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Multi-element geochemical mapping in Southern China ☆

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ABSTRACT

The 76-element Geochemical Mapping (76 GEM) Project was undertaken in southwestern China in 2000 and in southeastern China in 2008. In this project, 5244 composite samples of stream sediment at a density of one composite sample for each 1:50,000-scale map sheet were prepared from sample archives of the China Regional Geochemistry-National Reconnaissance (RGNR) Project, which have been available since 1978. The 76 elements were analyzed by using inductively coupled plasma mass spectrometry (ICP-MS), X-ray fluorescence (XRF), and inductively coupled plasma atomic emission spectroscopy (ICP-AES). In the present study, a new quality-control method known as the visualized standard map method was applied to the results of the 76 GEM project. Mean value and background value, which indicate the average concentration of the 76 elements in southern China, were derived from statistical data. Moreover, geochemical maps were compiled to demonstrate the distribution of the 76 elements in southern China.

1. Introduction

All elements in the periodic table appear in the Earth's environment and provide nutrients necessary for sustaining all life forms, ecology, and the environment. These elements and their isotopes are the smallest units used in geoscience research and can be compared to genes studied in biological disciplines. Mapping of the spatial distribution of nearly all elements in the periodic table will offer an updated knowledge of the construction of the Earth's surface for better stewardship of sustainable environmental management and mineral resource development.

In 1973, Webb et al. (1973, 1978) published *Provisional Geochemical Atlas of Northern Ireland*, which was the first geochemical atlas. Since that time, more than 40 regional and national geochemical mapping projects have been conducted (Bolivar, 1980; Bölviken et al., 1986; Bowie and Plant, 1978a, 1978b; De Caritat and Cooper, 2011; Chiprés et al., 2008; Cloete et al., 2009; De Vos and Tarvainen, 2006; Fauth et al., 1985; Friske and Hornbrook, 1991; Geological Survey of Canada, 1981; Imai et al., 2004; Koljonen, 1992; Laszlo et al., 1997; Prieto, 2009; Reedman, 1973; Reimann et al., 1998; Salminen, 2005; Shin, 2002; Simpson, 1993; Smith, 2009; Stephenson et al., 1982; Varna et al., 1997; Weaver et al., 1983).

During International Geological Correlation Programme (IGCP) 259/360 (1989–98), production of a global geochemical atlas of Earth's land surface was recommended in which 5000 Geochemical Reference Network (GRN) sampling cells were to be arranged to cover the entire planet, and 71 elements were to be analyzed (Darnley et al., 1995). To meet the requirements of this recommendation, a new national mapping program was initiated in 2000 after the development of a new 76-element analytical scheme that included Os, Ir, Ru, Rh, and Re in addition to the 71 suggested elements.

In 1978, the Regional Geochemistry-National Reconnaissance (RGNR) Project was initiated in China (Xie, 1977, 1978, 1979; Xie and Cheng, 1997; Xie et al., 1989a) in which various methods were used to analyze 39 elements; in 1993, the Environmental Geochemical Monitoring Network Project analyzed 54 elements (Xie and Cheng, 1997, 2001; Xie et al., 1997). In 2000, a project that plotted the geochemical maps for 76 elements, known as 76 GEM, was undertaken in southwestern China (Xie et al., 2008). In this project, approximately 100 samples within each 1:50,000-scale map sheet were combined and composited into one sample. A successor project that covered the rest of southern China was undertaken in 2008. Approximately 5244 composite samples were submitted for analysis. Several laboratories in China have collaborated on projects for developing analytical methods for platinum group elements (PGEs), rare earth elements (REEs), Re, and Te. The analytical scheme used was based largely on inductively coupled plasma mass spectrometry (ICP-MS), inductively coupled plasma-atomic emission spectrometry (ICP-AES), and X-ray fluorescence (XRF), supplemented with other techniques. In addition, the detection limits of all elements analyzed were less than their crustal abundance values. The geochemical maps produced

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through these projects show the distributions of most of the elements in the periodic table.

2. Sample collection

The RGNR program was conducted in China the late 1970s (Xie et al., 1989a, 1997). Stream sediment was used as the main sampling medium (Xie, 1979). Samples were collected from second-grade drainage or the mouth of first-grade drainage at a density of one to two samples per square kilometer. The minimum and maximum areas of the basin controlled by the samples in the uppermost region were 1/3 km^2 and 3 km^2, respectively. Samples were air-dried and sieved with a 60-mesh screen to obtain particles smaller than 0.22 mm. Parts of the original samples were used for analysis of 39 elements, and the remaining samples were archived for future applications. More than 3 million stream sediment samples have been collected in southern China. The present study utilized RGNR samples from 12 provinces in southern China including Sichuan, Yunnan, Guizhou, Guangxi, Guangdong, Hunan, Hubei, Jiangxi, Fujian, Anhui, Zhejiang, and Jiangsu in addition to several autonomous regions (Fig. 1).

3. Sample preparation and processing

The RGNR project conducted in the aforementioned 12 provinces in southern China commenced in 1980 and was completed in 1995. Approximately 100 RGNR samples from each 1:50,000-scale map sheet were composited into a single sample for reanalysis in 76 GEM. Each analytical sample contained all of the collected samples within each 1:50,000-scale map sheet included in an area of 410–460 km^2 from the RGNR sample bank. 20 g of sediment was collected every 4 km^2 to provide a composite sample. Blank spaces were not considered in this sample preparation plan. Overall, 5244 composite samples were prepared during this program, covering an area of 2,300,000 km^2.

The composite samples were ground by using an agate jar ball mill and sieved through a 200-mesh screen to obtain particles smaller than 74 μm. The processed samples were then analyzed by various laboratories.

4. Sample analysis and quality control

Analytical technology has advanced rapidly in recent decades. Since the analysis of 39 elements in the RGNR program, technological advances have enabled analysis of 54 elements through the National Environment Monitoring Network Program of China and through multi-purpose ecological geochemical survey. The precision and accuracy of testing have improved significantly, as demonstrated by the advanced analysis through 76 GEM (Xie et al., 2008).

The fundamental requirement (Darnley et al., 1995; Xie, 1995) of the present study was to ensure that the detection limits of trace and sub-trace elements are lower than their crustal abundance values. A multi-method–multi-instrument analytical approach was adopted, and the visualized standard maps method was established for strict data-monitoring.

According to the aforementioned requirements, ICP-MS, XRF, and ICP-AES were adopted to analyze most of the elements; alternative methods were used to analyze those with low crustal abundance values. Table 1 shows the analytical method adopted for each element.

A standard code for samples and duplicate samples was used to control the analytical quality and to ensure that both internal and external qualities are in good agreement with the results obtained in the present study (Xie et al., 2003; Ye, 2002; Ye and Yao, 2004).

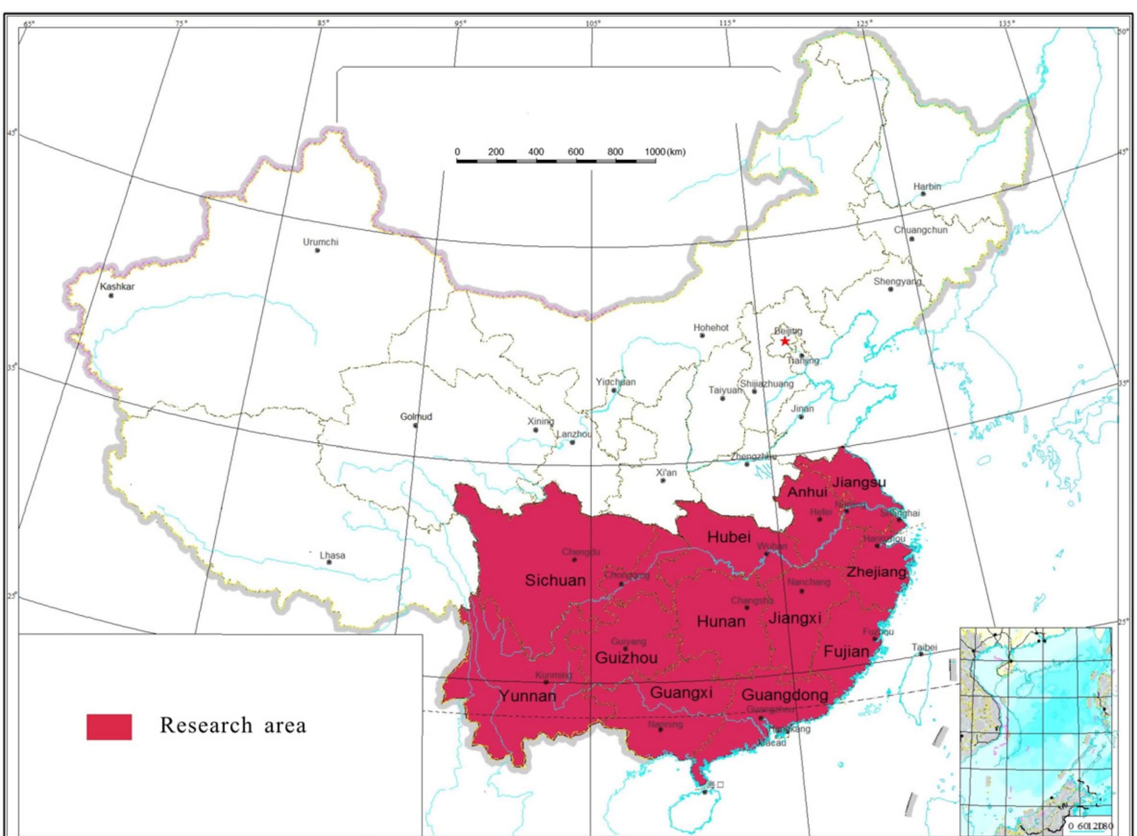

Fig. 1. Location of study area for the 76 element geochemical mapping in southern China.