Editorial

Advanced Coal, Petroleum, and Natural Gas Exploration Technology

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Oil, coal, and natural gas are traditional fossil energy sources and the main components of primary energy consumption globally. They will also remain the world’s major energy sources for a significant amount of time to come. The energy information administration’s 2019 energy report predicts that global energy consumption will continue to grow until 2050 [1]. Meanwhile, however, increasingly more attention is being paid to protecting the ecological environment. On the one hand, there is a movement to gradually seek, develop, and utilize renewable green energy. From 2020 to 2021, global renewable energy consumption increased by 15%. On the other hand, people are also constantly exploring high-efficiency fossil energy exploitation technologies that are environmentally friendly and reduce the negative environmental impacts of these energy sources while meeting the human demand for energy.

According to the relevant research data of some scholars, the world’s recoverable oil reserves are about $9.56 \times 10^{10}$ t, of which unconventional oil resources account for about 44%. The estimated recoverable natural gas reserves are $7.838 \times 10^{12}$ m$^3$, of which about 25% comprise unconventional natural gas resources. It is estimated that global unconventional oil production will exceed $10 \times 10^8$ t, accounting for about 20% of the world’s total crude oil supply, and that global unconventional natural gas production will increase to 42% of the world’s total natural gas production [2].

Traditional oil recovery methods, i.e., primary oil recovery and secondary oil recovery, can help make the recovery rate of original oil reach 20–40% [3,4]. The oil recovery efficiency must be continuously improved to ensure that people have sufficient use of oil resources [5]. Therefore, researchers have been promoting research into advanced oil extraction technology. For example, there has been progressed in the application of ultrasound technology for demulsification and enhanced oil recovery (EOR), large capacity hydraulic fracturing, and special horizontal wells for shale oil and gas production [6]. The fracturing of platform wells is key to the efficient development of unconventional oil and gas, and it has been widely used in oil fields. Field practice shows that different fracturing methods lead to different stimulation effects [7]. The permeability and porosity of unconventional reservoirs are usually relatively low, and hydraulic fracturing is often used to improve the flow performance of the formation, so as to achieve efficient and economic development [8]. Stress differences, rock brittleness, natural fractures, bedding, cluster spacing, fracturing method, fracturing fluid volume, displacement, and viscosity have important influences on fracture network complexity (FNC) [7]. Nanofluids and nanomaterials are great prospects for developing new technologies in the petroleum sector [9]. Therefore, as new technologies for oil and gas exploitation are constantly put forward and improved, it will promote more efficient, safe, and economic development of oil and gas. It is also very important for...
researchers to continue to pay attention to and research new technologies for oil and gas development, and pay attention to the application of these new technologies in engineering.

The world is rich in shale oil resources. As the United States has made excellent research achievements in shale oil exploration and exploitation, shale oil has become a major contributor to the growth of crude oil production [10]. The successful exploration and economic development of marine shale oil in the United States has benefited from the continuous improvement of basic geological knowledge [11]. At present, high-yield shale oil wells in the United States are mostly distributed in the Williston Basin, the Permian Basin, and the Gulf Coast Basin [12]. Shale oil exploration in China is mainly concentrated in continental basins. A Research Report points out that medium and high maturity shale oil is the key area for China’s strategic shale oil breakthrough, and strengthen the exploration and development of shale oil and gas [13].

Unconventional natural gas resources mainly include tight sandstone gas, coalbed methane, and shale gas. Unconventional gas reservoirs usually refer to low permeability gas reservoirs that do not contain or contain a small amount of associated fluid in the produced natural gas. In general, large-scale hydraulic fracturing, horizontal wells, multi-branch wells, and other technologies are used to exploit these kinds of resources economically and effectively. Natural gas development technology includes fractured gas reservoir development technology, condensate gas reservoir cyclic injection development technology, gas lift drainage technology, machine pumped drainage technology, deep carbonate gas reservoir development technology, and deep tight sandstone gas reservoir group development technology, among others. The development technology of these resources is of great significance for the exploitation of unconventional natural gas resources under various geological causes and occurrence conditions. In the future, it is not only necessary to deeply study these technologies, but also to explore new technologies for unconventional natural gas development in various complex environments, and the actual application effect of these new technologies should also be verified by the actual project site.

As a clean fossil fuel with huge reserves, natural gas hydrate (NGH) is widely considered to be an important alternative energy source for the future. NGHs are a kind of high-concentration natural gas and exist as a crystalline compound formed under low temperature and high pressure [14,15]. They can burn directly, and so they are also called “combustible ice”. NGH mainly occurs in the seabed and permafrost, where the high-pressure and low-temperature conditions required for its stability can be met. NGH has a significant impact on a series of scientific issues, such as the global carbon cycle, climate change, and geological disasters [16–18]. Several methods have been proposed for NGH exploitation [19]. Some studies have shown that depressurization may be a relatively economical and effective production method for NGHs [20]. Thermal stimulation is a very common method to improve the decomposition efficiency of natural gas hydrate. The technology of replacing CH$_4$ with carbon dioxide can not only produce methane but also store carbon dioxide [21]. CO$_2$ is injected into the deposition layer of NGHs to replace CH$_4$ in the hydrate and store CO$_2$ [22]. Since CO$_2$ hydrate is more stable than CH$_4$ hydrate at the same temperature and pressure, the CO$_2$ replacement method used for NGH production can maintain the mechanical stability of deposits [23]. The natural gas hydrate resource is also recognized globally as having the potential to replace the traditional fossil energy. Therefore, the research on its development technology is still the focus of energy workers. Particularly for the continuous improvement of traditional development technology and the exploration of new technology, there is a lot of research space.

Coal is a common fossil fuel and a valuable energy resource. Coal has been widely used around the world as a fuel source for transportation, industry, manufacturing, and power generation [24]. Due to the impact of COVID-19 and other factors, the world economy has slowed down. Compared with the past, the growth of global coal demand has slowed down significantly, and global coal consumption will peak in the mid-2020s [25,26]. Coal mining methods include surface mining and underground mining. With continual coal mining has come advances in coal mining technology, which has gradually been
innovated upon and improved. Coal mining also requires mining equipment to adapt to the complex technological and geological changes encountered in the mining process. Lvu et al. proposed a new fully mechanized top coal caving mining method of mining the middle layer first for an extra thick coal seam above 20 m [27]. US longwall mining has employed multiple entry development using a continuous mining system for panel development and mining in retreat. In Europe, the single arched entry development and advancing system has been employed [28]. However, longwall caving mining (LCM) can lead to many environmental problems [29].

With the progress of human society, coal mining is under increasing ecological and environmental protection pressure. Coal mining and CBM mining may cause changes in surface topography, groundwater level and connectivity, soil profile, vegetation coverage, etc. [24]. This requires coal mining activities to be performed in a way that minimizes its negative impact on the environment. We should also pay attention to the restoration of the ecological environment after coal mining.

With the development of global internet technology and informatization, coal mining has become more intelligent and new advances have been made and applied in some coal mines. Due to complex mining and geological conditions, various sensors and their software control algorithms used to detect unexpected underground events must be identified, developed, and tested successfully in advance to achieve full automation [28]. Rashed et al. proposed a novel framework for assessing and prioritizing smart mining strategies by integrating the Z-number theory and the fuzzy-VIKOR technique [30]. The modern longwall mining method adopted in Germany and the United Kingdom is a true continuous mining system with great potential to rapidly increase production to meet national energy needs [28]. China has 34 coal mines (under construction, reconstruction and expansion) of 10 million-ton and 47 intelligent unmanned coal mining faces [31]. China’s coal mines have the conditions required for the application of artificial intelligence, the internet, the Internet of Things (IoT), big data, and other technologies to achieve enhanced coal mining production [32]. As mines constitute an important part of a country’s economy with a considerable impact on socioeconomic development, smartening mining activities should be done to increase efficiency [30]. Therefore, intelligent and ecological coal mining and environmental remediation have become the forefront of coal mining research.

Energy is an important material basis for promoting the continuous progress of human society. Scientific researchers and engineering practitioners in the global energy field are constantly upgrading and developing advanced energy mining technologies. We cordially invite you to submit your high-quality manuscripts to the Special Issue of the journal Energies on advanced coal, petroleum, and natural gas exploration technology. The keywords for this Special Issue include (but are not limited to):

- Unconventional resources;
- Reservoir characterization;
- Enhanced oil recovery;
- Multiphase flow;
- Numerical simulation;
- Energy efficiency;
- Petroleum geology;
- Hydraulic fracturing.

This Special Issue will cover a broad range of topics concerning coal, petroleum, natural gas, coalbed methane, shale oil, combustible ice, and other fossil energies, as well as exploration, reservoir characterization, machine learning applications, well logging, and geological aspects. This issue will approach these topics from both an exploration and a production standpoint. We invite papers on technical development, basic theories, reviews, experiment, and engineering case studies in the field of energy development, as well as research papers in different disciplines that are related to energy themes.
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