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Application of fractal models to characterization and evaluation of vertical distribution of geochemical data in Zarshuran gold deposit, NW Iran

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ABSTRACT

Vertical distribution of geochemical data can provide useful information and appropriate criteria for recognition and classification of mineralized and non-mineralized zones. In this study, several fractal models including box-counting, power-law frequency and new Hurst exponent visual basic application (VBA) programming were applied to evaluate the continuity and irregularity of the Au mineralization, the characterization of the vertical distribution and identification of new exploration targets based on the 40 mineralized and non-mineralized boreholes in the Zarshuran gold deposit. The results of the box-counting method showed that the vertical distribution of the Au values in these boreholes exhibit self-similarity, with the values of box-dimension (Bd) ranging from 1.01 to 1.7. The Bd values indicated that all the boreholes have irregularities in the vertical distribution of the Au values. Power-law frequency results indicate that the vertical distribution of Au in the boreholes exhibit bi- and mono-fractal properties. The bi-fractal properties of the boreholes imply the multiple mineralization phases in the Zarshuran deposit. Fractal dimensions vary from 0.6 in the non- and weakly mineralized zones, to 3.4 in the mineralized zones. The large fractal dimensions of the mineralization showed more homogeneity within the mineralization. The Hurst exponent shows the homogeneous distribution of Au in the mineralized and non-mineralized boreholes. The values of the Hurst exponent range from 0.63 to 0.92, with R2 greater than 0.8, indicating good vertical distribution in the study area. The Au values for non-mineralized boreholes such as [A4] are greater than 0.5, which shows the homogeneous distribution of Au in the wall rocks. The interpolated maps of the Au mean grades, the coefficient of variation of the Au grades, Bd, dimension (D), Hurst exponents as independent variables, and the combination variable ('H + Bd') were utilized to predict the potential exploration targets at the surface. The results show that the zone of approximately the old arsenic mining (the main mine valley) and the Mal Darrassi Valley isthe main potential exploration targets in the Zarshuran mining district.

1. Introduction

The delineation and classification of mineralized and barren zones are important in mineral exploration. A combination of mathematical and geological knowledge can be utilized to identify and predict potential exploration targets. Like the distribution of geochemical elements at the Earth's surface, the vertical distribution of elements exhibits power-law characteristics which can be fitted by fractal models (Monecke, 2001; Sanderson et al., 1994; Wang et al., 2012; Zuo et al., 2009). Fractal theory is a non-linear mathematical method that was established by Mandelbrot (1983) and widely applied to calculate ore resources and to delineate potential exploration targets (e.g., Afzal et al., 2011, 2013, 2014; Agterberg, 1995; Agterberg et al., 1996; Carranza, 2008; Cheng, 2012; Deng et al., 2010; Hashemi and Afzal, 2012; Nazarpour et al., 2013; Sadeghi et al., 2012; Wang et al., 2012; Zuo, 2011; Zuo et al., 2012). In this paper fractal models, including box counting model, power-law frequency and a new Hurst exponent visual basic application (VBA) programming are applied to evaluate the vertical distribution of Au values and to predict and assess mineral targets from borehole datasets.

2. Geological setting and mineralization of the Zarshuran gold mining district

The Zarshuran gold deposit is located in north-western Iran, in a historic mining area for gold and arsenic and with considerable potential for discovery of new economic gold mineralizations. The Zarshuran area consists mainly of Precambrian rocks (Samimi, 1992). The oldest unit, the Iman Khan unit, forms the core of the Iman Khan anticline, symmetrically plunging both NW and SE over some 7 km (Mehrabi

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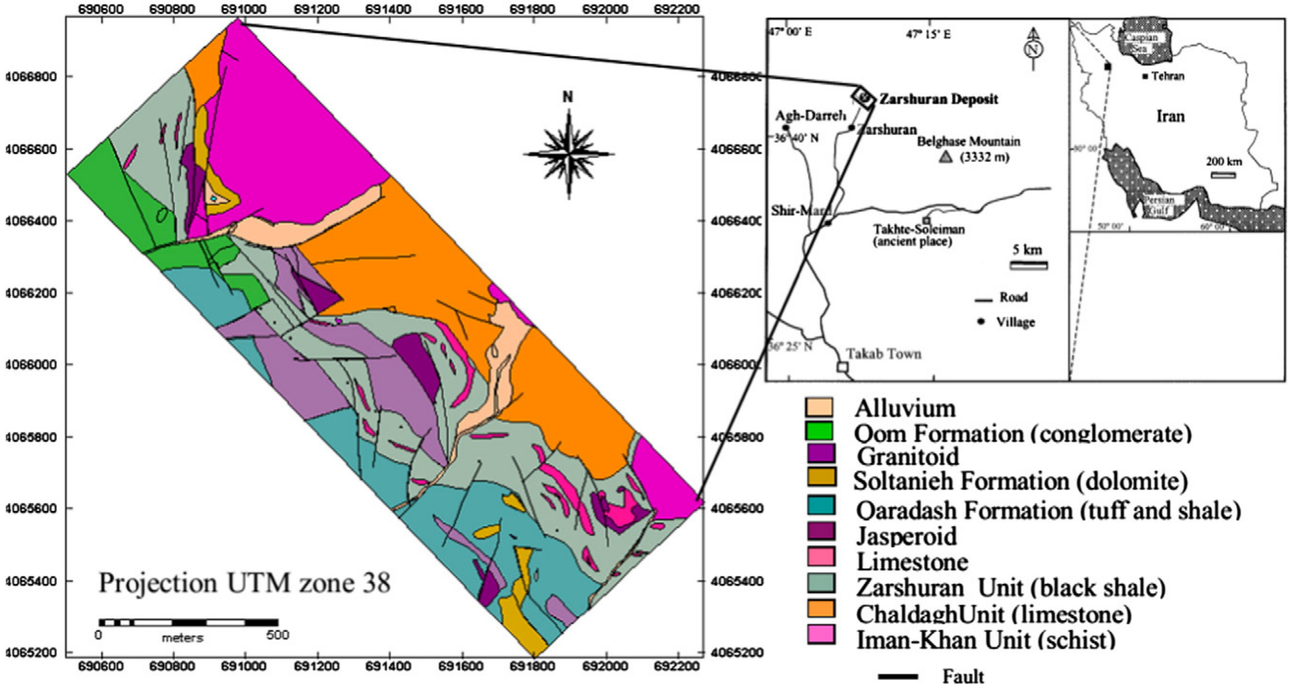

Fig. 1. Location and detailed geological map of the Zarshuran gold mining district, NW Iran (Asadi Harooni, 2000).

et al., 1999). The Iman Khan unit mainly consists of chlorite–amphibole–schist and locally serpentinite. The Iman Khan schist is followed stratigraphically upwards by the Chaldagh limestone, the Zarshuran black shale with silica and carbonate intercalations and the Qaradash shale, tuff and sandstone (Mohajer et al., 1989). An Oligocene to Miocene granitoid, intruded into the mineralized Precambrian formations and is highly altered, mylonitized and weakly mineralized (Fig. 1).

Gold mineralization occurs mainly as disseminations in carbonaceous, siliceous, and calcareous beds within the Zarshuran black shale (Karimi, 1992). Gold is also found in hydrothermal veins of massive quartz (jasperoid) and quartz veinlets formed by carbonate replacement along high-angle faults in Chaldagh limestone (Mehrabi et al., 1999). The Chaldagh limestone is also mineralized at its contacts - towards the Iman Khan schist and the overlying Zarshuran unit

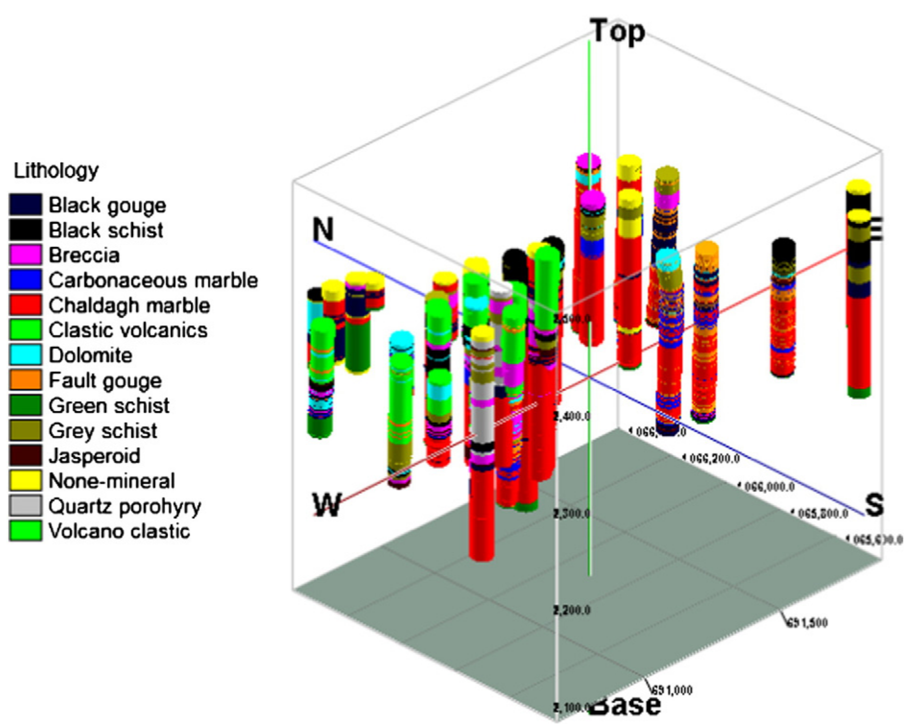

Fig. 2. 3D model of borehole locations in the Zarshuran gold deposit.