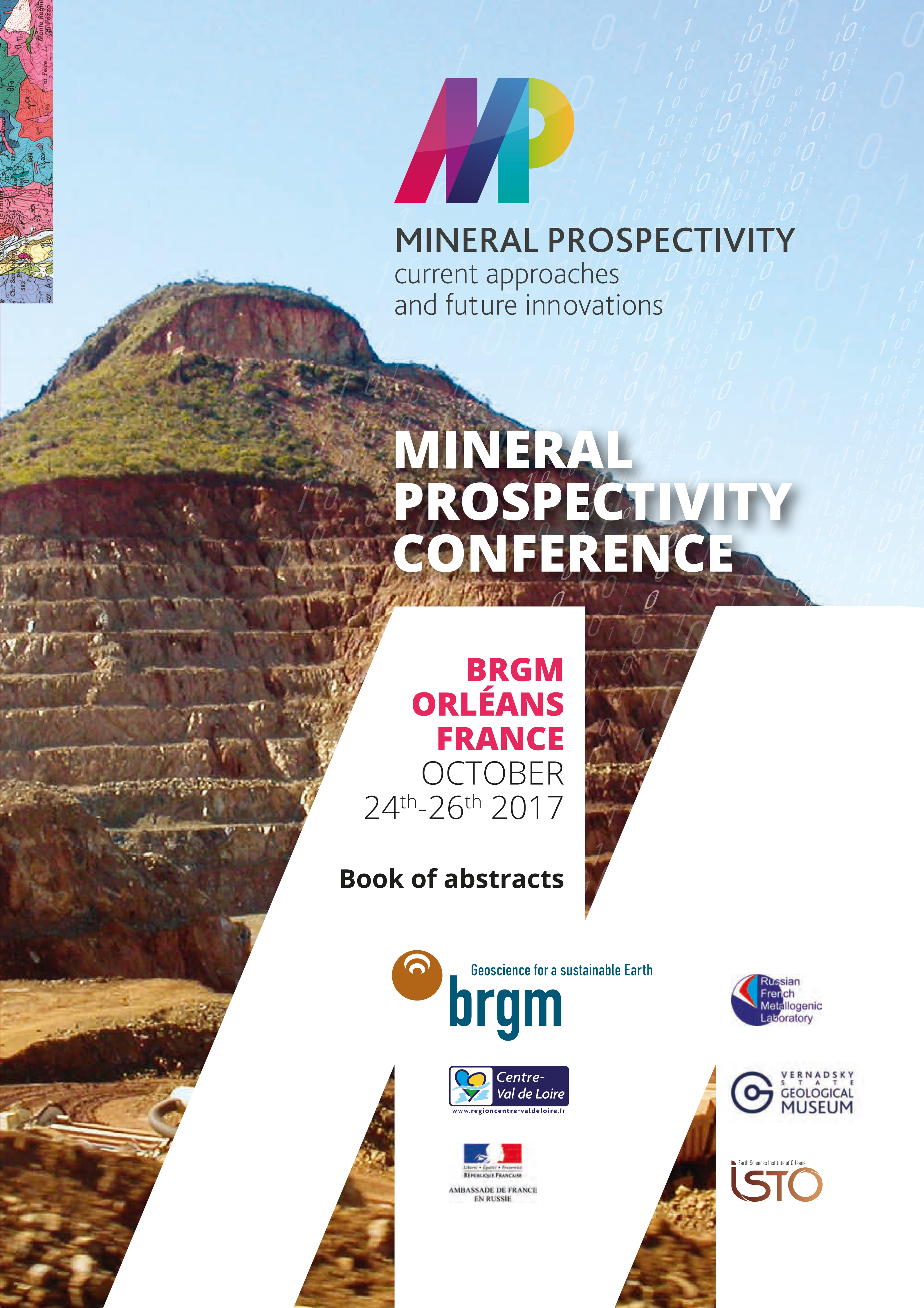

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The efficiency of logistic function and prediction-area plot in prospectivity analysis of mineral deposits

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***Abstract* - In this work, we present logistic-based mineral prospectivity mapping (MPM) methods concerning with assigning weights of exploration indicators, without contribution of training sites as in supervised MPM and without using user-judged weights as in unsupervised MPM, to modulate the problems of stochastic and systemic errors. In addition, we discuss the ability of prediction-area plot as a tool to assess and compare evidential layers and prospectivity models.**

I. INTRODUCTION

IN modeling of prospectivity for a certain type of mineral deposit, evidence maps are created from relevant exploration datasets, are weighted and then combined to delimit exploration targets. Weights of evidence classes are allocated based on either analyst's knowledge or known deposit locations, or a combination of both, or using user-defined functions, or using logistic sigmoid functions [1, 2].

Conventionally, continuous spatial values (e.g., distance to indicator features) are firstly discretized into a number of classes using haphazard intervals, and then every spatial value in each class are weighted through one of the above-mentioned methods for prospectivity analysis. The practice of discretizing spatial evidence values results in evidence layers that are affected by class interval. Thus, the comparative significance of spatial values in an exploration data set is not evaluated precisely that is due to the approximation convoluted in categorization of continuous spatial data, determining the intervals, and assigning their weights as indicator of mineral deposits. More importantly, there is no reliable proven weight indicating the comparative significance of exploration indicators that could be ascertained directly. Thus, two common problems affect integration of evidence maps [3, 4]: (1) stochastic error associated with sufficiency in number of known deposit locations used to estimate evidential weights; (2) systemic error associated with subjectivity of expert judgment applied to process, analyze, and assign weights to evidential data.

This paper aims to (a) demonstrate logistic-based assignment of spatial evidence values to avoids the above-mentioned errors, and (b) illustrate prediction-area (P-A) plot [2] for efficient evaluation of spatial evidence layers and prospectivity models. These are applied to exploration data for modeling prospectivity for porphyry-Cu mineralization in an area in southeast Iran.

II. METHODOLOGY

Mineral prospectivity modeling (MPM) is a decision making problem concerning the classification and prioritization of greenfields or brownfields into some delimited parts explicitly with (a) upper most priority as exploration targets, (b) lower most priority (in fact with no priority), and (c) some priorities between them. Accordingly, prospectivity models are presented as categorized maps [2, 3]. The transformation of continuous exploration evidence values resulting from multiple exploration data sets, using a logistic sigmoid function facilitates interpretation of exploration indicator patterns [2]. This is because the function transforms individual evidence data into the same space and has a more discretionary power to distinguish classification boundary. There are different types of logistic functions concerning with transformation of a collection of spatial values into [0,1] range respecting the lowest and highest spatial values and variations therein such as [3]:

$$F_{Sv} = 1/(1+e^{-s(Sv-i)}) \quad (1)$$

where F_{Sv} is a fuzzy weight ranging from 0 to 1, i and s are parameters of the logistic function, and Sv is spatial evidence value for which F_{Sv} is estimated. The parameters i and s determine the output fuzzy weights. For a spatial evidence data set with lowest, Es_{min}, and highest, Es_{max}, values, i and s are calculated as [3]:

$$s = 9.2/(Es_{\max} - Es_{\min}) \quad (2)$$

$$i = (Es_{\max} + Es_{\min})/2 \quad (3)$$

In MPM, exploration evidence data are elicited from various exploration methods, so their lowest and highest values do not lie in the same range and their units are also diverse. Transformation of a spatial exploration data set using (1) results in scores in [0, 1] range, i.e., fuzzy weights. Therefore, multiple exploration evidence data sets obtained by different exploration methods can be transformed to the same space using logistic functions. Thus, the ensuing values could be modeled as fuzzified evidence layers and their relative importance for MPM can be estimated more realistically.

Evaluation of exploration indicator layers and consequently generated prospectivity models are important in MPM to delimit target areas precisely. If a prospectivity model (or an evidence layer) predicts a smaller target comprising larger number of deposits, then it would be "easier" to discover deposits in the delimited target. Therefore, in the evaluation of evidence layers and prospectivity models the area occupied area by exploration targets and the prediction rate of mineral deposits should be contributed. For this, known deposit locations could be utilized in a P-A plot to asses both evidence layers and prospectivity models. In a P-A plot, the proportion of predicted deposits and the proportion of occupied areas corresponding to the prospectivity classes (or evidence values) are simultaneously used for the purpose of evaluation. In a P-

A plot, the intersection of the two curves, the curve of proportion of predicted deposits, and the curve of proportion of occupied areas, is a criterion to evaluate prospectivity models [2]. This is because if the intersection appears in a higher place in the plot, it means a smaller target comprises larger number of deposits.

III. RESULTS & DISCUSSION

In this paper, we used a layer of proximity to intrusive rocks and a layer of faults density (*FD*) representing heat-source and pathway proxies of porphyry copper mineralization, respectively. Then, for fuzzification of the proxies, we applied (1) to obtain weighted evidence maps. Then, the two fuzzified evidence layers were combined using fuzzy gamma (=0.9) operator to generate porphyry-Cu prospectivity model (Fig. 1).

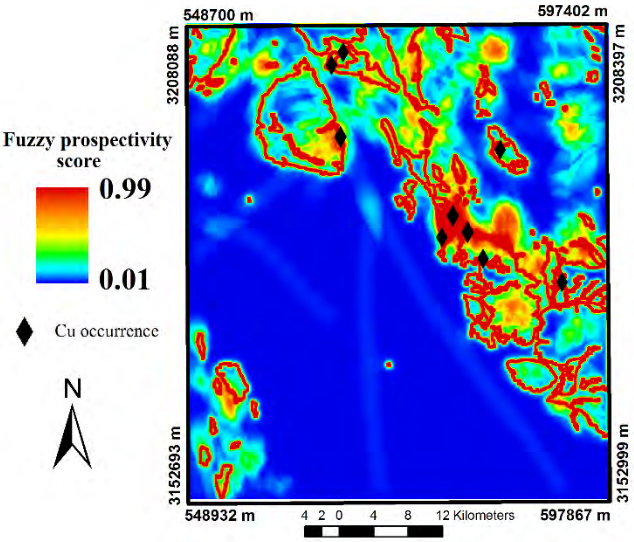

Fig. 1. Prospectivity model of porphyry-Cu deposit

Logistic-based fuzzification of exploration evidence data avoids the disadvantages of existing knowledge- and data-driven MPM methods in terms of (a) defining various empirical and generic functions to assign evidential weights, (b) carrying uncertainty due to simplification of data into classes, and (c) exploration bias resulting from using known deposit locations as training sites in the modeling [4]. Thus, the method is more objective rather than existing knowledge- and data-driven MPM methods.

To evaluate the prospectivity model generated we used P-A plot (Fig. 2). The P-A plot quantifies relationship of mineral deposits and exploration evidence values. Thus, it can be utilized to evaluate and compare different spatial proxies to recognize efficient indicator layers of mineral deposits. In addition, the P-A plot can evaluate the amount of efficiency of prospectivity models in recognition of mineralization footprints. As shown in Fig. 2, the prediction rate is ~90% indicating that the prospectivity model generated is reliable.

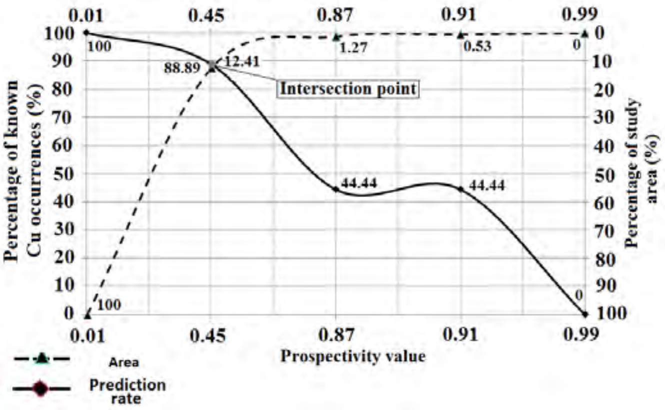

Fig. 2 - Prediction-area plot

IV. CONCLUSION

Mineral prospectivity modeling using logistic-based weighting approach alleviates the problem of stochastic and systemic errors in estimation of evidential weights. Consequently, the efficiency of prospectivity models, which created using logistic-based approach, is increased in comparison with prospectivity models generated using traditional weighting techniques used in knowledge- or data-driven MPM. Using logistic-based MPM is pertinent in either greenfields or brownfields.

Prediction-area plot could be used as a worthy tool not only to evaluate exploration evidence layers but also to appraise diverse prospectivity models regarding their capability to predict mineral exploration targets.

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