Modelling Ore Bodies of High-Nugget Gold Using Conditional Probability

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1 Introduction

In vein-hosted gold deposits, gold distribution typically shows very low spatial continuity, i.e., a very high-nugget effect, which makes it unreliable to model the ore-body using traditional geostatistical techniques [1, 2]. In such situations geologists may resort to using a proxy for gold, such as presence of alteration or deformation, to outline the ore-body extents. The requirement is that the proxy is significantly more spatially continuous than the distribution of high grade gold [3, 4]. We present a method for evaluating and combining several geological features or geochemical elements to provide a proxy for mineralisation using conditional probability.

The study is based on drill hole data (geological logging and geochemical analyses) from Sunrise Dam Gold Mine. The mine lies within an Archaean greenstone belt in the Yilgarn Craton of Western Australia. The host rocks of the gold mineralisation are structurally complex and deposits include vein stockwork lodes and shear hosted lodes [2, 5]. Gold grades tend to be elevated in regions of strong sericitic alteration and are closely associated with high arsenic values. This geological information is used to decide which geological and geochemical features may be useful proxies for predicting the extent of the gold ore-bodies.

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2 Calculating Conditional Probability

Conditional probability provides a data-driven method for determining which rock types and spatial regions are most favourable for mineralisation. Conditional probability is defined as the probability of an event occurring given that another event has already occurred. In this case we calculate the probability of a sample returning a gold assay value (Au) that exceeds a pre-determined cut-off value (v) given certain features observed in the sample. This can be expressed in the form:

$$p(\mathrm{Au} \geq \mathrm{v}|\mathrm{F}_1, \mathrm{F}_2, \ldots, \mathrm{F}_\mathrm{n}) \tag{1}$$

where $\mathrm{F}_1, \mathrm{F}_2, \ldots, \mathrm{F}_\mathrm{n}$ represents a set of geological features.

These features may be data logged by geologists in a categorical form, such as alteration intensity or vein density. For categorical data the conditional probability is calculated by creating an n-dimensional matrix of counts of samples; where n is the number of features used in the calculation. Each cell of the matrix represents a class. Conditional probability is calculated by dividing the number of samples in a class with gold assay values exceeding the cut-off value ($\mathrm{Au} \geq \mathrm{v}$) by the total number of samples in that class [1, 2].

Features may also be in the form of continuous numerical data such as geochemical data. For continuous numerical values the conditional probability is calculated using the density of data points in feature space defined by $\mathrm{F}_1, \mathrm{F}_2, \ldots, \mathrm{F}_\mathrm{n}$ (FS):

$$\mathrm{p}(\mathrm{Au} \geq \mathrm{v}|\mathrm{F}_1, \mathrm{F}_2, \ldots, \mathrm{F}_\mathrm{n}) = \text{prior probability} \times \frac{\text{density in FS (points Au } \geq \text{v)}}{\text{density in FS (all points)}} \tag{2}$$

The density of the data is calculated using a kernel density estimator [6]. The prior probability is the ratio of the number of samples with $\mathrm{Au} \geq \mathrm{v}$ to the total number of samples.

3 Results

In our first example we use conditional probability to predict favourable rock types for gold mineralisation from categorical data: foliation intensity (F), alteration intensity (A) and vein density (V) logged in drill holes. The prior probability value is used as the value which divides regions of favourable rock type from unfavourable rock type. Higher probabilities will delineate increasingly favourable regions. Figure 1 shows that the favourable regions in the drill holes are substantially more spatially continuous than the original gold assays at a cut off of 1 ppm Au. An isotropic interpolation has been performed on the conditional probability values, illustrated in Fig. 1 as traces of isosurfaces, to provide a first-pass orebody outline. Alternatively,

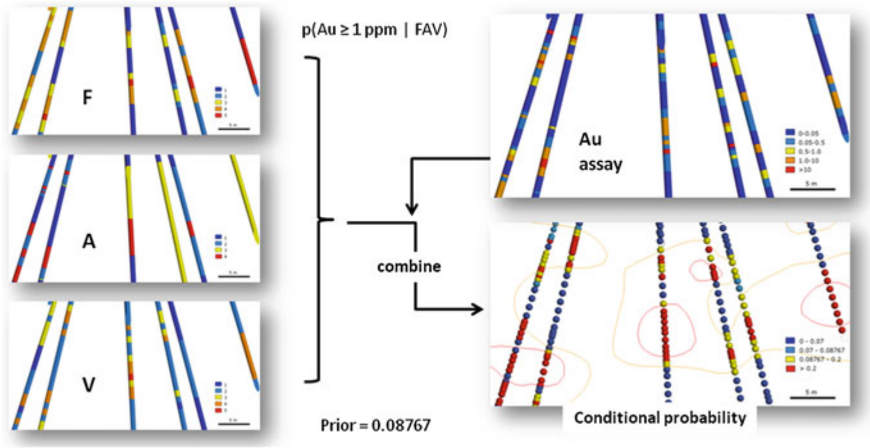

Fig. 1 F, A and V categories (*left*) are combined with gold assay data (*top right*) to generate conditional probability (*bottom right*). F, A, V: warmer colours represent stronger intensity. Au assay: *orange* >1 ppm, *red* >10 ppm. Conditional probability (of Au ≥ 1ppm): *yellow* >0.08767 (value of prior), *red* >0.2

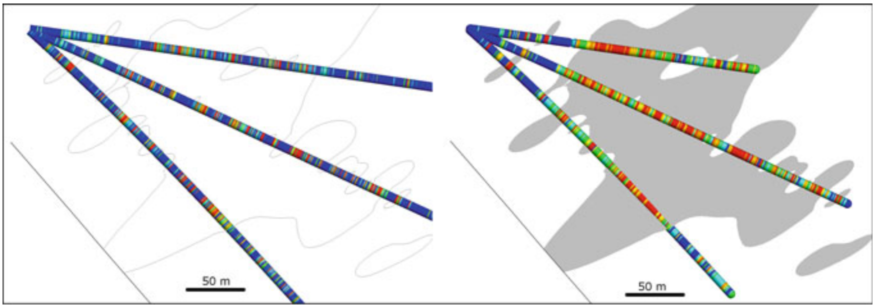

Fig. 2 Underground drill fan showing (*left*) distribution of gold assays and (*right*) conditional probability values (*blue* = *low* values, *red* = *high*). Grey domain in right image is the interpolated region where p > 0.308 (value of prior)

if the local structural trend was taken into account (left-to right horizontally across the figure) then 2 distinct bands of favourable rock could be interpreted.

In the second example we present results using conditional probability to predict favourable rock types from multi-element geochemical data; arsenic (As ppm), rubidium (Rb ppm) and potassium (K_2O %) reflect mineralisation-related alteration and are more spatially continuous than gold. The favourable rock types defined by this method appear to be more spatially continuous than the original gold assay values and should make the definition of the ore-body outline substantially easier (Fig. 2). Traces of isosurfaces are shown for an interpolation using a strong anisotropy parallel to the dominant structural trend in the region.

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