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The relationships between magnetic susceptibility and elemental variations for mineralized rocks

Yu Li [a,b], Renguang Zuo [a,*], Yin Bai [a,b], Mingguo Yang [b]

[a] State Key Laboratory of Geological Processes and Mineral Resources, China University of Geosciences, Wuhan 430074, China
[b] Faculty of Earth Resources, China University of Geosciences, Wuhan 430074, China

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ABSTRACT

Investigation of the geophysical and geochemical properties of rocks is essential for successful mineral exploration. In the present study, the Itrax core scanner, a fast and nondestructive instrument at China University of Geosciences (Wuhan), was applied to measure the magnetic susceptibility (MS) and elemental variations at specific intervals of two limestone samples collected from the Jinding sediment-hosted Pb–Zn deposit, Yunnan Province (China). Statistical methods, including correlation, cluster, and regression analysis, were used to explore the relationships between rock MS and elemental variations of Zn, Fe, Pb, Ni, Cr, Si and Ca. The resulting correlation analysis demonstrated that concentrations of Fe and Zn were positively correlated with MS, whereas Pb, Si and Ca concentrations were negatively correlated with MS. The resulting cluster analysis and stepwise multiple linear regression analysis between MS and elements concentrations show that Zn, and Cr are the crucial factors responsible for the variability of MS. These results are probably due to the Fe, Ni, and Cr elements existing in the lattice of sphalerite, which contributes positively to the MS of rocks.

1. Introduction

The relationships between magnetic susceptibility (MS) and elemental variations have been the focus of considerable study in the fields of environmental assessment and resource exploration. For instance, Zhang et al. (1998) investigated the subject and concluded that magnetic parameters are related to heavy metal content based on analysis of the magnetism of lake and tidal flat sediments. Similarly, Spiteri et al. (2005) studied the relationships between topsoil and the distribution of heavy metals in the Lausitz region of eastern Germany and demonstrated that MS can be used as a proxy for soil heavy metals contaminations. Wang et al. (2009) described an indicative function of rock MS in the exploration of iron oxide copper–gold (IOCG) deposits in Chile in another research, Deng et al. (2010) delineated rock MS anomalies in East Sichuan (China) in the exploration of IOCG-type deposits. Cao et al. (2007) explored the relationship between rock MS and gold mineralization in Henan (China). However, few studies to date have investigated the relationships between MS and elemental variations at the hand specimen scale.

To address this issue, we used the Itrax core scanner – a fast and nondestructive instrument – to measure MS and elemental concentrations of limestone samples collected from the Jinding Pb–Zn deposit, a world-class sediment-hosted deposit. In this paper, we discuss the relationships between MS and Pb–Zn mineralization using statistical approaches.

2. Study area and data

The Jinding deposit is one of the largest Pb–Zn deposits in China (a metal reserve of greater than 15 Mt deposit, average Zn = 6.08%, Pb/Zn = 1:4.7), located in the Lanping basin in northwestern Yunnan Province (Xue et al., 2003, 2004, 2007). The Lanping basin represents the northern part of the Lanping–Simao Mesozoic–Cenozoic basin, developed on the Changdu–Simao microplate between the Lancangjiang and Jinshajiang–Ailaoshan tectonic belts (Xue et al., 2003). The deposit is composed of six ore blocks (Beichang, Paomaping, Jiayashan, Xipo, Baicaoping, and Fengzishan blocks) and has a total area of less than 10 km^2 (Hu et al., 1998). The mining area has previously been affected by processes of sedimentation, thrusting, heat doming, and dome collapse, with local extension and heat flow upwelling accompanied by mineralization (Xue et al., 2003). The mineralization age coincides approximately with the initiation of Himalayan alkali magmatic intrusion (i.e., 68 Ma; Xue et al., 2003). The strata in the mining area include both autochthons and allochthons: the stratum overlying the flat-lying fault F2 is allochthonous and inverted, whereas that underlying the fault is autochthonous and exhibits a normal sequence (Fig. 1). The orebodies typically exhibit tabular or vein forms and are hosted by fine sandstones (in the western part of the Beichang block and in the Fengzishan and

* Corresponding author. Tel./fax: +86 27 67885096.
E-mail address: zrguang@cug.edu.cn (R. Zuo).

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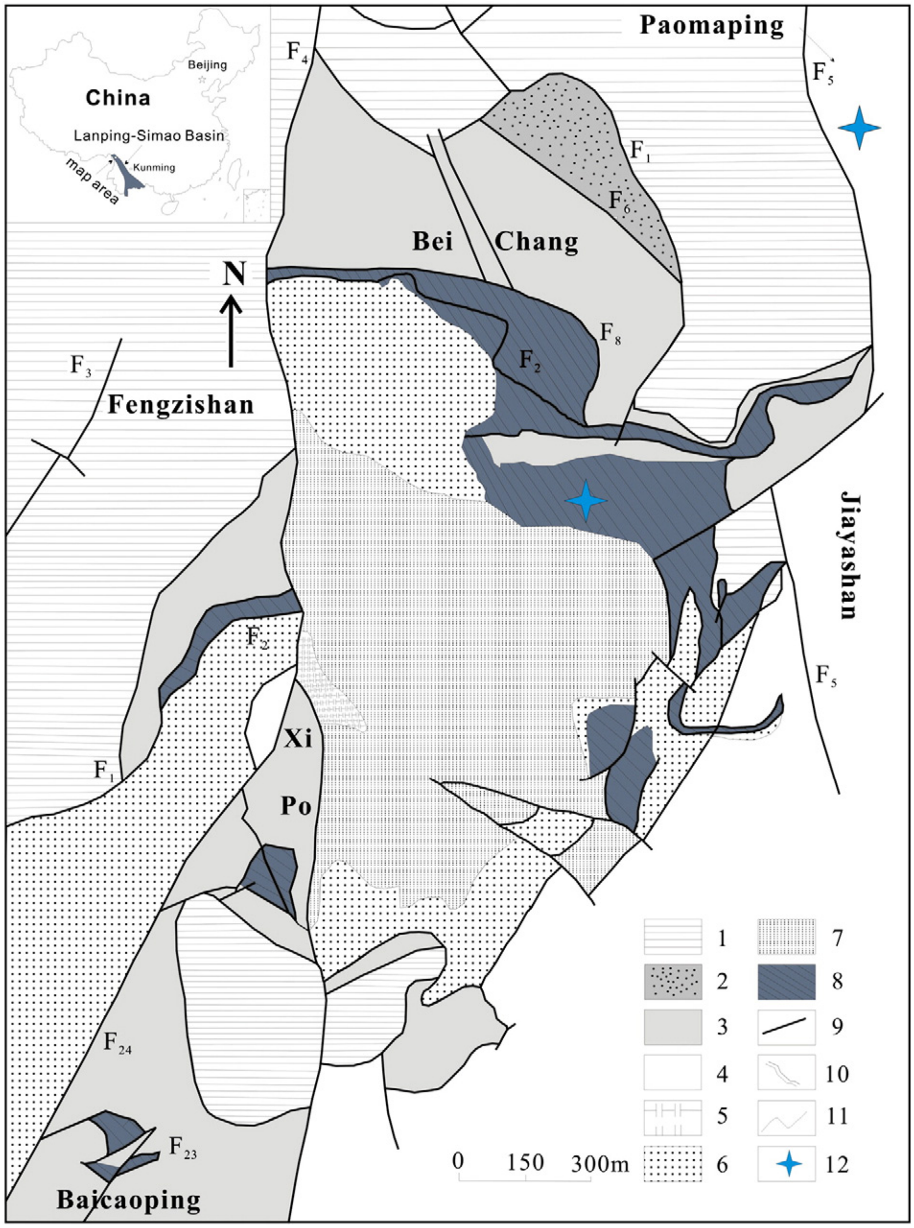

Fig. 1. Simplified geological map of the orefield (after Gao, 1989). 1: Limestone—Upper Triassic Sanhedong Formation; 2: Shale and siltstone—Upper Triassic Maichuqing Formation; 3: Siltstone and mudstone—Middle Jurassic Huakaizuo Formation; 4: Sandstone—Lower Cretaceous Jinxing Formation; 5: Sandstone—Middle Cretaceous Hutousi Formation; 6: Siltstone and mudstone—Paleocene Lower Yunlong Formation; 7: Sandstone—Paleocene Upper Yunlong Formation (sandstone); 8: Zn–Pb ore body; 9: fault; 10: unconformity; 11: geological boundary; 12: sampling location.

Xipo blocks) or calcibreccia (in the eastern part of the Beichang block and in the Jiayashan, Nanchang, and Paomaping blocks; after Zhao, 2007).

Samples Nos. 1 (sphalerite 35%, galena 5%, pyrite 3%, marcasite 1%, calcite 35%, quartz 10%) and 2 (sphalerite 20%, galena 10%, pyrite10%, marcasite 10%, calcite 40%, quartz 5%) were collected from the Pb–Zn mineralized breccia of Beichang and Paoma Ping in the eastern part of the mining area (Fig. 1). The length, width, and thickness of sample No. 1 (sample No. 2) were 10.5, 6.5, and 1.3 cm (7, 2.3, and 1.2 cm), respectively. The main metallic minerals in both samples were sphalerite and galena, and calcite was the primary transparent mineral; both samples contained a small amount of quartz. Galena and sphalerite were developed primarily along breccia fractures in sample No. 1, whereas two ore-forming stages were observed within sample No. 2: the first was characterized by a pyrite + marcasite + sphalerite assemblage and was found within the orebodies; the second was associated with sphalerite + galena and occurred within calcite veins, and some of the earlier pyrite was replaced by the later sphalerite (Fig. 2). Sphalerite was found to be more abundant than galena in both samples.

Magnetic susceptibility and elemental concentrations were measured with Itrax core scanner instrument at the State Key Laboratory of Geological Processes and Mineral Resources at China University of Geosciences (Wuhan) (Zuo, 2013). The Itrax core scanner is an automated instrument that can synchronously provide four datasets: micro-X-ray fluorescence analysis (μ-XRF) data, high-resolution X-radiographic images, high-resolution optical images, and MS profiles. It can be operated on rock or sediment cores up to 1800 mm long and with diameters ranging from a few cm up to 12 cm, and the abundances