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Mineralogy and geochemistry of Late Permian coals from the Donglin Coal Mine in the Nantong coalfield in Chongqing, southwestern China

Jian Chen, Ping Chen *, Duoxi Yao, Zhen Liu, Yingshuang Wu, Wenzhong Liu, Youbiao Hu

School of Earth and Environment, Anhui University of Science and Technology, Huainan, Anhui 232001, China

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ABSTRACT

The Donglin Coal Mine, an important mine in the Nantong coalfield in southwestern Chongqing, is immediately adjacent to the Songzao coalfield. To investigate the mineralogy and geochemistry of Donglin coals, profile channel samples from the mineable Nos. 4 and 6 coals were collected. The minerals, major element oxides, and trace elements were analyzed by LTA-XRD in combination with Siroquant software, XRF, ICP-MS, ICP-CCT-MS (As and Se), ISE (F), and DMA-80 Hg analyzer (Hg). The results indicate that the Donglin low volatile bituminous coals were characterized by low ash yields and high total sulfur contents. The minerals varied between the Nos. 4 and 6 coals, differentiated by montmorillonite, calcite, ankerite, and pyrite. Despite the low boron concentration, Donglin coals were influenced by brackish water during coal accumulation. Selenium (10.9 mg/kg), F (431 mg/kg), Hg (0.350 mg/kg), Nb (20.7 mg/kg), and Ta (3.68 mg/kg) in the No. 4 coals, and F (425 mg/kg), Be (7.11 mg/kg), Ga (14.5 mg/kg), Ge (22.5 mg/kg), Zr (218 mg/kg), Nb (35.5 mg/kg), and Ta (4.42 mg/kg) in the No. 6 coals are slightly enriched. Four vertical distributions of elements were demonstrated, i.e., roof, floor, roof and floor, and middle enrichments. The slightly enriched trace elements and UCC-normalized REY distribution patterns of the Donglin coals jointly eliminated the impact of various volcanic ashes and terrigenous input from the Kangdian Oldland during the Late Permian. However, the roof rock samples shared the geochemical feature of mafic tonstein (enriched Sc, V, Cr, Co, and Ni), while the floor rock of the No. 6 coals resembles alkali tonsteins (enriched Ga, Zr, Nb, Ta, Hf, and REY). Lithium, Ga, Zr, Ag, Cd, In, Sn, Cs, Hf, Bi, Th, and U occurred in kaolinite and/or montmorillonite in the No. 4 coals, while Li, Nb, Ag, Cd, In, Cs, Ba, and Th occurred in kaolinite in the No. 6 coals. Vanadium, Sr, and Mo in the No. 4 coals, and Sr and Sc in the No. 6 coals were associated with calcite and/or ankerite. Arsenic, Se, Hg, Sb and Tl, and Hg and Mo were associated with pyrite in the Nos. 4 and 6 coals, respectively. Lithium, Be, Ge, and Sb in the No. 4 coals and Be and Ge in the No. 6 coals might be of organic affinity.

1. Introduction

The Nantong coalfield, an important coking coal production base for Chongqing, is located in the Wansheng district in southeastern Chongqing, southwestern China (Fig. 1a and b). There are five coalfields in Chongqing, i.e., Nantong, Songzao, Yongrong, Tianfu, and Zhongliangshan (Fig. 1b).

The geochemistry and mineralogy of the Chongqing coals are of special concern recently, not only because of the anomaly of some elements with industrial potentials but also of the special academic significance due to the influence of the Emeishan basalt eruption on coal deposition in the Late Permian period. For example, the enriched REY (rare earth elements and yttrium) in the K2 coal of the Moxinpo Mine in the Tianfu coalfield (Zou et al., 2014) and Nb and Ga in the No. 11 coal of the Songzao coalfield (Dai et al., 2007) are associated resources occurring in the coal. Moreover, the REEs (rare earth elements), Zr, Nb, and Hf in the Moxinpo K2 coal (Zhuang et al., 2003), Ta, Se, Nb, Hf, and V in the Zhongliangshan and Moxinpo coals (Zhuang et al., 2007), and REEs in 39 Chongqing coals (Li et al., 2008) are enriched when compared to common world coals reported by Ketris and Yudovich (2009). The tonsteins, which were derived from volcanic ash materials related to the Emeishan basalt, were widely developed in the coal-bearing measures in southwestern China with an area of 67,000 km^2 (Zhou et al., 1982) and affected both the mineralogy and geochemistry of coals, such as the Xinde coal in eastern Yunnan (Dai et al., 2014a), the Huayingshan coal in Sichuan (Dai et al., 2014b; Luo et al., 2012), and the Songzao coal in Chongqing (Dai et al., 2007, 2010, 2011; Zhao et al., 2013). Surprisingly, the tonsteins were not found macroscopically in the coalbeds during field sampling in the Donglin Coal Mine in the Nantong coalfield, which is adjacent to the Songzao coalfield (Fig. 2b). Furthermore, the mining activities, such as coal exploitation, in the Wansheng district (where the Nantong coalfield located) have had an adverse impact on local environment (Song et al., 2015). Therefore,

* Corresponding author.
E-mail addresses: cscchenjian@163.com (J. Chen), pchen87@163.com (P. Chen), dxyao@aust.edu.cn (D. Yao), 657792151@qq.com (Z. Liu), 13515548073@163.com (Y. Wu), njumedia@163.com (W. Liu), ybhu@aust.edu.cn (Y. Hu).

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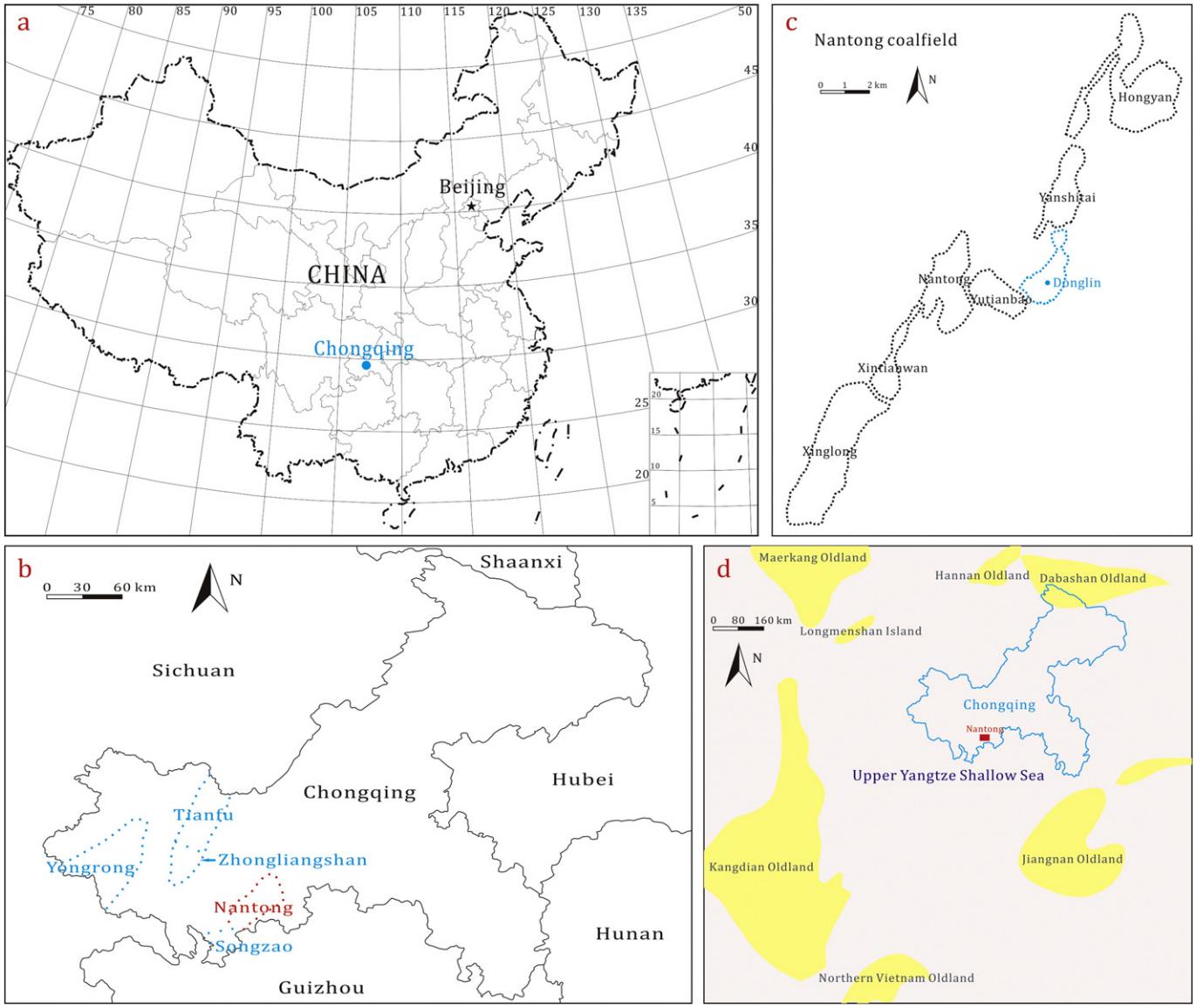

Fig. 1. Locations of Chongqing (a), Nangtong coalfield (b), and Donglin Coal Mine (c), and the paleogeography of Nantong coalfield (d). Note: the paleogeography of Nantong coalfield was redrawn from Gao et al. (2012).

the mineralogy and geochemistry of the Late Permian Donglin coals from the Nantong coalfield are of special importance.

This paper presents a mineralogical and geochemical investigation of 29 channel samples (e.g., roof rock, coal, and floor rock) from the Nos. 4 and 6 coals in the Donglin Coal Mine of the Nantong coalfield.

2. Geological setting

Seven coal mines, including Xinglong, Xintianwan, Nantong, Yutianbao, Donglin, Yanshitai, and Hongyan Mines, constitute the Nantong coalfield (Fig. 1c). The Donglin Coal Mine, which is close to the Yutianbao and Yanshitai Mines, is approximately 7-km long and 2-km wide, with a total area of 18 km^2. The Donglin Coal Mine was built in 1966 and has a production capacity of 300 thousand tons per year.

The coal-bearing measures occur in the Late Permian Longtan formation, which unconformably overlies the early Permian Maokou formation and conformably underlain by the Late Permian Changxing formation (Fig. 2a). The Maokou formation, with a mean thickness of 230 m, is composed mainly of gray limestone. The Longtan formation is composed primarily of gray/black laminar mudstone, sandy mudstone, sandstone, pelitic siltstone, bioclastic limestone, shale, and coal that overlies an aluminous mudstone layer. The average thickness of the coal-bearing strata is approximately 87.8 m. A total of 6 coalbeds (from the No. 1 coal at the top to the No. 6 coal at the bottom) occur in the Longtan formation in the Nantong coalfield (Fig. 2a). In general, only the Nos. 4 and 6 coals in the Donglin Coal Mine are stable and mineable. The thickness of the No. 4 coal ranges from 1.36 to 5.35 m, with an average of 2.78 m. The immediate roof and floor are mudstone or sandy mudstone. Furthermore, the No. 6 coal, with a mudstone and aluminous mudstone floor, varies in thickness from 0.69 to 3.10 m, with a mean of 1.49 m. The Changxing formation is composed of bituminous and bioclastic limestone with a total thickness of approximately 61 m.

The Nantong coalfield was surrounded by the Kangdian Oldland, Longmenshan Island, Hannan Oldland, Dabashan Oldland, and Jiangnan Oldland (Gao et al., 2012) (Fig. 1d), suggesting multiple sources of detrital material. The coals were accumulated in a paralic transitional environment (cf. its paleogeographic location demonstrated in Fig. 1d), which might be influenced by periodic tides.