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Research Advances

New Discovery of Post-Magmatic Pyrite in Natural Coke at Yangliu Coalmine, Northern China

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Objective

Material exchange between magma and coal has recently received much attention, with published studies dedicated mainly to intrusion-related geochemical anomalies (An et al., 2017). It is found that magmatism not only alters the chemical compositions of coal seams, but also brings new minerals to natural coke. Although some studies have related magmatic water to secondary minerals in the natural coke, the mineral formation mechanism remains controversial (An et al., 2017). In this work, we tackle this issue from a pyrite mineralogical and geochemical perspective. Using SEM and LA-ICP-MS analyses, we first proposed that the pyrite in natural coke at the Yangliu coal mine was mainly derived from mafic intrusions.

Methods

Pyrite samples were collected from the intrusion, natural coke and unaffected coal in Coal Seam No. 10 from the Yangliu coalmine, and thin sections were prepared for SEM observation at the Key Laboratory of Geological Process and Mineral Resource Survey of Guangdong and LA-ICP-MS analysis at the Laboratory of Sample Solution in Wuhan. A SEM (FE-ΣIGMA VP300, Carl Zeiss AG., Heidenheim, Germany) coupled with an EDS (X-MAX020, Oxford Instruments, Oxford, UK) was used to study the mineral morphology and elemental distribution. SEM-EDS operating conditions include 10 mm working distance, 20.0 kV beam voltage, 6 nm aperture and 5 nm beam size. LA-ICP-MS analysis was conducted with an Agilent 7700 ICP-MS (Agilent Technologies, Santa Clara, CA, USA) coupled with a Resonetic RESOLution M-50 ArF-Excimer laser ablation system (λ=193 nm) (Coherent Inc., Santa Clara, CA, USA), using 80 mJ laser energy, 10 Hz frequency, 44 μm spot size, and He as carrier gas. REE contents were calculated using the software ICPMS DataCal (version 10.2) (developed by the China University of Geosciences). The detection limits were 2–8 ppb, and the accuracy of the analysis was mostly better than 5%.

Results

Pyrites in the different types of samples appear very differently in SEM images. Pyrite in the intrusion is skeletal and commonly embedded in other minerals (Fig. 1a), indicative of a co-magmatic genesis. Pyrite in the natural coke is mainly colloidal and encapsulated numerous mesocarbon microbeads (Fig. 1b), suggesting that the colloidal pyrite was formed after the mesocarbon (An et al., 2017). Pyrite in the unaffected coal (intrusion-distal) occurs dominantly as fine aggregates in the fissures of fusinite (Fig. 1c), indicating that the pyrite was likely formed during early diagenesis (Gao Shang et al., 2017). In summary, the pyrite in the natural coke is most likely post-magmatic, whilst those in the intrusion and unaffected coal are likely co-magmatic and sedimentary, respectively.

This conclusion is also supported by REE evidence. The pyrite total REE contents of unaffected coal range from 13.57 to 23.12 ppm, and the pyrite REE contents are higher in the natural coke (up to 39.45 ppm) than in the intrusion (<1.17 ppm). This indicates that the pyrite chemistry in the natural coke was inherited from both the pyrites in the coal and in the intrusion (Gao Shang et al., 2016). In addition, there are strong positive Eu anomalies in the pyrite from the intrusion (δEu=9.61–15.59) (Fig.

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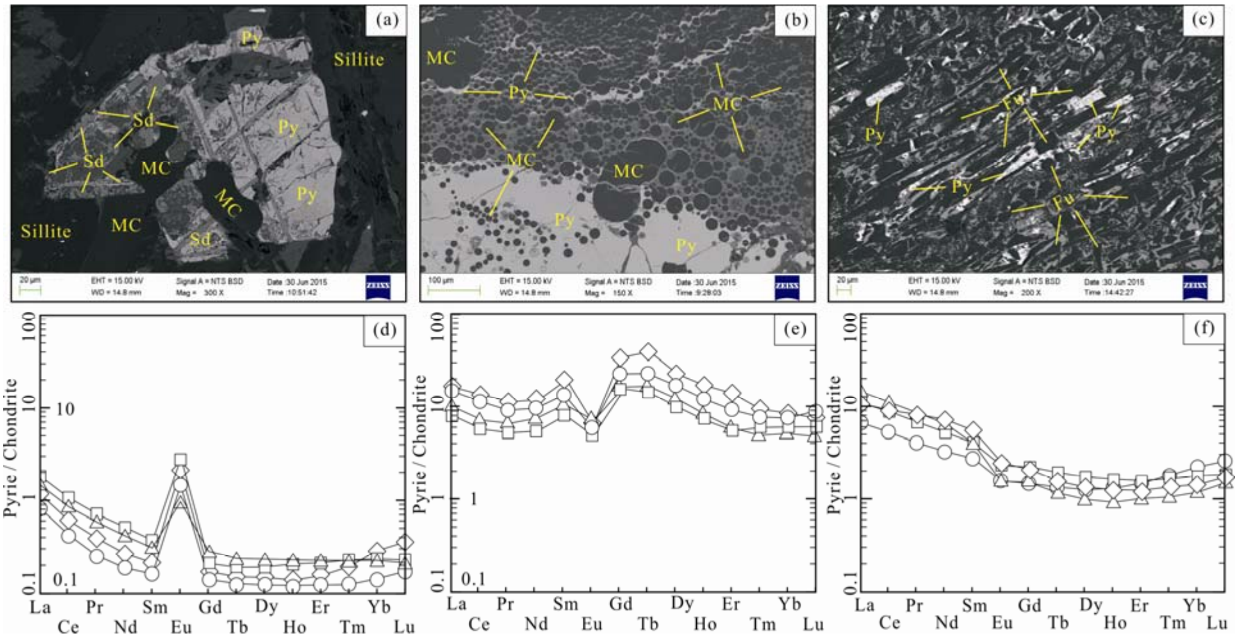

Fig. 1. Pyrite SEM images and chondrite-normalized REE diagrams of the Yangliu coal mine, northern China.
(a), Skeletal pyrite filled with mesocarbon in intrusive rock; (b), Colloidal pyrite encapsulated and crosscut mesocarbon microbeads in natural coke; (c), Fine pyrite aggregates in the fissures of fusinite in unaffected coal; (d), Chondrite-normalized REE diagram of pyrite in intrusive rock; (e), Chondrite-normalized REE diagram of pyrite in natural coke; (f), Chondrite-normalized REE diagram of pyrite in unaffected coal. Abbreviations: Py, Pyrite; Sd, Siderite; MC, Mesocarbon; Fu, Fusinite.

1d), strong negative ones in the pyrite from the natural coke (δEu = 0.28–0.36) (Fig. 1e), but no pronounced Eu anomalies in the pyrite from the unaffected coal (δEu = 0.78–1.14) (Fig. 1f). This suggests that the pyrite from the natural coke may have had a mixed source from the intrusion and unaffected coal (An et al., 2017), which cancelled out the Eu anomalies. Therefore, pyrite in the natural coke is most likely post-magmatic.

Conclusions

In this study, three types of pyrite from the Yangliu coalmine were identified, i.e., fine pyrite aggregates in the unaffected coal, skeletal magmatic pyrite in the intrusion, and colloidal pyrite in the natural coke. Pyrite REE compositions suggest that the pyrite in the natural coke have had a mixed source from the intrusion and unaffected coal, which further indicates that the pyrite in the natural coke may have been post-magmatic.

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