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Case study

A batch sliding window method for local singularity mapping and its application for geochemical anomaly identification

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ABSTRACT

In this study, a novel batch sliding window (BSW) based singularity mapping approach was proposed. Compared to the traditional sliding window (SW) technique with disadvantages of the empirical predetermination of a fixed maximum window size and outliers sensitivity of least-squares (LS) linear regression method, the BSW based singularity mapping approach can automatically determine the optimal size of the largest window for each estimated position, and utilizes robust linear regression (RLR) which is insensitive to outlier values. In the case study, tin geochemical data in Gejiu, Yunnan, have been processed by BSW based singularity mapping approach. The results show that the BSW approach can improve the accuracy of the calculation of singularity exponent values due to the determination of the optimal maximum window size. The utilization of RLR method in the BSW approach can smoothen the distribution of singularity index values with few or even without much high fluctuate values looking like noise points that usually make a singularity map much roughly and discontinuously. Furthermore, the student's *t*-statistic diagram indicates a strong spatial correlation between high geochemical anomaly and known tin polymetallic deposits. The target areas within high tin geochemical anomaly could probably have much higher potential for the exploration of new tin polymetallic deposits than other areas, particularly for the areas that show strong tin geochemical anomalies whereas no tin polymetallic deposits have been found in them.

1. Introduction

Singularity has been considered as one of the most important properties for non-linear natural processes or systems in various branches of earth science such as cloud formation (Schertzer and Lovejoy, 1985), flooding (Malamud et al., 1996), earthquakes (Turcotte, 1997), rainfall (Veneziano and Furcolo, 2002; Veneziano and Yoon, 2013), hurricanes (Sornette, 2004), landslides (Malamud et al., 2004) and hydrothermal mineralization (Cheng, 2007). From a viewpoint of geological application, it can be defined as a special phenomenon with anomalous amount of energy release or material accumulation occurring in narrow spatial-temporal intervals (Cheng, 2007). Taking metallic mineralization process as an example, it usually happens with a lot of metal elements precipitation and becomes to be enriched in relatively short geological time and small space scale of ore deposits. Singularity has considered to be a useful property in characterizing local depletion or enrichment of elements from a two dimensional geochemical map for identifying and extracting geochemical anomalies (Cheng, 2007). In practical application, to estimate the singularity exponent, a sliding window (SW) approach was originally developed by Cheng, 2006 on the basis of multifractal relationships between the density of metal and the corresponding area. Since the SW method based singularity mapping technique was proposed, it has been successfully proved to be a powerful tool for mineralization associated geochemical anomaly identification (e.g. Cheng, 2004, 2007, 2012, 2014; Chen et al., 2007; Cheng et al., 2009a, 2009b; Cheng and Agterberg, 2009; Arias et al., 2012; Zuo and Cheng, 2008; Zuo et al., 2009, 2015; Xiao et al., 2012, 2014; Zuo and Wang, 2015) and applied in a wide range of other geo-information anomaly recongnization associated fields such as geophysical exploration (Chen et al., 2015; Wang et al., 2013a), remote sensing (Cheng, 1999a; Neta et al., 2010), and tectonics data modeling

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List of notations

V	Volume
$\mu(V)$	The total amount of metal in V
$C(V)$	The density of metal in V
A	Area
$\mu(A)$	The total amount of metal in A
$\rho(A)$	The density of metal in A
α	Local singularity index
ε	Window size
W^{+}	Positive weight in the weights of evidence modeling
W^{-}	Negative weight in the weights of evidence modeling
M	Presence of a prospect
$\overline{M}$	Absence of a prospect
E	Presence of an evidence theme
$\overline{E}$	Absence of an evidence theme
C	Contrast of the weights of evidence modeling
t	Student's t-statistic value
$s^2(W^{+})$	The variances of W^{+}
$s^2(W^{-})$	The variances of W^{-}
$N(E \cap M)$	Numbers of unit cells or pixels of $E \cap M$
$N(E \cap \overline{M})$	Numbers of unit cells or pixels of $E \cap \overline{M}$
$N(\overline{E} \cap M)$	Numbers of unit cells or pixels of $\overline{E} \cap M$
$N(\overline{E} \cap \overline{M})$	Numbers of unit cells or pixels of $\overline{E} \cap \overline{M}$

(Wang et al., 2012, 2013b; Zhao et al., 2014). However, on the one hand, the maximum window size in the SW approach, i.e. an important parameter used to define the largest scale where the power-law relationships probably exist between measure and scale for local singularity index estimation, should be empirically predetermined by applicants. On the other hand, the linear regression method used for fitting the power-law relationships on log-log plots is sensitive to outliers. These two issues significantly affect the estimation accuracy of singularity index values in practical applications (Cheng, 1999b; Chen et al., 2007; Zuo et al., 2013; Zhang et al., 2014).

In order to overcome the disadvantages in traditional SW based singularity mapping technique, the purpose of this paper is mainly dressed on a procedure to improve SW approach in its accuracy of computation, and a batch SW (BSW) method was therefore developed in this study. It will show that the BSW method was a robust approach for singularity analysis. The concentration values of stream sedimentary geochemical data of tin, i.e. the predominant ore forming element of tin polymetallic mineralization in Gejiu distinct, Yunnan, China, were used to illustrate the implementation of the BSW based singularity analysis approach and a comparison study of BSW and SW in geochemical anomaly identification was conducted.

2. The SW approach

The general principle and procedure of the SW approach can be summarized as follows. In the multifractal context, the singularity phenomenon of hydrothermal mineralization can be characterized by power-law models. For convenience but without losing generality, in a three dimensional space, assuming that $\mu(V)$ is the total amount of metal in volume V, and $C(V)$, the density of metal in V is therefore equal to $\mu(V)/V$. Obviously, $\mu(V)$ and $C(V)$ accordingly change with V. If this relationship is multifractal, the power-law relationship between $\mu(V)$ or $C(V)$ and V can be expressed as follows:

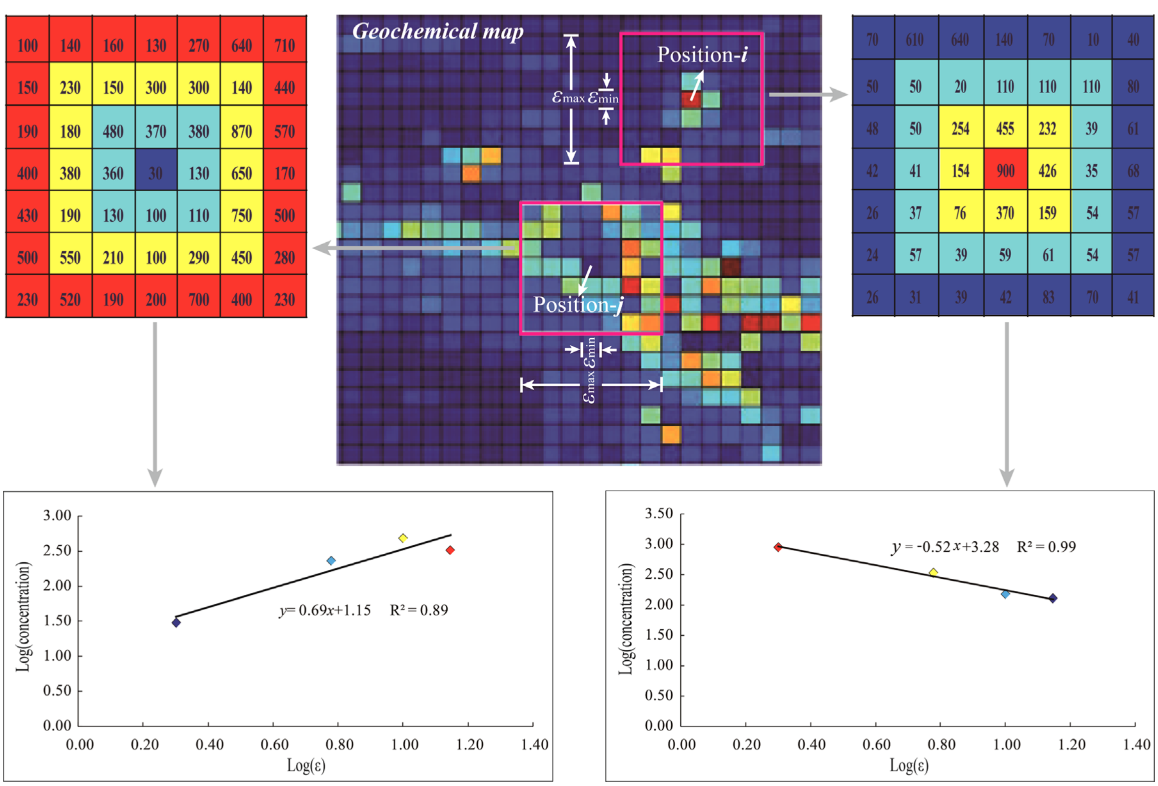

Fig. 1. The sketch diagram for illustrating SW method based singularity mapping technique.