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Comparative study of C–A, C–P, and N–S fractal methods for separating geochemical anomalies from background: A case study of Kamoshgaran region, northwest of Iran

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A B S T R A C T

Separation of geochemical anomalies from background is a fundamental topic in the field of geochemical exploration. Fractal and multifractal modeling of geochemical data are among these methods and have been used by many geoscientists for more than two decades. In this study, three fractal methods, consisting of concentration–area (C–A), concentration–perimeter (C–P), and number–size (N–S) methods, were applied to identify geochemical anomalies in 317 stream sediment samples from Kamoshgaran region, Kurdestan province, northwest of Iran. Implementation of C–A, C–P, and N–S methods showed that southwestern, eastern, and central parts of Kamoshgaran region were the most important parts and future detailed exploration including lithogeochemical sampling should be focused on these parts. Also, a good relationship was found between alteration units and anomalous areas using fractal methods. Results also demonstrated a strongly positive relationship between As and Au anomalous areas in the region. The resulted thresholds for C–A and C–P methods were slightly different; consequently, the suggested anomalous areas were slightly different. In addition, distinction of the anomalous areas in terms of Au, Cu, and Mo based on N–S method was much better, which could be attributed to the point that there was no data pre-processing and only the raw data were processed for drawing the N–S log–log plot. Maps of the anomalies revealed that As, Cu, and Mo anomalies were simultaneously located in the eastern part of the studied area and corresponded to Au anomalies. From this point of view, it can be said that the studied area could be very important for Au mineralization and its eastern part can be the target of future exploration.

1. Introduction

Delineation of anomalies from background is an essential task in geochemical exploration (Hashemi and Afzal, 2013). Traditional statistical methods assume that the chemical elemental concentrations in the crust follow a normal or log-normal distribution (Afzal et al., 2010). Geochemical data are usually characterized by their spatial positions, meaning that elemental concentration varies spatially. However, traditional methods consider only the frequency distribution of elemental concentration and ignore its spatial variability (Afzal et al., 2010). In addition, traditional statistical methods are only applicable to the cases, in which geochemical data follow a normal distribution (Afzal et al., 2010; Li et al., 2003). The distribution of elemental concentrations in stream sediment samples is irregular; therefore, fractal methods can be used to determine the threshold and to delineate geochemical anomalies from backgrounds (Agterberg et al., 1993; Davis, 2002; Hashemi and Afzal, 2013; Sim et al., 1999). Methods based on fractal geometry have been applied to geoscientific studies in recent decades (e.g., Afzal et al., 2010, 2011, 2012; Agterberg et al., 1996; Carranza and Sadeghi, 2010; Cheng, 1999; Cheng et al., 1994; Deng et al., 2010; Goncalves et al., 2001; Hashemi and Afzal, 2013; Li et al., 2003; Lima et al., 2003, 2008; Sim et al., 1999; Turcotte, 1986; Wang et al., 2011a,b; Zuo, 2011a,b, 2014; Zuo and Cheng, 2008; Zuo et al., 2009a,b, 2012, 2013a, b, 2014). The concentration–area model (C–A model) proposed by Cheng et al. (1994) has been developed and applied by many geoscientists (e.g., Ali et al., 2007; Goncalves et al., 2001; Sim et al., 1999; Wang et al., 2012; Zuo et al., 2009a). Another useful method for separating anomaly from background is the number–size model (N–S model) proposed by Mandelbrot (1983), which has been widely used by many geoscientists (e.g., Agterberg, 1995; Turcotte, 2002; Wang et al., 2010; Zuo et al., 2009c). The concentration–perimeter (C–P) fractal model is related to the C–A and perimeter–area (P–A) fractal models (Cheng, 1995). This paper used the C–A, C–P, and N–S fractal models to describe the distribution of regional geochemical data, to compare the results obtained via the three different methods, and to identify geochemical anomalies in stream sediment samples ($n = 317$) of Kamoshgaran region, northwest of Iran.

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2. Methodology

2.1. Concentration–area (C–A) model

Cheng et al. (1994) proposed the concentration–area (C–A) method, which can be used for separating geochemical anomalies from background. Concentration–area (C–A) method has the general form of:

$$A(\rho \leq v) \propto \rho^{-a1};\ A(\rho \geq v) \propto \rho^{-a2} \quad (1)$$

where $A(\rho)$ denotes the area with the concentration values greater than contour value ρ, v represents the threshold, and $-a1$ and $-a2$ are fractal dimensions. Two approaches that were used by Cheng et al. (1994) to calculate $A(\rho)$ include: (1) $A(\rho)$ is the area enclosed by contour value ρ on a geochemical contour map resulting from the interpolation of the original data by weighted moving average method, and (2) $A(\rho)$ is the value obtained by the box-counting of original elemental concentration values. By box-counting, one superimposes the grid with cells on the studied region. The area $A(\rho)$ for a given ρ is equal to the number of cells multiplied by the cell area with the values greater than ρ (Cheng et al., 1994). Area–concentration $[A(\rho)]$ with the elemental concentrations greater than ρ usually shows a power-law relation (Cheng et al., 1994). The breaks between straight-line segments on this log–log plot and the corresponding values of ρ have been used as

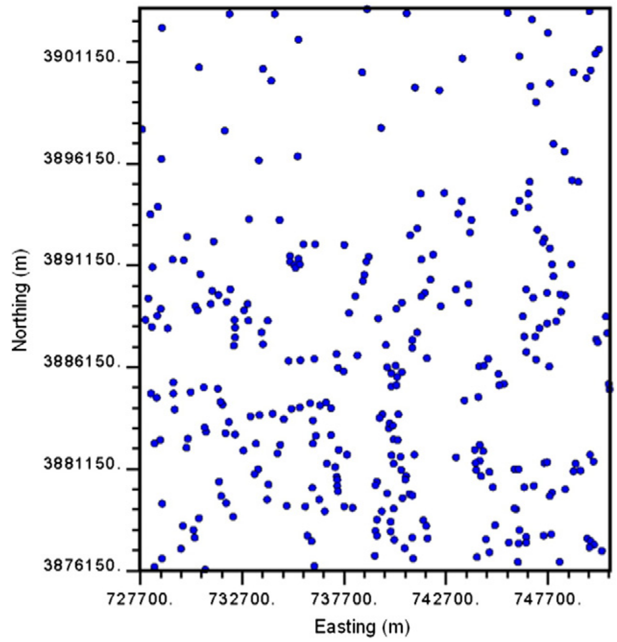

Fig. 2. Sampling locations of stream sediments from Kamoshgaran region.

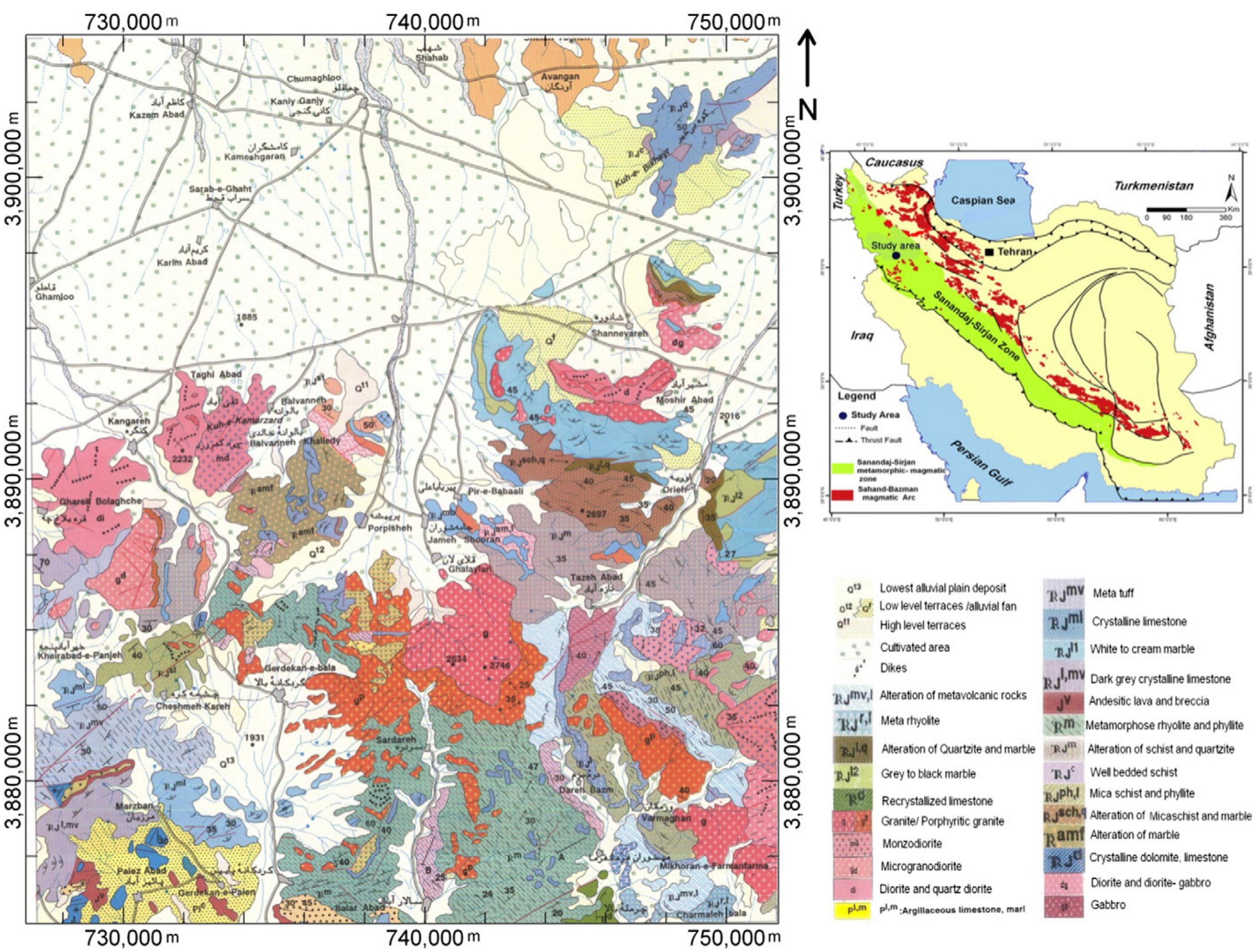

Fig. 1. Geological map of Kamoshgaran region (based on the 1:100,000 geological map of Qorveh) and geology of Iran showing the location of the studied area in metamorphic–magmatic Sanandaj–Sirjan zone (compiled and simplified by Sahandi et al. (2005) based on the 1:2,500,000 geologic map of Iran).