Journal of Geochemical Exploration 148 (2015) 259–269

Contents lists available at ScienceDirect

Journal of Geochemical Exploration

journal homepage: www.elsevier.com/locate/jgeoexp

Spatial characteristics of geochemical patterns related to Fe mineralization in the southwestern Fujian province (China)

Haicheng Wang [a], Qiuming Cheng [a,b], Renguang Zuo [a,*]

[a] State Key Laboratory of Geological Processes and Mineral Resources, China University of Geosciences, Wuhan 430074, China
[b] State Key Laboratory of Geological Processes and Mineral Resources, China University of Geosciences, Beijing 100083, China

ARTICLE INFO

Article history:
Received 5 May 2014
Accepted 25 October 2014
Available online 4 November 2014

Keywords:
Geostatistics
Fractal
Spatial autocorrelation
Skarn-type iron deposits

ABSTRACT

In this paper, geostatistical, fractal, and spatial autocorrelation methods were applied to investigate the spatial characteristics of stream sediment geochemical data of Cu, Mn, Pb, Zn, and Fe_2O_3 collected from southwestern Fujian province of China. The spatial variograms showed that these elements are spatially correlated up to 40 km, which is consistent with ranges of positive spatial autocorrelation computed using spatial correlograms based on Moran's I. The coefficients of variation of these elements are less than 0.25, exhibiting strong spatial dependence. All the five elements have fractal dimensions of around 2.9 and showed similar spatial complexities. These results indicate that the spatial characteristics of each element were controlled by similar geological factors or processes. The integrated map of local Moran's I for these five elements, produced by principal components analysis, was decomposed into two components using the spectrum–area fractal model: a background map and an anomaly map, and the latter showed that the areas linked to high values have a strong spatial correlation with the known skarn-type Fe deposits. These results suggest that geostatistical, fractal, and spatial autocorrelation methods are helpful for identifying potential target areas for Fe mineral exploration in the study area.

1. Introduction

Quantification of the spatial characteristics of geochemical patterns is an important component of mineral exploration. Various methods, consisting of frequency-based and spatial frequency-based methods, are popular in processing geochemical data (Carranza, 2010a, 2010b; El-Makky, 2011; Singer and Kouda, 2001; Zuo et al., 2013a). Traditional statistical analysis techniques such as probability graphs (Sinclair, 1974), multivariate data analysis (e.g., Yousefi et al., 2012; Zuo et al., 2009, 2013a) and trend surface analysis (e.g., Agterberg, 1964; Watson, 1971) have been widely applied to process geochemical data. However, these methods ignore spatial structures of geochemical data, which bear the most important inherent properties of geochemical patterns. Spatial statistical techniques that consider spatial features and attributes have been applied to analysis of geochemical data (e.g., Carranza, 2010b; Cheng et al., 1994; Cinti et al., 2013; Cliff and Ord, 1981; Goovaerts, 1997; Luz et al., 2014; Matheron, 1971; Zhang et al., 2008). Spatial distribution and variation of geochemical data can be quantified using geostatistics (Goovaerts, 1999; Hamedani et al., 2012; Matheron, 1962), fractal/multifractal models (e.g., Afzal et al., 2011, 2013; Agterberg, 2012; Bölviken et al., 1992; Carranza, 2009; Cheng, 2007; Cheng et al., 1994, 1999; He et al., 2013; Zuo, 2011a, 2011b, 2014a; Zuo and Cheng, 2008; Zuo et al., 2009, 2012a, 2013a, 2013b, 2014a, 2014b), and spatial autocorrelation (e.g., Griffith, 1987; Zhang and Selinus, 1997; Zhang et al., 2008).

The spatial distribution of geochemical variables is controlled by various geological processes, which can be used to explain geochemical processes and guide mineral exploration (Carranza, 2004, 2010a; Carranza and Hale, 1997; Yousefi et al., 2013; Zhang and Selinus, 1997).

A stream sediment survey can be used for geochemical investigations, and stream sediment data can be analyzed to reveal patterns that are useful for geochemical exploration (e.g., Bölviken et al., 1992; Carranza, 2004, 2010a; El-Makky and Sediek, 2012). Stream sediment geochemical data have been used to characterize spatial distributions of geological bodies associated with mineralization (e.g., Carranza, 2010a, 2010b; Cheng, 2011; Rose et al., 1979; Zhao et al., 2014). Geostatistics, fractal, and spatial autocorrelation were used, in this study, to quantify spatial characteristics of iron-related mineralization elements from stream sediment samples collected in the southwestern Fujian province (China).

* Corresponding author.
E-mail address: zrguang@cug.edu.cn (R. Zuo).

http://dx.doi.org/10.1016/j.gexplo.2014.10.010
0375-6742/

2. Study area and data

The study area is located in the southwestern Fujian depression belt (SFDB) which is one of the most important iron metallogenic belts in China (Fig. 1). Almost 98% of the known iron deposits in the Fujian province are found in this region. The main types of mineral deposits are the primary skarn-type and the secondary gossan limonite of weathering-leached Fe–Ca-rich skarn (Zhao et al., 1980). These deposits are mainly situated in the early Hercynian Yongan–Meixian fold belt, which is composed of a central anticline flanked by two synclinal basins, upon the Caledonian basement (Ge et al., 1981). Late Paleozoic lithologies are the dominant ore-hosting rocks and are discontinuously distributed along the mainly NE–NNE controlling basement faults in the region (Han and Ge, 1983). Skarns and skarn mineralizations are formed by the intrusions of granitoids due to the gas–liquid metasomatism. According to constituents, the skarns are mainly calcic skarns, while only a small amount of magnesian skarns are found, which may be caused by the low content of MgO in the Paleozoic limestones in the study area. Calcic skarns are mainly garnet skarn, pyroxene–garnet skarn, pyroxene skarn, secondly vesuvianite skarn, wollastonite skarn, and pyroxene (or garnet)–epidote skarn (Zhao et al., 1980). The climate of the study area is hot and humid with abundant rainfall, as a result, the outcropped iron-riched skarn minerals and metal sulfides are susceptible to be oxidized. Most of impurities such as sulfur, lead and zinc were taken away, and a part of silica was also leached out, at the same time limonites were formed, making the weathering-leached magnetite ore grade improved (Zhao et al., 1980). Previous research indicates that the skarn-type iron deposits are strongly correlated to the element association of Cu–Mn–Pb–Zn–Fe_2O_3 (e.g., Zuo et al., 2012b, 2014b).

The geochemical data at a scale of 1:200,000 were collected by the Chinese National Geochemical Mapping project (Xie et al., 1997). The original geochemical data are comprised of 39 major and trace elements at (I) low density of 1 sample per 20–50 km^2 from areas of extremely difficult assess, and (II) high density of 1 sample per km^2, out of which four samples were composited into one sample representing 4 km^2. The concentration values of Cu and Pb are determined by inductively

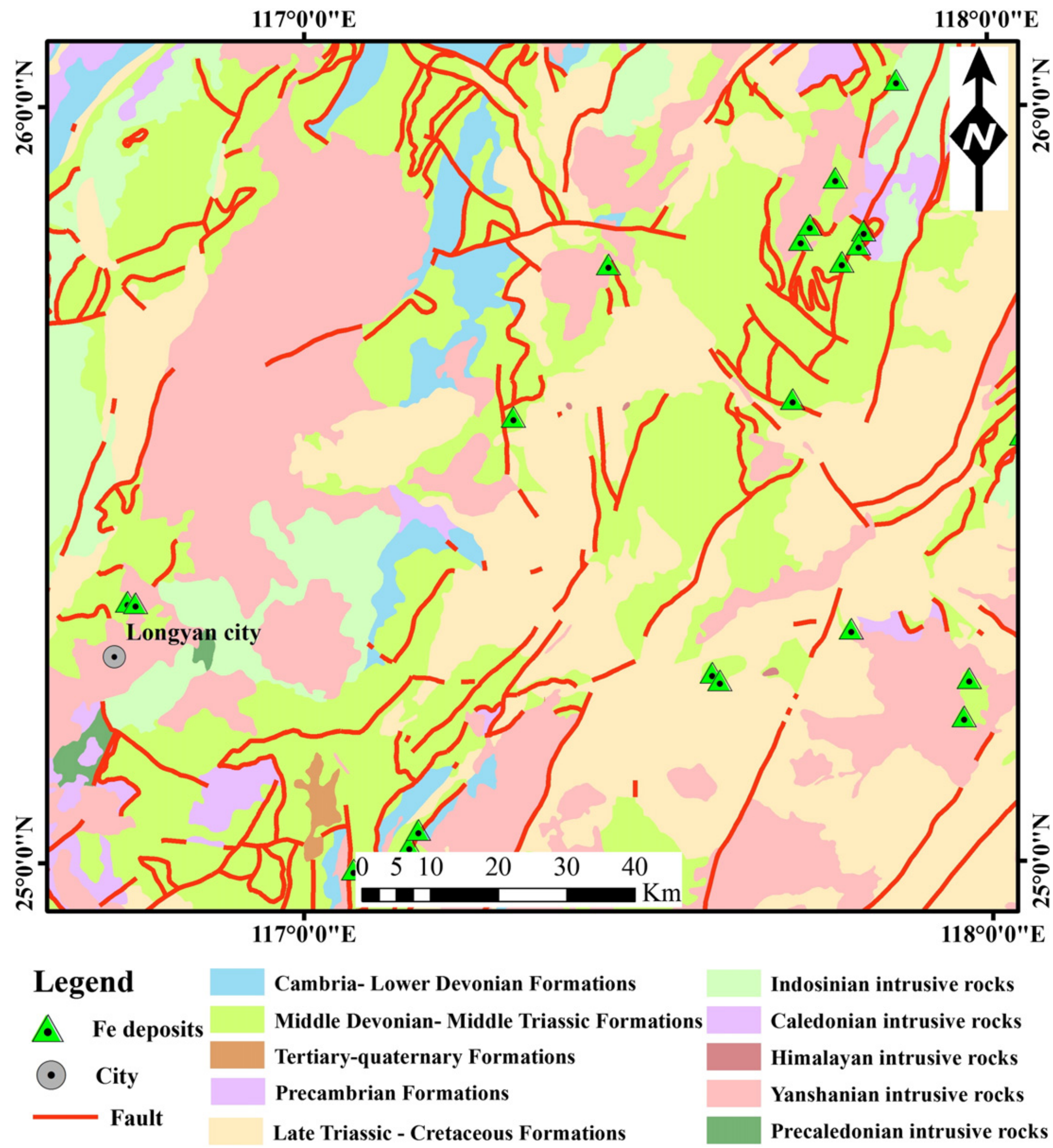

Fig. 1. Simplified geological map of the southwestern Fujian province in China (modified from Geological Survey Institute of Fujian, 2011).