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Geochemical multifractal distribution patterns in sediments from ordered streams

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ABSTRACT

For geochemical exploration, the stream sediment survey is of great importance for the delineation of geochemical anomalies and the distribution patterns of chemical elements are critical for anomaly recognition and mineral resource assessment. To study the distribution patterns of elements, we collected 7113 stream sediment samples along stream networks with seven orders from an area in the Qulong region of Tibet in southwest China where numerous polymetallic Cu deposits have been found. Thirteen elements, including Cu, Ag, As, Au, Ba, Bi, Hg, Mo, Pb, Sb, Sn, Zn, and W, were measured in each sample. The distribution patterns of the element concentrations are represented by multifractal spectrum estimated by the method of moments and characterized by six quantitative multifractal parameters. The multifractalities and inhomogeneity of the elements grow stronger as the elements transported from the main streams to the streams of order 1. Our study shows that the Cu anomalies delineated by the multifractal inverse distance weighted interpolation analysis correspond from streams of order 1 to streams of order 5, which indicates the self-similarity of geochemical variables. These results strongly suggested that the multifractal model and the multifractal parameters might be useful in estimating other stream sediments' properties and studying the geochemical dynamic transport behaviors of elements in stream sediments, which also might be extended to study the physical and chemical properties of soils from different horizons and other kinds of media at different scales as well.

1. Introduction

The purpose of geochemical stream sediment surveys is to prospect for geochemical anomalies (cf. Reimann et al., 2005) through an analysis of the chemical compositions of stream sediment samples that have been systematically collected. Due to mechanical transportation and chemical dissolution, the weathering products of rocks are transported in stream networks and accumulated as the physical and chemical environment changes. Thus, stream sediments can be regarded as bulk samples that contain information about the entire catchment basin. From this perspective, the stream sediment survey is one of the most efficient ways to conduct a large-scale geochemical investigation, and analyzing the spatial distribution pattern of stream sediment data is of great importance in geochemical exploration (Bölviken et al., 1992; Xie, 1997).

Over the past few decades, the hierarchy of geochemical patterns at different scales has been gradually discovered and accepted, and also systematically summarized (Bölviken et al., 1992; Xie and Yin, 1993; Allègre and Lewin, 1995). Many scholars have applied fractal and multifractal models to characterize the concentrations of geochemical elements in various media, such as soils and stream sediments (Cheng et al., 1994; Lima et al., 2003; Xie et al., 2005). The self-similarity or self-affinity and singularity of geochemical patterns in stream sediments have attracted much attention and various classical spatial statistics and nonlinear models have been applied. Bölviken et al. (1992) analyzed the perimeter–area and number–area fractal relationships in geochemical dispersion patterns of elemental concentrations in 6000 stream sediment samples. Geochemical dispersion patterns and spatial distributions of mineral depositions had also been discussed with fractals by Agterberg et al. (1993). Quantitative empirical modeling based on fractal and multifractal models had been applied for mapping significant geochemical anomalies (Agterberg, 2007) and prospective areas (Agterberg, 1974; Grunsky et al., 1994; Xie et al., 2007). The fractal and multifractal properties of Au and other associated elements in stream sediments were also studied to detect geochemical anomalies (Cheng et al., 1994, 1996). Shi and Wang (1998) applied the perimeter–area method (Mandelbrot, 1982; Cheng, 1995) to study the geochemical pattern in stream sediments from regional to local scales and established the hierarchy of geochemical patterns on known deposits. Rantitsch (2001) applied the perimeter–area model and multifractal spectrum curves to study the fractal and multifractal natures of geochemical stream sediment data and concluded that fractal and

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multifractal properties can be used as an indicator of weathering and transport processes. Cheng (2007) and Cheng and Agterberg (2009) showed that stream sediments in the neighborhoods of ore deposits can also have singular properties for ore-minerals. The multiscale structures of geochemical concentrations in stream sediments have been explored and the multifractal inverse distance weighted (IDW) interpolation technique (Cheng, 1999, 2000) and a fractal filtering model were applied to separate natural background and anthropogenic values for the compilation of environmental geochemical mapping from stream sediment samples in Campania region, Italy (Lima et al., 2003). Both multifractal power spectrum and singularity have been used to identify geochemical anomalies (Ali et al., 2007). Wang et al. (2008) proposed a dynamic feedback model to study the sediment transport in river systems. Corresponding fractal and multifractal models together with GIS techniques had been used for geochemical anomaly prospecting and reviewed by Carranza E. J. M. (2008).

In this paper, 7113 stream sediment samples from stream systems in Qulong area, Tibet, China (Fig. 1), are investigated to study the multifractal nature of elements. By the method of moments and the multifractal IDW technique, we investigate the multifractal properties of element concentrations at various scales and try to delve into the

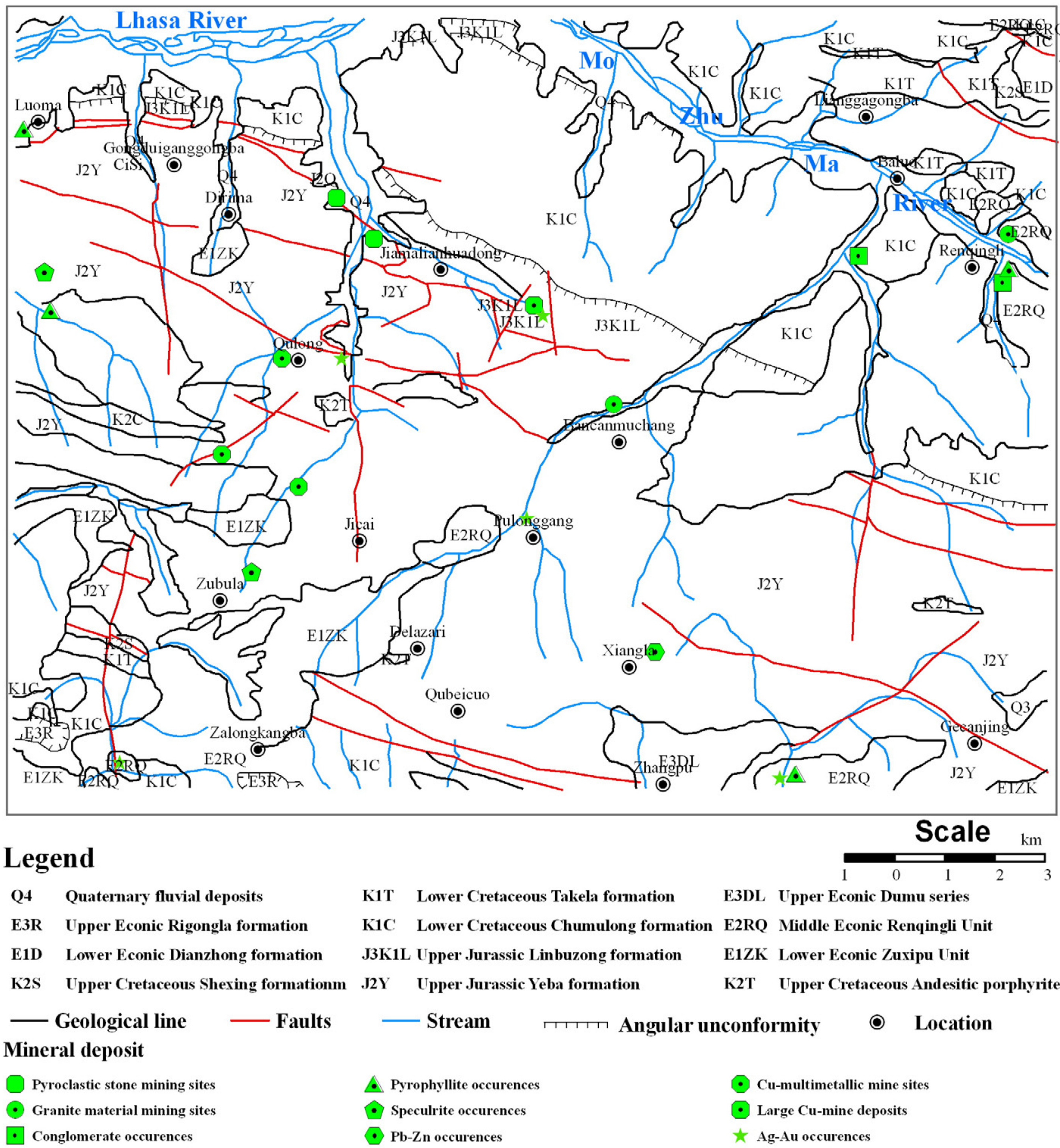

Fig. 1. Simplified geological map of the study area in Tibet, China.