Journal of Applied Geophysics 92 (2013) 39–49

Contents lists available at SciVerse ScienceDirect

Journal of Applied Geophysics

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

Application of singularity index mapping technique to gravity/magnetic data analysis in southeastern Yunnan mineral district, China

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ARTICLE INFO

Article history:
Received 11 October 2012
Accepted 4 February 2013
Available online 24 February 2013

Keywords:
Fractal/multifractal
Band-pass filter
Granitic intrusions
Anomaly
Mineral exploration

ABSTRACT

The fractal/multifractal based singularity index mapping technique efficient in characterizing singular physical or chemical properties is applied for the analysis of gravity and aeromagnetic data in southeastern Yunnan mineral district, China. As follow-up after the introduction of singularity theory to geochemical and geological mapping scenarios, this study extends its application to delineate geophysical potential fields. Based on low gravity and low magnetic properties of granitic intrusions in the study area, singularity mapping technique is used as a high-pass filter to emphasize the geophysical anomalies caused by granitic intrusions in support of future mineral exploration. Comparing with the traditionally used band-pass filtering method, it is shown that the new technique provides an improved and simplified approach in geophysical data analysis with the advantage of scale independence.

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1. Introduction

Geophysical exploration has been greatly aided over past decades by the development in computer sciences and the availability of multi-source geophysical data which has become an important geo-information source in engineering, environment study, and resource exploration (Nabighian et al., 2005a, 2005b). From a geological perspective, mineralization related geological bodies can arouse geophysical anomalies (Zhao, 1999). Interpreting geophysical anomalies from various observational datasets is not only beneficial to recognition of the presence and spatial distribution of underneath geological bodies (i.e., causative bodies), but also significant to knowledge of geological settings and mineral potential mapping issues (Cheng, 2012; Cianciara and Marcak, 1979). Among various geophysical datasets, gravity and magnetic data are broadly employed in mineral resource exploration. Although these two typical observational datasets are distinctive in potential fields, measured parameters, and operative physical properties, they are processed by similar and even same ways during data processing in many cases (e.g., wavelength filter, upward continuation, vertical derivative, directional filter) (Bhattacharyya, 1965; Hood and McClure, 1965; Hood and Teskey, 1989; Kearey et al., 2002; Wang et al., 2010).

Gravity and magnetic data detect spatial variations of gravitational and geomagnetic fields caused by causative bodies. In practice, regional anomalies caused by large or deeply buried sources are of low-frequent with long wavelength (e.g., sedimentary basin), while local anomalies caused by small or shallow sources are of high-frequent with short wavelength (e.g., anticline and salt dome) (Kearey et al., 2002). Anomaly interpretation requires gravity/magnetic data to be decomposed into two constituent parts, so called regional–residual separation (Agarwal and Sivaji, 1992; Li and Oldenburg, 1998). Spatial and frequency analysis is popular in geophysical exploration with an assumption that the source distribution is random (Dimri, 2000). Methods involving Fourier transformation are mostly utilized. Meanwhile, many world-wide borehole measurements show that source (e.g., density or susceptibility) distribution is fractal (Dimri, 2000). Therefore, fractal and multifractal methods which consider both frequency distribution and spatial self-similar properties of causative bodies are effective on analyzing causative bodies as well (Cheng, 2007a; Li and Cheng, 2006).

Since the concept of fractal/multifractal introduced by Mandelbrot (1977, 1989), numerous studies have been carried out to understand complex natural properties. Researches in various fields were focused on characterizing measures with scale independence (Agterberg, 2012; Cheng, 2007a; Dimri and Srivastava, 2005). Natural processes with fractal behaviors like rainfall (Veneziano and Furcolo, 2002), flooding (Cheng, 2008; Malamud et al., 1996), cloud formation (Schertzer and Lovejoy, 1987) and mineralization (Cheng, 2007a, 2007b) exhibit non-linear characteristics that satisfy fractal or multifractal statistics. Comparing with the classic geophysical data analysis, fractal/multifractal methods are advanced to characterize the spatial distribution of underground causative bodies with arbitrary shapes. Dimri and Srivastava (2005) used modified Voronoi tessellation to generate fractal geometry

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http://dx.doi.org/10.1016/j.jappgeo.2013.02.012

of the causative bodies and provided an irregular realistic final model. Thorarinsson and Magnusson (1990) defined the fractal dimension as roughness of Bouguer anomaly surface, and by minimizing the roughness, they used a new method to determine density values for the Bouguer reduction. Based on a series of experiments, Lovejoy et al. (2001) and Pecknold et al. (2001) concluded that the multifractality and scaling anisotropy as two essential components cannot be ignored in geophysical modeling. Cheng (2007a) introduced some multifractal imaging filtering and decomposition methods in space, frequency, and eigen domains, in which the singularity theory (Cheng, 1999) was applied to quantify the local scaling property in space domain and used as a high-pass filter to enhance high frequency patterns.

Current research applies a singularity theory based technique integrated in GeoDAS software (Cheng, 2000) to characterize Bouguer gravity and aeromagnetic anomalies in southeastern Yunnan district, China. The spatial information of the causative bodies of these anomalies can be further used to support mineral exploration in the study area.

2. Study area and datasets

The southeastern Yunnan district, China chosen for current research is well-known for its world-class Sn–Cu polymetallic mineral deposits. A simplified geological map and a location of this area are shown in Fig. 1. The study area is approximately bounded to the east by the Wenshan area, to the west by the Jianshui–Yuanyang area, to the south by the Red River fault, and to the north by the Wenshan fault. Magmatic–hydrothermal ore deposits as a major type of mineralization in this area are mostly explored in the Gejiu and Wenshan ore districts spreading from the west to the east.

Former researches indicated that regional tectonic activities are an important controlling factor to the mineralization and mineralization related granitic intrusions (Qin and Li, 2008). Major faults in this area are the NW–SE trending Red River deep crustal fault (Qin and Li, 2008), the N–S trending Xiaojiang fault dividing the Gejiu ore district into the eastern and the western part, the NW–SE trending Ailaoshan deep crustal fault parallel to the Red River fault, and the NE–SW trending Zongshi–Mile fault. These faults control the spatial distribution of the granitic intrusions and ore bodies in southeastern Yunnan mineral district (Wang et al., 2012). Many discovered ore deposits are concentrated around the intersections of NNE–SSW and E–W trending faults (Cheng et al., 2011).

During the geological history, magmatism was widespread within the study area: medium to small scale eruption of ultramafic–felsic magma in Jinning–Hercynian epoch (1000–257 Ma), massive emplacement of mafic igneous rocks along the Red River fault in Indo-China epoch (257–205 Ma) (Guan, 1991), and granite emplacement in Yanshanian epoch (205–135 Ma) (Guan, 1991; Luo, 1995). By the participation of contact-metasomatism and filling processes, enrichment of ore forming elements is occurred in and/or near the contact zones of granitic intrusions and the Gejiu formation (i.e., Middle Triassic limestone and dolomite) under the effects of hydrothermal fluid and heat provided by the granitic intrusions (Cheng et al., 2011). Therefore, three main controlling factors of mineralization have been known as intensive tectonism (i.e., fault activity), magmatism (i.e., Yanshanian granitic intrusions), and proper lithologic unit (i.e., the Gejiu formation) (Zhuang et al., 1996).

Since the significance of magmatism to mineralization, most researches used the geo-information of granitic intrusions as a main component in mineral exploration modeling (Cheng et al., 2011; Wang et al., 2011, 2012; Xiong and Shi, 1994). Among these efforts, Xiong and Shi (1994) demonstrated a physico-geological exploration model to delineate spatial distribution of igneous rocks in this area by using geophysical data; nowadays, it still provides an important clue

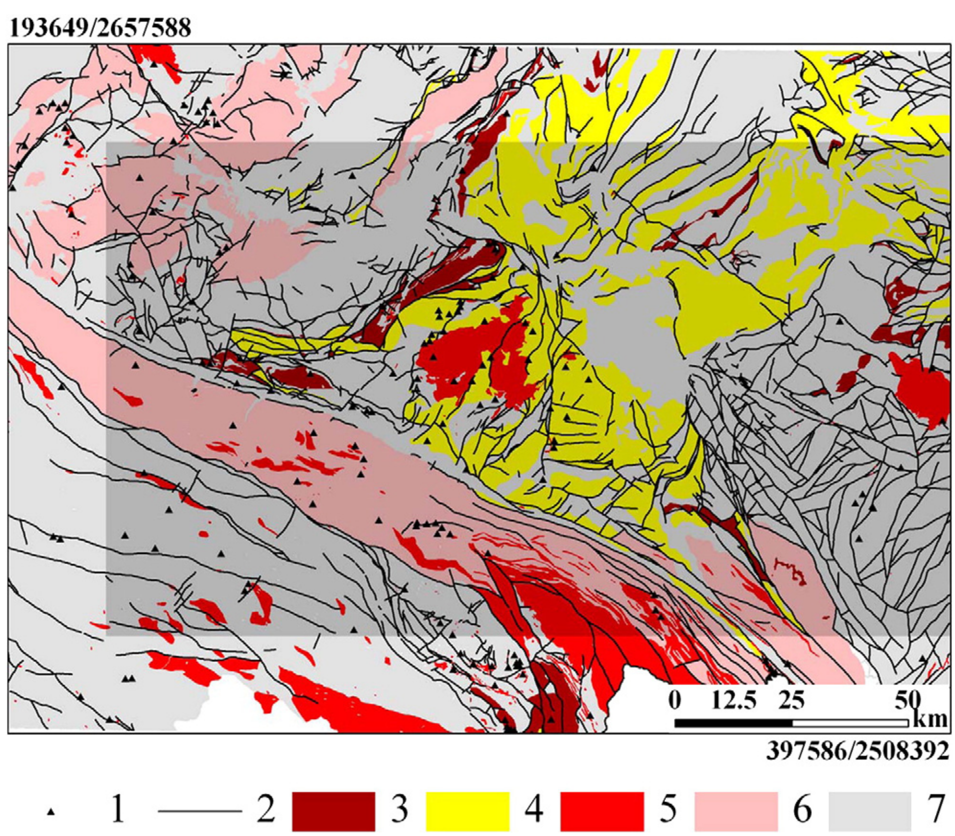

Fig. 1. A simplified geological map of the southeastern Yunnan mineral district, China (308 Geological Exploration Team, 1984). 1: Occurrences of mineral deposits; 2: Fault traces; 3: Mafic rocks; 4: the Gejiu formation; 5: Granitic intrusions; 6: Metamorphic rocks; 7: Other sedimentary rocks. The study area is shaded.

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