WEIGHTS-OF-EVIDENCE MODELLING OF SEDIMENTARY PHOSPHORITE DEPOSITS IN BRAZIL

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1. INTRODUCTION

The Irece phosphorite ore, Bahia (Brazil), occurs within the Neoproterozoic meta-sedimentary Una-Bambui Group, which comprises glaciogenic sediments (Bebedouro Formation) and carbonate successions (Salitre Formation). The Salitre Formation consists of a thick (about 1.2 km) dominantly carbonate sequence, lying over glaciogenic diamictites of the Bebedouro Formation. Sedimentary and structural features of the Salitre Formation indicate that primary phosphate concentrations formed in shallow-water sedimentary facies and are directly related to biogenic structures (columnar and laminar stromatolites). The presence and proximity to a laminated limestone and cherty dolomite (B and B1 units of Salitre Formation) is particularly important to characterize this stratigraphic level (Misi et al, 1999).

The purpose of this study is to test an innovative exploration approach based on a weights-of-evidence combination of geological features, LANDSAT TM spectral characteristics, soil geochemical signatures and other variables associated with the phosphate mineralization to predict the potential of P_2O_5 mineralizations on the Irecê Sedimentary Basin.

2. METHODOLOGY

The methodology involves the application as data integrator of the weights-of-evidence modeling, a log linear form of Bayes Rule with conditional independence. This method allows the user to explore the spatial relationship between known mineral deposits and exploration datasets from a variety of sources (Bonham-Carter, 1994). Because most studies of this type have a limited number of deposits, it is advantageous to generalize the maps to a small number of classes, often to binary classes. The process of evaluating weights and reclassification gives invaluable insights into the spatial associations present in the data (e.g. separation of background from anomaly in geochemistry, selection of optimal distances for buffering linear features, etc.).

Weights-of-evidence procedure consists in the calculation of the posterior logit from the prior logit and sum of weights, one for each map, see Bonham-Carter (1994). The posterior logit is evaluated over the map region and is usually converted to posterior probability for display. The effects of various sources of uncertainty on the final result can be modelled such as the variances of weights and variance due to missing data (incomplete surveys).

The seven themes used as evidence of deposits in this study were derived from the raw data sets that consisted of a digitized geological map, DEM, remotely sensed data, airborne radiometric and soil geochemical survey data. The uranium and thorium maps are incomplete (i.e. the surveys have gaps, or missing data) and the P_2O_5 map is based on uneven sample density, giving rise to sources of uncertainty in the posterior probability map that can be taken into consideration in modeling. Twenty-one P deposits were used as training points. to calculate statistical parameters for weighting the evidence by data-driven modeling. Weights (W+, W-), contrast (C=W+-W-) and confidence calculations guided the data-driven methods modeling.

Several statistical procedures can be used for helping to define geochemical and geophysical anomalies. These include the use of moving averages, kriging, probability graphs and other techniques. Most methods employ concentration values only. In order to improve the results of interpretation of geochemical and geophysical data by considering both the frequency distribution of concentration values and their spatial distribution, the concentration-area fractal method (C-A method) was introduced by Cheng, Agterberg, and Ballantyne (1994) for anomaly separation. In this study we used the C-A method to identify both geochemical and geophysical anomalies. The C-A method separates anomalies from background on the basis of the frequency distribution of values, as well as the spatial and geometrical properties of geochemical and geophysical patterns.

The geochemical survey shows high concentration values of P_2O_5 in very small areas, relatively low values in a much larger area and very low concentrations values in all other regions, typical of many trace element distributions. Situations of this type can be often described by using multifractal models (Cheng, Agterberg and Ballantyne, 1994).

The study area is considered to have high potential for P mineral deposits. The soil geochemical survey was designed to discover P occurrences related to dolomitic shallow-water facies in the carbonate sequences of the Una-Bambui Group of Proterozoic age. All soil samples, not always regularly spaced, (12,900 samples) were chemically analyzed for P, Pb, and Zn, among others, and the results were stored in a GIS.

The C-A method was also applied to the gridded airborne radioelement values. Plots for U and Th were produced, again indicating that power-law relationships were satisfied. As a consequence, breaks in slope were determined giving estimated thresholds of Th=7 cps and U=8 cps.

3. RESULTS & DISCUSSION

Binary anomalous maps were obtained from processing of theme weights that were used as evidence map: Morphology or topographic relationship, Stratigraphic control - unit B1, Map of P_2O_5 in soil, Map of buffered lineaments, Airborne radiometric maps (thorium and uranium), and a spectral signature extracted from LANDSAT TM satellite image.

For each map, threshold selection were guided on a way to maximize as far as possible the spatial association of the deposits with the resulting binary pattern. Table 1 summarizes the statistics from the weights of evidence (WOFE) method, as applied to the 21(twenty one) P_2O_5 deposits in the Irecê Basin.

The geochemical map was gridded by kriging and analyzed by the concentration-area method to determine the threshold between anomalous and background concentrations. Seven binary maps representing diagnostic deposit recognition criteria were combined in weights-of-evidence model to predict the spatial distribution of known mineral occurrences and to calculate a prospective map of further phosphate potential in the Irece Basin.

Figure 1 shows the results and indicate that thorium geophysics and soil geochemical data are valuable predictors of the key dolomite unit and can be applied to prospect in less well mapped parts of these Proterozoic basins. Stratigraphic, structural and spectral evidence were locally less important evidences. Among the three targets obtained in this modeling, the central-north one named Irecê-Lapão, was the most important, showing concentration of P deposits and the highest posterior probability values.

Table 1 - Weights (W+, W-), contrast (C) values and studentized contrast values or confidence (C/s(C)). Rows are sorted by decreasing C, a measure of spatial association between the deposits and the map. Prior probability is 21/1146.83=0.0183 (assuming unit cell=1 km2).

EVIDENCE MAPS	W+	W-	C	C/S(C)
Th	0,9674	-1,8839	2,8513	3,8119
P2O5 soil	-0,2580	2,1472	2,4053	4,4056
Topograph	-0,5986	1,1102	1,7088	3,7466
Unit b1	-0,3135	0,8035	1,1169	2,4123
U	0,1112	-0,6662	0,7774	1,0377
Lineaments distance	0,4685	-0,2670	0,7356	1,6190
Landsat class	0,4606	-0,2200	0,6806	1,4746
Deposits	21,0000	1146,8300	0,0183	

4. REFERENCES

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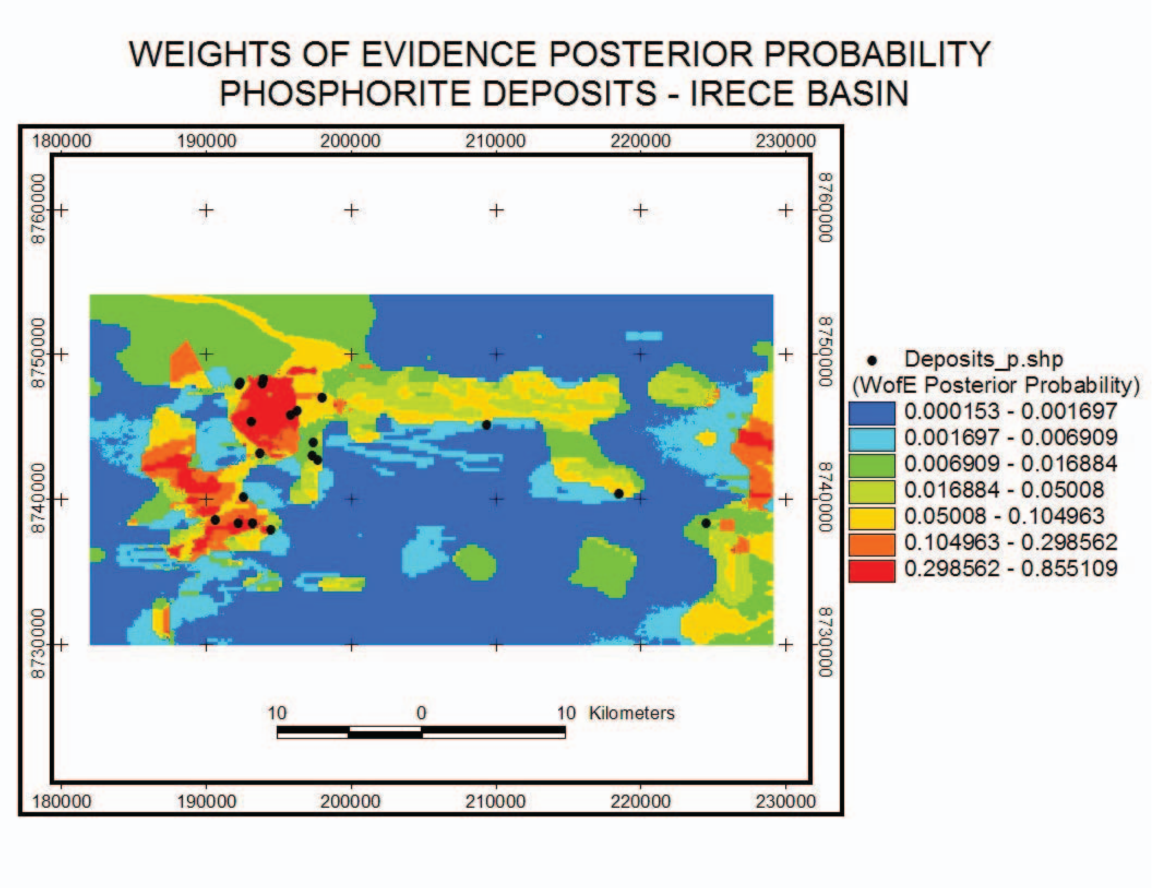

Figure 1 – Maps of mineral favorability for P_2O_5 according weights-of-evidence approach. Red saturation means highest mineral potential. Blue saturation means low favorability areas. Black dots are locations of P_2O_5 deposits