



Fractal/multifractal modeling of geochemical data: A review



Renguang Zuo *, Jian Wang

State Key Laboratory of Geological Processes and Mineral Resources, China University of Geosciences, Wuhan 430074, China

ARTICLE INFO

Article history:

Received 27 February 2015

Revised 9 April 2015

Accepted 21 April 2015

Available online 1 May 2015

Keywords:

Fractal/multifractal

Concentration–area fractal model

Spectrum–area multifractal model

Concentration–distance fractal model

Concentration–volume fractal model

Singularity

ABSTRACT

Over the past several decades, a wide range of complex structures or phenomena of interest to geologists and geochemists has been quantitatively characterized using fractal/multifractal theory and models. With respect to the application of fractal/multifractal models to geochemical data, the focus has been on how to decompose geochemical populations or quantify the spatial distribution of geochemical data. A variety of fractal/multifractal models for this purpose have been proposed on the basis of the scaling characteristics of geochemical data. These include the concentration–area (C–A) fractal model, concentration–distance (C–D) fractal model, spectrum–area (S–A) multifractal model, multifractal singularity analysis, and the concentration–volume (C–V) fractal model. These fractal models have been widely demonstrated to be useful, as indicated by the increasing number of published papers. In this study, fractal/multifractal modeling of geochemical data including its theory, the way it works, its benefits and limitations, its applications, and the relationships between these models are reviewed. The comparison among of C–A, S–A, and multifractal singularity analysis based on simulated data suggested that mapping singularity technique can enhance and identify weak anomalies caused by buried sources. Future study should focus on how to distinguish the true anomalies associated to mineralization with the false anomalies from a fractal/multifractal perspective.

© 2015 Elsevier B.V. All rights reserved.

Contents

1. Introduction	33
2. Fractal/multifractal models	34
2.1. Number–size model	35
2.2. Concentration–area fractal model	35
2.3. Spectrum–area fractal model	35
2.4. Concentration–distance fractal model	35
2.5. Concentration–volume fractal model	36
2.6. Local singularity analysis	36
2.7. Other parameters related to fractal methods	36
3. Application	36
3.1. Identifying geochemical anomalies	36
3.2. Mapping mineral prospectivity	37
3.3. Characterization the vertical distribution of geochemical element concentration	38
4. Comparison the C–A, S–A and singularity index	38
5. Discussion and conclusions	39
Acknowledgments	39
References	39

1. Introduction

Decomposition of geochemical patterns is a basic task for applied geochemists. With environmental problems becoming increasingly

important in recent years, discrimination between anthropogenic pollution and natural background is assuming increasing relevance (Albanese et al., 2007; Darnley et al., 1995; Lima et al., 2003, 2005, 2008; Plant et al., 2001). Similarly, how to effectively detect geochemical anomalies from background is one of the major concerns of geochemical exploration, which continues to be a cornerstone to mineral exploration at all scales ranging from regional reconnaissance to local

* Corresponding author.

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

exploration (Cohen et al., 2010; Grunsky, 2010). Anomaly patterns, as the end product of either common geological processes over long periods of time or uncommon processes such as ore-forming processes, weathering, human activities and element dispersion from an orebody, are defined simply as geochemical features different from those that usually occur more frequently. These differences consist not only of the frequency and spatial distribution of geochemical data, both of which have been investigated widely in the past several decades (e.g., Agterberg, 2007; Ahrens, 1954; Carranza, 2009; Krige, 1966; Reimann and Filzmoser, 2000; Turcotte, 1986, 1997), but also the geometrical characteristics and scale invariance of geochemical patterns (Afzal et al., 2010, 2011, 2012, 2013a; Agterberg, 2012a,b; Cheng et al., 1994, 1996, 1997, 1999, 2000; Li et al., 2003; Lima et al., 2003; Xu and Cheng, 2001; Zuo et al., 2015). It has been shown that ore elements, especially trace elements, do not follow a normal or lognormal distribution, but instead follow a positively skewed distribution with a long Pareto tail toward high values (e.g., Ahrens, 1957). With respect to the spatial distribution of geochemical data, autocorrelation often exists over a certain spatial range. The geometry of geochemical anomalies, also an important aspect, indicates geological structures. For example, linear anomalies may be associated with underlying faults, while arcuate anomalies may imply intrusive bodies (Cheng et al., 1999). Recent studies of geochemical patterns at different scales have shown that self-similarity or self-affinity are fundamental properties of geochemical data (e.g., Bölviken et al., 1992; Cheng et al., 1994; Zuo et al., 2009a,b). The most effective way to distinguish geochemical anomalies from the background is to adopt a comprehensive technique that combines the properties mentioned above.

The typical and most widely used method for detection of geochemical anomalies is setting threshold values, which contain the upper and lower limits of background variations (Hawkes and Webb, 1962). Observations outside of this range are referred to as anomalies, whereas those within background are not. However, traditional methods, including the one mentioned above, exploratory data analysis (Behrens, 1997; Carranza, 2010; Reimann, 2005a,b; Tukey, 1977), and multivariate statistics (Yousefi et al., 2012, 2014; Zuo, 2011a,b; Zuo et al., 2009a,b, 2013), are based on the frequency distribution of geochemical values and, therefore, neglect spatial variation and other potential characteristics that can provide valuable information. Considering the fact that exploration geochemical data are typically spatially dependent, a couple of frequency-space-based methods, such as the inverse distance-weighted

(IDW) and different kriging methods, have been put forward (Krige, 1978; Lam, 1983; Zimmerman et al., 1999). Although these methods acknowledge the spatial dependence of element concentrations, they do not consider that spatial variability is rugged and singular rather than smooth and differentiable.

The main attraction of fractal/multifractal theory lies in its ability to quantify irregular and complex phenomena or processes that exhibit similarity over a wide range of scales, which is termed self-similarity (Feder, 1988; Mandelbrot, 1983). Since the concept of fractal was introduced by Mandelbrot in the 1960s, a number of studies were applied to geological processes and phenomena to characterize the spatial distributions of concentrations and the relationship between tonnage and grade of deposits (e.g., Cheng et al., 1994, 2000; Lavalley et al., 1993; Mandelbrot, 1983; Turcotte, 1986, 1997, 2002). With respect to applied geochemistry, various researches are being implemented on the fractal properties of geochemical patterns over different scales, as indicated by the increasing number of published papers (Fig. 1). For example, the number of papers published in the Journal of Geochemical Exploration (JGE) at the five-year scale has increased nearly exponentially as the total number of papers in JGE, Applied Geochemistry (AG), and Geochemistry: Exploration, Environment, Analysis (GEEA). These numbers indicate that fractal/multifractal models have an important role, especially in applications to geochemical exploration. In detail, three important achievements have been made over the past thirty years. The first one is the proposal of a series of fractal/multifractal models used for separating geochemical anomalies from background or for determining baseline concentration in environmental studies. The second is the introduction of the concept of singularity, which enables us to study mineralization from a new nonlinear perspective and provides an effective tool for mapping local and weak anomalies, and the third is the ability to quantify the vertical distribution of geochemical elements using fractal methods.

Based on previously published researches, this paper provides an overview of fractal/multifractal modeling of geochemical data, including its theory, the way it works, its benefits and limitations, its applications, and the relationships among various models.

2. Fractal/multifractal models

The study of Bölviken et al. (1992) was early to address the importance of fractal models used for geochemical landscape studies and to

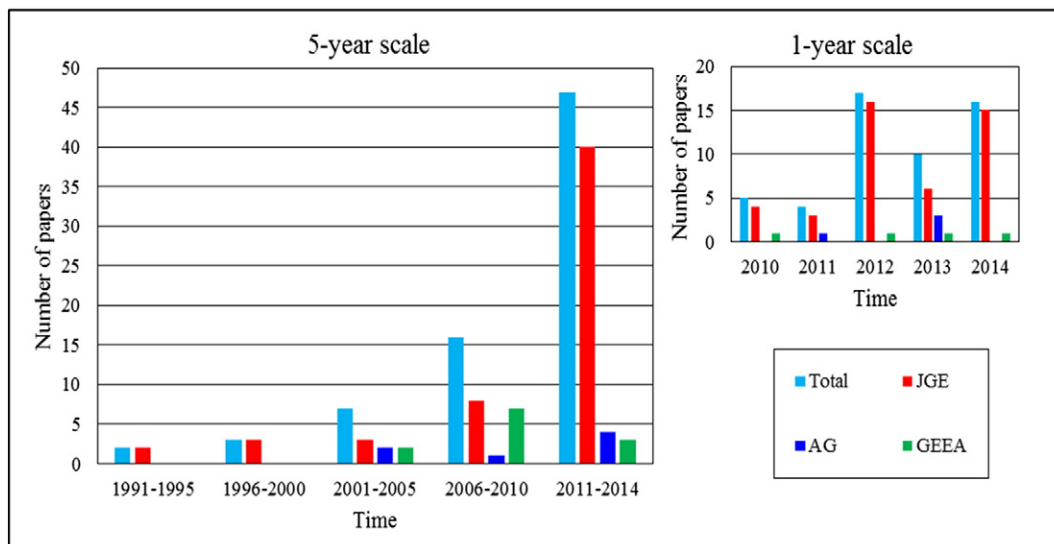


Fig. 1. Histogram of the number of papers related with fractal/multifractal modeling of geochemical data published in Journal of Geochemical Exploration (JGE), Applied Geochemistry (AG) and Geochemistry: Exploration, Environment, Analysis (GEEA) during 1991–2014.

Download English Version:

<https://daneshyari.com/en/article/4456977>

Download Persian Version:

<https://daneshyari.com/article/4456977>

[Daneshyari.com](https://daneshyari.com)