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Identification of geochemical anomalies associated with mineralization in the Fanshan district, Fujian, China

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ABSTRACT

The Fanshan district is a prospective area to explore for epithermal-type Cu–Au mineralization that is similar to the Zijinshan Cu–Au deposit in the neighboring region which is the largest Cu–Au deposit in southern China. In this study, the robust principal component analysis (RPCA) method and spectrum-area (S-A) fractal model were applied to multi-element data from 2042 stream sediment samples collected in this region. The isometric logratio (*ilr*) transformation was used to open the geochemical data for reducing the effects of data closure problem. The resulting PC1 obtained using RPCA displays two different compositional assemblages: (I) Pb, Zn, Sn, W, Mo, Bi, Hg, and Ag, perhaps representing hydrothermal-type Zn–Pb polymetallic mineralization, and (II) As, Au, Cu, Sb and Mn, likely representing epithermal-type Cu–Au mineralization. The decomposed anomaly map from the PC1 obtained from the S-A model illustrates that highly anomalous areas occurring around the intrusions are correlated with hydrothermal-type Zn–Pb polymetallic mineralization, and areas with lower anomalies such as Dafanshan and Xiaofanshan are perhaps associated with Cu–Au polymetallic mineralization, and should be further studied to explore for epithermal-type Cu–Au mineralization.

1. Introduction

Extensive high quality, multi-element, and multi-scale geochemical data sets have been collected since the Chinese geochemical mapping program was launched in 1978 (Xie et al., 2008). It plays a significant role in mineral resource exploration in China as a number of mineral deposits have been discovered (Xi and Li, 2012). The processing of geochemical data for detecting multivariate geochemical patterns or signals associated with mineralization in support of mineral resource exploration is challenging.

In this regard, two important issues should be addressed. The first one is the data closure problem for geochemical data analysis. Geochemical data are typically compositional data with the components measured as proportions or percentages of some whole data and only provide relative information because the information is the proportion of the element in the complete sample (Aitchison, 1982, 1986; Aitchison et al., 2000; Buccianti and Pawlowsky-Glahn, 2005). The data closure problem may result in spurious correlations or associations between geochemical variables and complicate the interpretation of different correlations between the same variables among different subcompositions. For instance, a scatterplot of SiO_2 versus Al_2O_3 for Kola Project *C*-horizon soils indicates that SiO_2 has a negative correlation ($r = -0.65$) with Al_2O_3 (Fig. 1a) (Reimann et al., 2008). When the closed data is opened using the additive logratio transformation (*alr*) proposed by Aitchison (1982) (TiO_2 as denominator) to eliminate the spurious relationships between geochemical variables, the relationship between SiO_2 and Al_2O_3 becomes positive ($r = 0.91$) (Fig. 1b). The same phenomenon also occurs in stream sediment data collected from Fujian Province, China (Zuo, 2013). The Harker diagram for the raw data also shows a negative relationship ($r = -0.83$) between SiO_2 and Al_2O_3 (Fig. 2a) because the major component SiO_2 increases and all other components decrease due to the fixed sum (100%) (Reimann et al., 2008). The Harker diagram for the opened data using *alr* (CaO as denominator) demonstrates that SiO_2 has a positive correlation ($r = 0.81$) with Al_2O_3 (Fig. 2b). The positive relationship can be interpreted due to the presence of both Al and Si in most common rock-forming minerals and their weathering products (Reimann et al., 2008). The differences between Fig. 1a and b, and between Fig. 2a and b display a serious problem when analyzing inter-element relationships in geochemical data.

Palarea-Albaladejoa and Martín-Fernández (2013) showed the biplots for the Hongite dataset from Aitchison (1986). The biplot is a powerful tool to display the relationships between variables via loadings and observations via the scores (Gabriel, 1971). It can simultaneously visualize scores (data points or sample identifiers) and loadings (vectors) of the principal components (PC). The correlations between variables are measured by the angle between any two vectors. The dataset consists of 25 mineral samples of the composition $x = [$albite,

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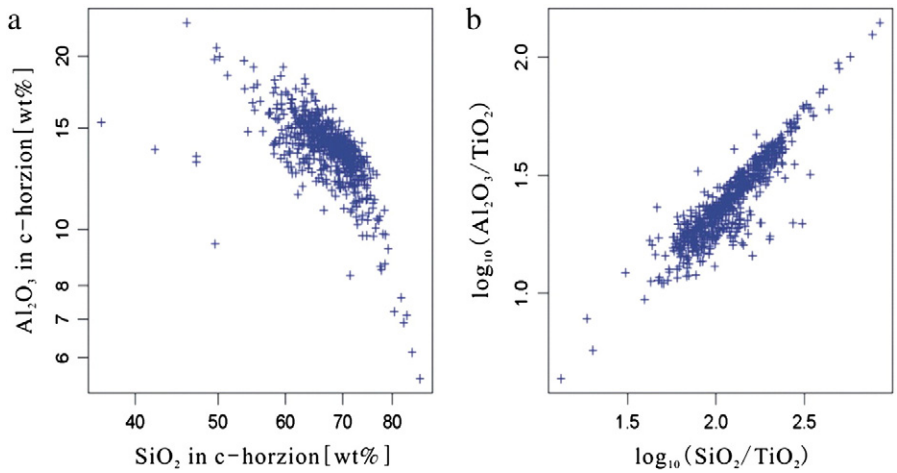

Fig. 1. Scatterplot of SiO_2 versus Al_2O_3 for Kola Project C-horizon soils: (a) the raw data, and (b) after *alr* transformed data. After Reimann et al., 2008).

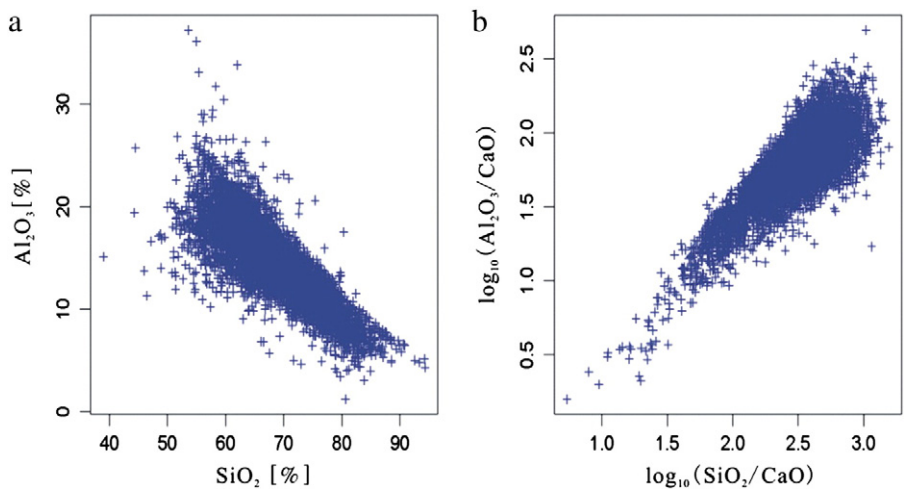

Fig. 2. Scatterplot of SiO_2 versus Al_2O_3 for Fujian stream sediment data: (a) the raw data, and (b) after *alr* transformed data.

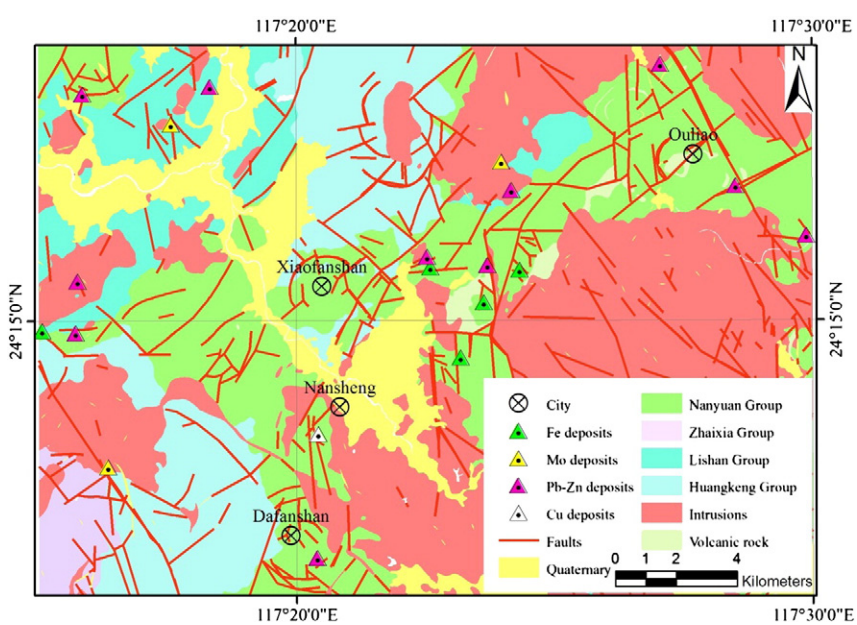

Fig. 3. Simplified geological map.
Modified from Geological Survey Institute of Fujian, China, 2011.