Mapping Spatial Distribution Characteristics of Lineaments Extracted from Remote Sensing Image Using Fractal and Multifractal Models

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ABSTRACT: Mapping mineral prospectivity in vegetated areas is a challenge. For this reason, we aimed to map spatial distribution characteristics of linear structures detected in remote sensing images using fractal and multifractal models. The selected study area was the Pinghe District of the Fujian Province (China), located in the Shanghang-Yunxiao polymetallc and alunite ore belt (within the Wuyishan polymetallc belt), where mineral resources such as copper, molybdenum, gold, silver, iron, lead, zinc, alunite and pyrophyllite have been discovered. The results of our study showed that: (1) the values of fractal dimension for all lineaments, NW-trending lineaments, and NE-trending lineaments, are 1.36, 1.32, and 1.23, respectively, indicating that these lineaments are statistically self-similar; (2) the fractal dimensions of the spatial distribution of the linear structures in the four selected hydrothermal-type ore deposits of the Pinghe District, named Zhongteng, Panchi, Xiaofanshan and Wuyishan, are 1.43, 1.52, 1.37 and 1.37, respectively, which are higher than the mean value in South China; (3) the spatial distribution of the linear structures extracted from the remote sensing image and displayed by the contour map of fractal dimensions, correlates well with the known hydrothermal ore deposits; and (4) the results of the anomaly map decomposed by the spectrum-area (S-A) multifractal model is much better than the original fractal dimension contour map, which showed most of the known hydrothermal-type deposits occur in the high anomalous area. It is suggested that a high step tendency possibly matches with the boundary of the volcanic edifice and the deep fault controlling the development of the rock mass and the volcanic edifice. The complexity of the spatial distribution of mapped lineations (faults) in the Pinghe District, characterized by high values in the anomaly map, may be associated with the hydrothermal polymetallc ore mineralization in the study area.

KEY WORDS: fractal model, ETM+ data, vegetation coverage area, Pinghe molybdenum deposit.

0 INTRODUCTION

Existing studies show that most of the linear structures in remote sensing images reflect the stress produced by rock deformation belts or stress concentration belts (Ma and Xu, 1999). Consequently, the spatial distribution of faults in vegetated areas could be extracted from the linear structures in remote sensing images, which is a practical, low-cost, efficient, and fast technology. Faults can provide the pathway for hydrothermal fluids, resulting in significant metal depositional sites. However, irregularities in the linear structures often render the study of their spatial aspects difficult. The analyses of linear structures, including length, density and orientation, cannot adequately reflect their complex spatial distribution (Zhao S et al., 2011).

Since Mandelbrot founded the fractal theory in the mid-1970s, the fractal geometry has been widely used in earth science as a new scientific and practical method to study remote sensing lineaments for mineral exploration (Yu and Yuan, 2005). In the past few decades, the application of fractal geometry in quantitative descriptions of natural phenomena, especially of spatial distribution of mineral deposits, has been developed (Zhao J N et al., 2011). Fractal statistical analysis has been demonstrated as a useful tool for identifying irregularities in the patterns of natural objects and for describing self-similarities in geological surveys (Ke et al., 2015; Gumiel et al., 2010; Zuo et al., 2009, 2008; Cheng et al., 1996, 1994; Carlson, 1991; Mandelbrot, 1983). Fractal analyses have also been used to interpret the relationships between linear structures from remotely sensed images and mineral deposits, which are with the geological map using concentration-area (C-A) fractal model based on remote sensing data (Aramesh Asl et al., 2015). A correlation

between remote sensing data and geochemical data has been validated using the C-A fractal model for Cu anomalies associated with alteration zones (Afzal et al., 2015).

The purpose of this study is to characterize the spatial distributions of linear structures extracted from remote sensing images in vegetated areas, and to examine their possible relationships with the hydrothermal mineral deposits, using fractal and multifractal models in 2-D space.

1 STUDY AREA AND DATA
1.1 Geological Setting
Our study region is located in the Pinghe region, southern Fujian Province, and measures 1408 km² (Fig. 1). The area is heavily vegetated and undulating in landform. The area hosts the Jurassic Lishan, Zhangpin, and Nanyuan groups, the Cretaceous Huangkeng and Zhaixia groups, and the Upper Jurassic granites and granite porphyries (Fig. 1). The strong Late Jurassic–Early Cretaceous Yanshanian tectonic movement produced widespread block structures, magmatic intrusions, and volcanic eruptions in the region. The Zhongteng volcanic structure, a circular structure located in the study area, is a part of a volcanic edifice formed during this period. The intrusive rocks are present either along the regional tectonic structures or along the center of volcano structures (center intrusions or center intrusive rock group) and circular radiated structures (circular intrusions or cyclic combination intrusive rock group). The magmatic intrusions, including the Zhongteng, Gushuang, Dingcheng, Ouliao, and Neiguoxi intrusions, are mostly complex and composed of mainly acid and intermediate-acidic rocks. The Jurassic Nanyuan Group, widely developed in this area, is mainly composed of intermediate-acid and acid continental volcanic eruptive rocks. It is an important ore-hosting horizon that contains a number of hydrothermal deposits, such as Zhongteng Cu-Mo deposit, Panchi Cu-Mo deposit, Xiaofanshan alunite deposit and other polymetallic mineralized points showing with green dot in Fig. 1. The study area experienced Yanshan and Himalayan multistage tectonic movements that affected the formed Fu’an-Nanjing and Shanghang-Yunxiao deep faults and formed several fault zones and fracture belts of different sizes and properties. The main faults in the study area, which provided the pathway for the hydrothermal fluids that produced the significant metal depositional sites (Shi and Wang, 2014; Zuo et al., 2013), have NW and NE orientations.

1.2 ETM+ Data
The ETM+ instrument carried by Landsat satellite records data in seven multispectral bands, including six bands in the visible and reflected infrared part of the electromagnetic spectrum and one channel in the thermal infrared region (Rajendran et al., 2012). The ETM+ data used in this study was obtained from the Computer Network Information Center, Chinese Academy of Sciences (http://www.cnic.cn/zcfw/sjfw/gjkxsjjx/), which was covered the entire study area. It was acquired on Feb. 28, 2002 with less than 2% cloud cover. The orbit number is p120/r42. It is georeferenced to the UTM projection and for the WGS-84 ellipsoid. The image was pretreated for geometric and radiometric corrections, band combination, and wavelet fusion based on IHS transformation. In order to optimize and enhance the visual effect, the 3-D visualization of remote sensing image was carried out based on software platform ArcGlobe10.0.

Figure 1. Simplified 1:50 000 geological map of Pinghe District (modified from Geological Survey Institute of Fujian, 2011).