

Advances in Exploration, Development and Utilization of Coal and Coal-Related Resources: An Overview

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The worldwide development of clean and low-carbon energy is undoubtedly imperative in the coming decades. Coal is definitely an indispensable source of energy necessary for techno-economic progress, currently accounting for 41% of global electricity needs. The combustion of a high volume of coal has led to the release of CO₂, NO_x, SO₂ and toxic elements, as well as to the accumulation of huge amounts of coal combustion products (CCPs), which may pose a severe threat to ecosystems [1]. As a consequence, deep exploration and development, as well as the clean and efficient utilization of coal and coal-related resources (e.g., toxic elements in coal, strategic metals in coal, coal measure gases, black shale gases, etc.), is of great significance to achieve carbon neutrality.

As is known, strategic metal resources are extremely important in economic development and defense security. Coal is a particular sedimentary organic rock, in which strategic metals (e.g., Ge, U, Ga, Li, and rare earth elements and Y) can be enriched and subsequently form large or super-large ore deposits under some specific geological conditions [2,3]. Given the continuous discovery and promising prospect of strategic metal ore deposits in coal-bearing strata, research on coal-hosted strategic metal ore deposits has been one of the most important subjects in coal geology and mineral deposit, and also been the frontier issue of international mineral geology. The recovery of critical metals from coal and CCPs will contribute not only to the remission of global demand for strategic metal resources but also to the clean and efficient utilization of coal. The novel utilization of CCPs, e.g., synthesis of zeolite, manufacture of foam glass and fire-resistant panels is not only eco-friendly (saving useful land, reducing emissions of pollutants and greenhouse gas), but also economically significant [4–8]. However, due to the complexity of the necessary questions and difficulties, the research on ore-forming theory, exploitation and exploration, and extraction technologies of strategic metals, as well as on development of new technology for the efficient utilization of CCPs, still faces big challenges and needs further investigation.

Meanwhile, research on the characterization and evaluation of coal measure gases, and other coal-related unconventional resources in coal and coal-bearing sequences, will also greatly promote the development of low-carbon energy. For instance, research on controlling factors of coal measure gas production and on advanced techniques to increase coal measure gas production, is to a large extent conducive to achieving carbon neutrality. In addition, natural gas generation is the result of organic matter degradation under the effects of biodegradation and thermal degradation. Black shales are rich in organic matter and have shown great shale gas potentiality in recent years. Note that stone coal, a special kind of coal, is a combustible, low-heat value, high-rank black shale mainly derived from early Paleozoic bacteria and algae after saprofitation and coalification in a marine-influenced environment [9]. Apart from the great potentiality of shale gas, under some special geological conditions, stone coals are also enriched in strategic elements (V and Se) that are industrially and agriculturally utilized, as well as some toxic elements



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that have caused environmental pollution (e.g., SO₂ emission during their combustion) and endemic diseases such as selenosis and fluorosis. Furthermore, research on stone coal can provide useful information for geological events and regional geological setting (e.g., hydrothermal activities).

Furthermore, the exploration and mining process of coal seams, especially those thin and medium thick coal seams with complex geological structure and close distance, is mostly accompanied by violent mine pressure and continuous large deformation of surrounding rock, which will restrict the improvement of the coal mine safety situation and production efficiency in coal mines. Therefore, it is urgent to further reveal the deformation characteristics of surrounding rock and to provide the scientific basis for safe exploration and mining process of coal seams.

The Special Issue encompasses a series of research papers, which provide several representative research aspects of advances in exploration, development and utilization of coal and coal-related resources. For instance, Li et al. and Wei et al. discussed the geological and geochemical characterization, respectively, of coals from typical coalfields in China, with special emphasis on the strategic metal enrichment in coal [10,11]. Zhang et al. investigated the distribution, occurrence, and integration of As in Permian coals in North China, and inverted influence of depositional environment on enrichment of As and other toxic elements in coal [12]. These studies will play an important role in the potential extraction of strategic metals from coal, as well as in environmental protection (environmental pollution control and the implementation of carbon neutralization).

With respect to the advanced research on the characterization and evaluation of coal measure gases to fulfill the efficient exploration, development and utilization of coal measure gases, Chen et al. revealed the controlling mechanism of fracturing fluid on CBM migration and found that both fracturing fluid volume and ratios of critical desorption pressure to reservoir pressure (R_c/r) have a significant impact on coal measure gas production [13]. This research can provide guidance for the optimal design of hydraulic fracturing parameters for CBM wells. With respect to the research on characterization and evaluation of other unconventional resources, Xia et al. conducted a comprehensive study of marine redox conditions, primary productivity, sedimentation rate, terrigenous input and hydrothermal activity of early Cambrian Niutitang black shales (usually called stone-coal) in the Upper Yangtze Region, and revealed the organic matter enrichment of the black shales deposited in different settings [14]. This study provides important information for predicting favorable areas for shale gas production.

In view of the safe and efficient exploration and mining process of coal seams, Liu et al. investigated the physical similarity simulation of deformation and failure characteristics of coal–rock rise under the influence of repeated mining in close distance coal seams [15]. This research put forward an accurate laying of model and precise excavation of roadway test method which can effectively solve the problem of accurate laying of model and precise excavation of roadway in physical similarity simulation test of roadway with special surrounding rock structures.

Finally, as we stated above, due to the complex of the scientific questions and difficulties, there are still big challenges and several outstanding questions on the exploration, development and utilization of coal and coal-related resources, e.g., advanced extraction technologies of strategic metals from coal. Further studies are needed to fulfill the most efficient and clean utilization of coal and coal-related resources.

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