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In seam variation of element-oxides and trace elements in coal from the eastern Ordos Basin, China

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ABSTRACT

This paper investigated the mineralogical and geochemical compositions of the upper Pennsylvanian coal from Hedong Coalfield, in the eastern Ordos basin, China, using SEM, XRD, ICP-MS, ICP-CCT-MS, DMA-80 and ISE methods. The bituminous coal samples were collected form Nos. 3 and 4 Coal, which had low ash yield and were medium volatile, and had low sulfur content and low hazardous trace elements concentrations (Be, F, As, Hg, U and Pb). Maceral compositions were dominated by vitrinite (up to 90.2%), and to a lesser extent by inertinite and liptinite, all subgroups were detected in the coal samples. Minerals included quartz, clay minerals, sulfide and other oxide minerals. SiO_2 and Al_2O_3 were the dominant major elements-oxides in both coal seams with much higher concentrations than in Chinese coal, while other major elements-oxides (Na_2O, K_2O, Fe_2O_3, MgO) had average values compared to Chinese coal. No. 3 Coal was enriched in Li and Zr, and No. 4 Coal was enriched in Li, Be, Cu, Se, and In. Elemental occurrence was studied using statistical methods, and Li, Rb, Zr, Cs, Ba, Hf, Tl, Pb, and Th were inorganic affinities, while F, V, Cr, Ga, Ni, As, In, Ta occurred as inorganic–organic affinities and Fe and S may have occurred in pyrite. Coal facies indicators (GI, TPI, GWI, and VI) plots suggested that the two coal seams were deposited in different environments: No. 3 Coal was deposited in a wet forest swamp, while No. 4 Coal was formed in a mesotrophic to ombrotrophic environment. The geochemistry of these coal samples (Al_2O_3/TiO_2, TiO_2/Zr, Zr/Sc and Th/Sc ratios) indicated that the coal samples sediment was sourced from intermediate and felsic igneous rocks.

1. Introduction

Coal is the most abundant fossil fuel in China, and is a reliable long-term fuel source for China (Dai et al., 2017c) and other countries, including Turkey (Erarslan and Örgün, 2017; Erarslan et al., 2014) and South Africa (Wagner and Hlatshwayo, 2005). With the increasing use of coal in China, a large amount of pollutants has been produced, not only in the form of gas emissions but also as ash residues. Studies on the elemental geochemistry of coal have demonstrated the environmental impacts of coal. The geochemical and mineralogical compositions of coals are also mainly controlled by the sediment source and sedimentary mire environments. Previous investigations have studied the geochemistry and mineralogy of coal deposits around the world, such as coal producing areas in northern China (Dai et al., 2015a; Dai et al., 2015b; Sun et al., 2016), southern China (Dai et al., 2017b; Zhao et al., 2017), Iran (Rajabzadeh et al., 2016), Ukraine (Misch et al., 2016), Russia (Dai et al., 2016) Canada (Goodarzi, 1987, 1988; Pollock et al., 2000) and the USA (Hower et al., 2017).

China's Liulin district, located at the Hedong Coalfield, eastern Ordos basin, is famous coal producing area, because the coal is characterized by low ash yield and low harmful elements concentrations. Previous work has focused on the relationships between coal facies and pore structure (Zhang et al., 2010). The geochemistry and minerology of coal in these areas have rarely been reported.

In this study, we collected "super-clean" coal from the Liulin, Hedong Coalfield, and described the petrological, geochemical and mineralogical characteristics. The main goal was to identify coal features, investigate the sedimentary conditions during peat accumulation, and study the sediment source.

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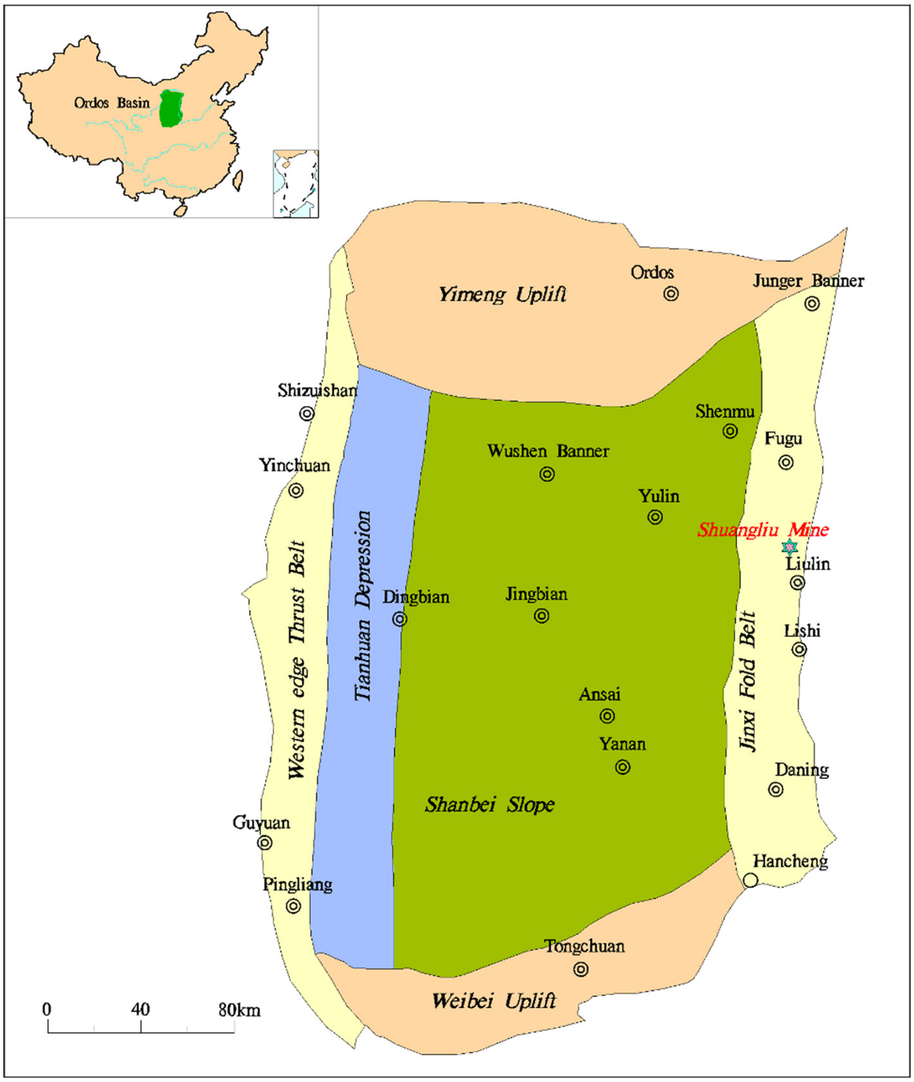

Fig. 1. The geological map of Ordos Basin and sampling location.

2. Geological setting

The Ordos basin is the oldest craton, the second largest sedimentary basin in China (Dai et al., 2006a). The Shuangliu coal mine is in the Liulin county, in the middle of Hedong coalfield, located along the eastern margin of the Ordos basin (Fig. 1). The geological setting is simple and faults are less well developed in this area (Xu et al., 2015). The stratigraphic strike is nearly NE-SW, and dips westward at 3 to 10°.

The main coal-bearing strata in the Liulin area are the upper Pennsylvanian Taiyuan Formation (C_2t) and the lower Permian Shanxi Formation (P_1s) which have a total thickness of 137–138 m and nine coal seams (Zhang et al., 2010). The main coal seams in the Taiyuan Formation are No.8 and No.9 Coal, and in the Shanxi Formation are No.3, No. 4 and No.5 Coal (Fig. 2a).

The samples in this study were collected from Nos. 3 and 4 Coal (Fig. 2b), which developed together in Shuangliu Mine and have a total thickness of 3.6 m, buried at a depth of 400 m.

3. Samples and analytical methods

The samples were collected from the faces of Shuangliu Mine along the eastern margin of the Ordos basin and included 15 coal samples (Nos.3&4 coal) and three coal bed roof and floor samples from the early Permian Shanxi formation.

Proximate analyses (Aad, Mad, and Vdaf,) of the coal samples were performed in accordance with ASTM standards (ASTM D3173-11, 2011a; ASTM D3175-11, 2011b and ASTM D3174-11, 2011c). Total sulfur was determined according to the ASTM D3177-02, 2011d standard. Mean vitrinite reflectance (%R_o) measurements and maceral analyses (500 points) were performed on the same polished section of the coal samples based on Taylor et al. (1998) and the ICCP System 1994 (ICCP, 1998, 2001). The scanning electron microscope (SEM) was used to study the distribution of minerals in the coal and the accelerating voltage was set to 20 KV, with a beam current of 10^{-10} A.

Samples were grounded to finer than 200 mesh for the major and trace elements analyses. X-ray diffraction (XRD) was performed for selected samples using a D/max-2500/PC powder diffractometer (Rigaku, Tokyo, Japan) with Ni-filtered Cu−K radiation and a scintillation detector to examine the mineral content. The major elements oxides (i.e., SiO_2, TiO_2, Al_2O_3, Fe_2O_3, MgO, CaO, MnO, Na_2O, K_2O, and P_2O_5) were analyzed using X-ray fluorescence (XRF) spectrometry (ARL ADVANT' XP +), and the trace elements (except for As, Se, Hg and F) were determined by inductively coupled plasma mass spectrometry (X series II ICP-MS). While in pulse counting mode (three points per peak), the samples were digested in an UltraClave Microwave High Pressure Reactor (Milestone, Sorisole, Italy). More details are given in previous reports (Dai et al., 2015a; Dai et al., 2012b; Yang et al., 2016). Arsenic and Se were analyzed using a collision/reaction cell technology for