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Application of classical statistics, logratio transformation and multifractal approaches to delineate geochemical anomalies in the Zarshuran gold district, NW Iran

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ABSTRACT

The aim of this study is to discriminate the geochemical anomalies in the Zarshuran district, NW Iran, using different geochemical methods and present a more useful method where anomalous areas better coincide with the geological features. For this methods of delineation, geochemical anomalies were compared using geological features, occupied area of anomalies respect to the total study area, and field observations. Frequency based analysis such as mean + 2SDEV and median + 2MAD and concentration–area (C–A) multifractal methods were adopted for estimating thresholds and separating geochemical anomalies in uni-element data, as well as multi-element ones. Threshold values obtained from mean + 2SDEV and median + 2MAD, from original point geochemical data, are smaller than those of the pixel values; this may be due to the stronger variance of pixel values. In addition, the C–A multifractal method, as a useful tool to identify weak geochemical anomalies, was applied for defining the threshold values. Robust principal component analysis (RPCA) methods coupled with isometric log-ratio (ilr) transformations were utilized to open the geochemical data in order to reduce the effects of the data closure problem. The 20-quantile intervals decomposed anomaly maps from PC1 were obtained from the classical PCA, robust PCA showed that the upper quintile (>80 quintile) of classical PCA covers a larger area (32.54%) than the robust PCA (18.16%), and as a result, the robust PCA displayed smaller areas and has good spatial associations with outcrops of hydrothermal Au–As mineralization in this area; coincident with the known Zarshuran former mining area (ore field), Zarshuran unit, Ghaldagh silicified limestone occurrence and newly explored works confirmed by field observation. Although the C–A model shows a smaller area (8.06%), this anomaly location is limited to the Zarshuran old mining area with no new exploration targets. Comparison of the models indicates that the RPCA model is not only beneficial to further Au exploration in the study area, but also provides a meaningful geological study to the community of the compositional data analysis.

1. Introduction

One of the most fundamental tasks of recent geochemical data processing is determining thresholds to separate anomalies from background values and then delineate the mineralized areas (Afzal et al., 2010; Bai et al., 2010; Cheng and Li, 2002; Hassanpour and Afzal, 2013; Kürzl, 1988; Yousefi et al., 2012, 2013; Zuo et al., 2013). Various methods have been applied successfully for mapping geochemical data and defining the thresholds (upper limit range of background values) in exploration geochemistry and distinguishing anthropogenic versus natural sources of materials (Chiprés et al., 2009; Nazarpour et al., 2013; Yousefi et al., 2013; Zhang and Lalor, 2002).

These methods correspond to two groups: classical methods, as a first group, deal with the frequency distribution of elements,

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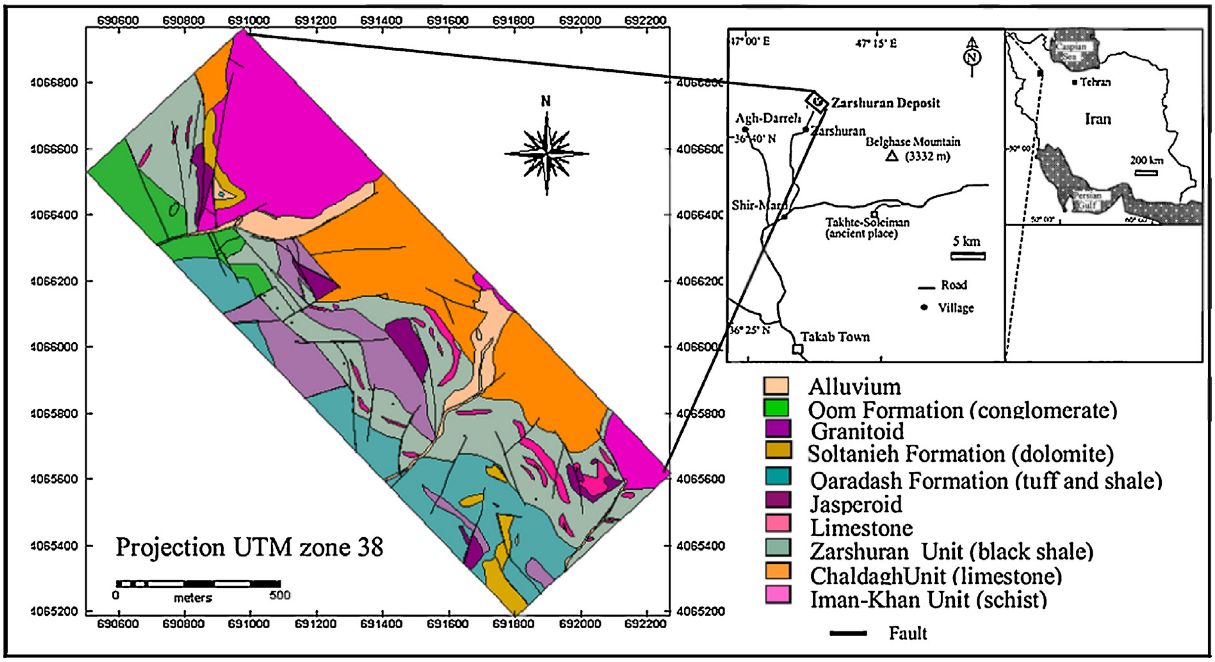

Fig. 1. Location and detailed geology map of the Zarshuran gold mining district, NW Iran (Asadi, 2000).

Table 1
Statistical parameters of raw data based on soil sample analysis.

	Concentration				
	Maximum	Minimum	Median	Mean	St. dev.
Au	10,090	1.5	20	270.03	916.21
As	34,569	9	564.66	1244.5	2336.1
Sb	5571	2	62	141.32	329.42
Cu	1111	1.25	42	50.51	48.21

involve interactive mean ± 2SDEV (Gałuszka, 2007; Hawkes and Webb, 1962), histograms, box plots (Tukey, 1976), median + 2MAD (Rose et al., 1979), the fence method (Schwertman and de Silva, 2007; Schwertman et al., 2004) and other techniques including probability graphs, univariate and multivariate analyses. The second group concentrates the spatio-statistical distribution of geochemical values, for example, geostatistical techniques, fractal methods, etc.

Classical statistical methods are popular frequency based methods and widely used in many fields. The main limitation of the classical approach is that they do not consider the spatial information, geometry (e.g., shape or form), extent and magnitude of anomalous areas (Cheng et al., 1994; Rafiee, 2005) and could fail to recognize anomalies in regions with high-value background or miss weak anomalies in region with known mineral deposits (Bai et al., 2010; Hassanpour and Afzal, 2013; Nazarpour et al., 2013).

The fractal theory is one of the non-linear mathematical methods that was established by Mandelbrot (1983) and widely used in many scientific fields including geosciences e.g., (Agterberg et al., 1993; Ali et al., 2007; Carranza, 2008; Cheng et al., 1994; Deng et al., 2010; Sadeghi et al., 2012; Sim et al., 1999; Turcotte, 1986; Wei and Yang, 2010). Several fractal and multifractal models including concentration–area (C–A) (Cheng et al., 1994), spectrum–area (S–A) (Cheng, 2004; Cheng et al., 2000; Xu and Cheng, 2001), concentration–distance (C–D) (Li et al., 2003), concentration–volume (C–V) (Afzal et al., 2010; Sadeghi et al., 2012), number–size (N–S) (Agterberg, 1995; Deng et al., 2010; Mandelbrot, 1983; Turcotte, 2002; Wang et al., 2010) have been

Table 2
Results of Shapiro–Wilk testing of soil geochemical data from the Zarshuran mining district.

Element	Test statistic		
	Raw data	Transformed applied	Transformed data
Au	0.198	Cox–Box	0.911
As	0.234	Cox–Box	0.941
Sb	0.360	Cox–Box	0.924
Cu	0.231	Johnson	0.938

developed for application in geosciences, especially geochemical data processing. Yousefi et al. (2012) proposed a new approach of weighted drainage catchment basin mapping of stream sediment geochemical anomalies which can be used directly as a geochemical evidence layer in fuzzy-based mineral prospectivity mapping.

Almost all geochemical data are compositional, describing the contribution of D-parts of some whole, which carry exclusively relative information (Aitchison, 1982, 1989; Carranza, 2011; Egozcue et al., 2003; Filzmoser et al., 2009a,b; Zuo, 2014; Zuo et al., 2013). The results of geochemical analysis were expressed as proportions or percentage of some whole data of various chemical compounds. This shows that these data are not the absolute values, and provide relative information of the element in the complete samples, so they are called compositional data (Aitchison, 1982, 1989; Filzmoser et al., 2010; Zuo, 2011; Zuo et al., 2013). Therefore, compositional data are closed and should be opened prior for using any of the aforementioned methods (Carranza, 2011; Zuo et al., 2013). Logratio transformations are commonly employed in geochemical