Journal of Geochemical Exploration 190 (2018) 336–344

Contents lists available at ScienceDirect

Journal of Geochemical Exploration

journal homepage: www.elsevier.com/locate/gexplo

Element geochemical characteristics and formation environment for the roof, floor and gangue of coal seams in the Gujiao mining area, Xishan coalfield, China

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A R T I C L E I N F O

Keywords:
Gujiao mining area
Roof and floor
Gangue
Element
Sedimentary environment

A B S T R A C T

The roof, floor and gangue samples of coal seams were collected from a borehole in the Gujiao mining area. The vertical distribution of major elements, trace elements and rare earth elements (REEs) was tested through X-ray fluorescence spectrometry and inductively coupled plasma-mass spectrometry (ICP-MS). The formation environment and material source of the strata were analysed. The results showed that the major elements of the coal seam roof, floor and gangue are Si and Al, followed by Fe, K, and Ti. In the Shanxi Formation, Sn, B, Ta, Bi, Th, U, Li, Be, Nb, In, Cs and Hf are enriched. In the Taiyuan Formation, B, Bi, U, Li, Sr, Mo and Sb are enriched. Sn, B, Th, U, and Be of the Shanxi Formation and B, U, Mo, and Sb of Taiyuan Formation are enriched hazardous elements. The ratios of Sr/Ba, U/Th, Ni/Co and V/Cr could indicate the paleosalinity and redox conditions. The Shanxi Formation was mainly formed in an oxic environment. The roof and floor of the No. 7 coal and the roof of the No. 8 coal are limestone, indicating anoxic and suboxic to dysoxic environments. The lithology of the Shanxi Formation and Taiyuan Formation material source is complex, including sedimentary rocks, granite and alkaline basalt. Most samples are distributed at the intersection of the granite and alkaline basalt, indicating dual sourcing from the granite and alkaline basalt.

1. Introduction

China is the largest coal producing and consuming country in the world. A large amount of coal gangue (including the coal roof, floor and gangue), approximately 10–15% of coal production, is produced in the process of coal production and preparation (Liu and Liu, 2010; Jabłońska et al., 2016). At present, the stock of China's coal gangue is approximately 4.5 billion tons. In addition to large amounts of coal gangue occupying land, the hazardous element occurred in it is easy to be released into the surrounding environment which pollute atmosphere, soil and groundwater (Swaine, 2000; Ribeiro et al., 2010; Wang et al., 2014; Wu et al., 2017). However, the enrichment of trace elements and rare earth elements in coal gangue may have the value of industrial utilization. For example, the recovery of gallium from coal gangue which is rich in gallium is feasible and the benefit is remarkable (Liu and Dai, 2000). Different types of enrichment characteristics of elements represent different geologic origin. Therefore, the geochemical study on coal gangue can not only provide theoretical basis for the pollution study and recycling of coal gangue (Ding et al., 2011), the formation environment and material source of the roof, floor and gangue of coal seam can also be learn (Eker et al., 2012; Pozo et al., 2016; Blake et al., 2017; Ayinla et al., 2017; Xie et al., 2018).

There are many previous studies on the elemental geochemical characteristics of the roof, floor and gangue of coal seams in the Gujiao mining area (Zhang, 2012; Yang et al., 2015; Pu et al., 2012; Wang et al., 2016). The content and mode of occurrence of trace elements is different in different layers. However, there is a lack of research on the vertical trends of the geochemical characteristics of the roof, floor and

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https://doi.org/10.1016/j.gexplo.2018.04.007
Received 18 December 2017; Received in revised form 22 March 2018; Accepted 15 April 2018
Available online 19 April 2018
0375-6742/

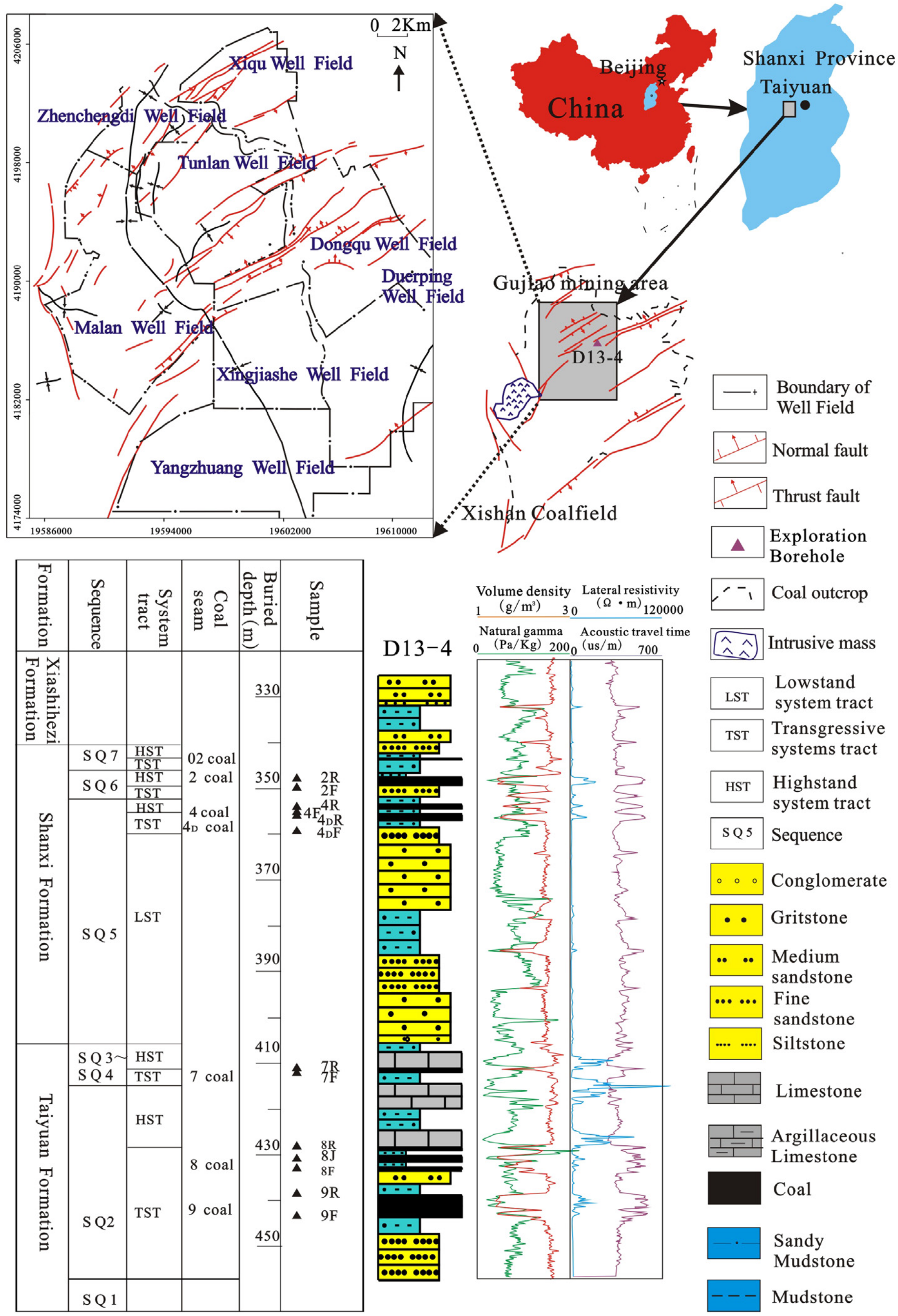

Fig. 1. Sample distribution in the Gujiao mining area and the column of the D13-4 borehole.

gangue for different coal seams.

Therefore, based on systematic sampling of the roof, floor and gangue of coal seams from one borehole in the Gujiao mining area, and using various methods of analysis and testing, the vertical distribution of major elements, trace elements, rare earth elements, source rock elements, and the formation environment was analysed.

2. Regional geological setting

The Gujiao mining area is located in the Xishan coalfield, Taiyuan city, Shanxi Province, belonging to the central part of the Craton in North China (Sun et al., 2013). The width is approximately 40 km from east to west, and the length is approximately 75 km from north to south. The area is approximately 1898.4 km^2 and is an important coking coal production base for China. The structure of the Xishan coalfield is generally small in the south and very large in the north, appearing as a “torch shaped” compound syncline structure (Wang et al., 2015; Huang et al., 2017; Fig. 1).

The main coal bearing strata in the Gujiao Mining area are the Lower Permian Shanxi Formation and the Upper Carboniferous Taiyuan Formation. The thickness of the Shanxi Formation ranges from 30 to 70 m, with an average of 46.98 m. It is a set of argillaceous rocks, with clastic and coal seam deposits. The No. 2 coal is the main mineable coal seam. The No. 2 and No. 4 coal seams are partially mineable. The thickness of the Taiyuan Formation ranges from 84 to 136 m, with an average of 101.5 m and it consists of mudstone, sandstone and siltstone, 6 to 8 layers of coal seams, and 4 to 6 layers of limestone. Nos. 8 and 9 coal are the main mineable coal seams. The bottom of the Taiyuan Formation (Jinci sandstone) is a conformable contact with the under layer. The Nos. 2, 8 and 9 coal seams are given priority for lean coal,