHILLIPS, J.D., PITKIN, J.A., SMITH, S.M., STOESER, D.B., TYSDAL, R.G., VAN GOSEN, B., 1999. Geoenvironmental Assessment of Montana. U.S. Geological Survey Digital Data Series DDS-XX.

RIBEIRO-RODRIGUES, L.C. 1998. Gold mineralization in Archaean banded iron formation, Quadrilátero Ferrífero, Minas Gerais, Brazil - The Cuiabá Mine. (Ph.D. thesis, RWTH Aachen, Germany, Aachener Geowinssenschftiche).

SILVA, A.M. (in preparation). Data integration for mining exploration in the Rio das Velhas greenstone belt, Quadrilátero Ferrífero, Minas Gerais state, Brazil. Ph.D. Thesis. University of Brasília, Brazil.

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