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Environmental Challenges and the Future of Mining

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Abstract

Great achievements have been made in mining industry to extract mineral and ore deposits. In this paper, significance of mining technology is introduced firstly. The course and history of mining technologies as well as the progresses made in the past have been summarized. Environmental issues associated with mining are discussed. The power determines the direction and propels the advance of mining technology is analyzed. It is concluded that the mining technology in the future is going to be safer, more intelligent, comprehensive, interdisciplinary and environmentally friendly. The mining objects will shift from traditional reserves to unconventional resources such as geothermal energy, methane clathrate, etc., from the earth's crust to the earth deeper core, the deep ocean and the outer space. The intensified competition between countries on resources will expedite the advance of new mining technologies and legislation for the United Nations to protect environment of competition around the world.

Keywords: Mining technology; Environmental issues; Unconventional resources; Methane clathrate; Moon mining

Introduction

Minerals are very important in our lives. They are fundamental components of everyday items ranging from tires, concrete, cell phones, motor vehicles to toothpaste, lipstick and makeup, etc. (Figure 1). Gasoline, electricity, plastics, cosmetics, steel, glass, concrete, fertilizer, and food additives are all derivative of such raw earth materials as oil, coal, asphalt, iron, silica, limestone, phosphate, etc. [1]. Data published by The World Mineral Production show that mineral production in Europe still slightly increased from 2013 to 2017 despite the world economic downturn [2]. Mineral production as well as prospecting in other parts of the world increased significantly from 1970 to 2017 and are increasing now [3]. But we are not able to get mineral and ore deposits if it were not for the mining technologies (Figure 2).

Figure 1: The Fundamental Components of Minerals for Everyday Items.

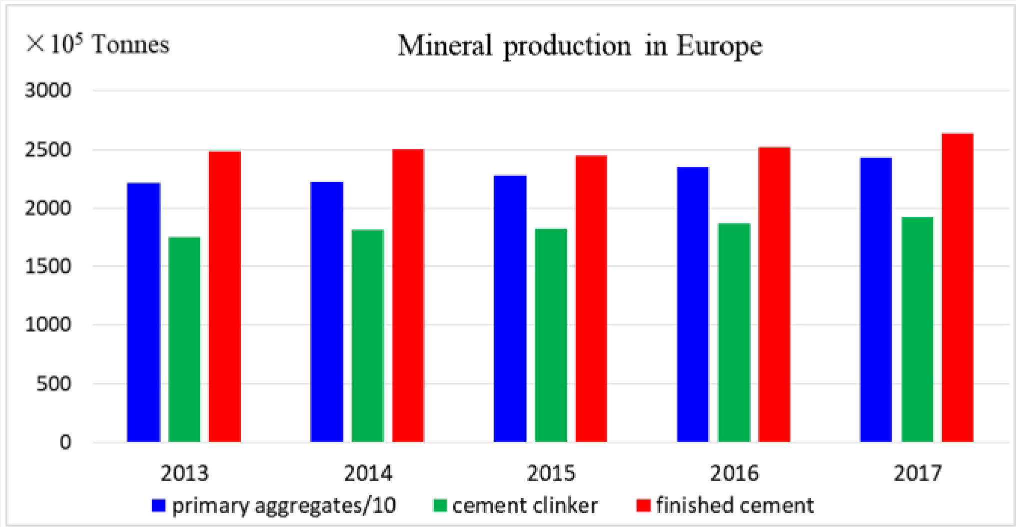

Figure 2: Mineral production in Europe (Primary aggregates are sand, gravel and crushed rock).

Development of Mining Technology before 21st Century

In the pioneering days, mining was hard and hazardous manual work before invention of productive equipment and blasting agents. Mineral deposits were mined manually using pick and bars, transported by wheelbarrows in pioneering days. Mining technologies have developed considerably over past 200 years and spurred the boom of other industries. The steam engine was first used for draining coal mines. The first rail transportation, the first steam locomotive, and the first electric locomotive were all invented for coal mines. Hydraulic powered shield, armoured face conveyor, and shearer, etc. were invented in 1900s for coal mines [4]. Technical and innovative development of equipment is making mining safer and more efficient. The power is transformed from pneumatic to hydraulic, the haulage from rail bound to trackless, rock drills from handheld to rig mounted, and lately, operation from manual to computerized. Apart from the mining equipment, many advanced mining methods have been put forward. In addition to open pit mining, such high efficient underground mining methods as room and pillar method, sublevel caving, cut and fill, longwall top coal caving, solution mining (use drilled wells to dissolve the minerals with solutions), hydro-fracking, etc. are gaining great developments.

Concerns and Issues Related to Mining

Despite the development of mining technology, however, more attention has been paid to mine safety, low resource recovery, environment issues (Figure 3) including destruction of landscapes, water contamination and air pollution, etc. [5-8]. Mining activity has a profound influence on reshaping topography. Topsoil for open pit mining is removed on a large scale leading to the transformation of the landscape, deforestation, water contamination, etc. Dust at mining operations can be caused by drilling and blasting operations, trucks being driven on unsealed roads, ore crushing and wind blowing over areas disturbed by mining; Main sources of noise pollution are blasting, movement of heavy earth moving machines, drilling and handling plants [9-11].

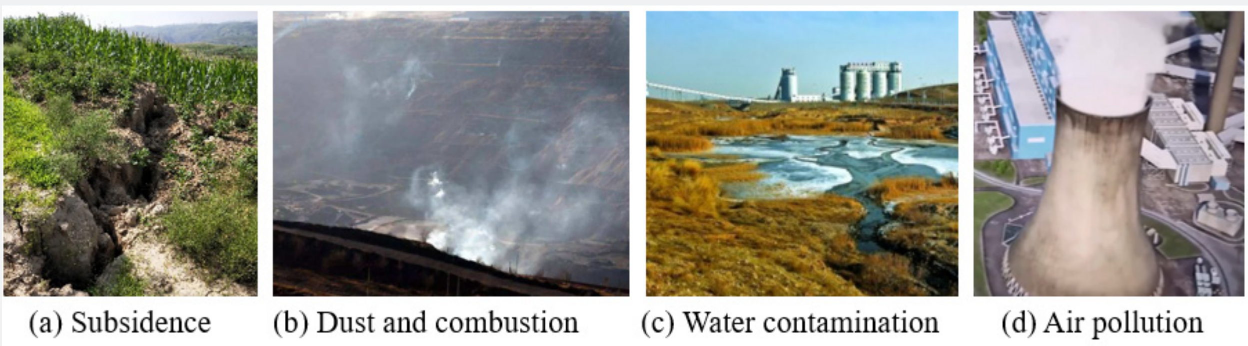

Figure 3: Mining-related Environmental Issues.

Underground mining methods such as room and pillar method, longwall mining with coal pillars etc. give rise to wavy deformation on ground surface which is detrimental to buildings and structures [12]. Subsidence troughs over abandoned mines

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frequently occur when the overburden sags due to failure of remnant coal pillars or an inadequate backfill. Time-dependent failure of pillars may cause devastating disasters. 437 people were killed in Coalbrook disaster due to cascading pillar failure [13]. Room-and-pillar mining had ceased 118 years before sandstone beds collapsed abruptly over workings in Lanark, Scotland [13]. 9 percent of total potential subsidence occurred during a 6-year period after a 166-m-deep longwall face advance stopped at Peterlee, UK [14]. Many coal mines in South Africa also experienced and are experiencing severe pillar failure problems [15]. What's more, mining and mineral-processing wastes are one of the world's largest chronic waste concerns because several environmental problems are associated with the disposal of this waste, including contamination of streams and lakes and pronounced landscape transformation [16]. Ensuring safety and no destruction would occur or the damaged area is able to be repaired during or after mining activities is of great significance for sustainable development of mining industry as well as the society. Prevention is far better than cure. Therefore, mining technology should be safe, high recovery, and environmentally friendly or "green" oriented.

Recent Advance and Future Direction of Mining

Keep pace with the times, "green mining technologies" were proposed covering a wide spectrum including water-protection-mining, backfilling mining, gasification and liquefaction of underground ore body, partial extraction, bed separation grouting to reduce surface subsidence, underground discharge of rock refuse, simultaneous extraction of multiple resources, gradual and complete subsidence by leaving no pillars (extracting all pillars out), advanced deep mining, high recovery mining method, etc. [17-19]. In accordance with "green mining technologies", "clean mineral" technologies are promising solution for China to meet its carbon reduction targets while still obtaining a considerable share of energy from coal. Significant progress is being made in these technologies to ensure the sound development of mining industry.

With the large amount consumption of resources of society, especially during the past several decades, easily mined deposits are being depleted. Deposits are less favorable due to rapidly increasing cover depth and larger inclination of ore bodies, reserves become more limited and precious. Due to limitation of technologies in the past, large amount of remnant natural resources are left unmined. Figure 4 shows an example of large portion of unmined remnant coal left underground. As pointed out earlier, devastating disasters may occur due to deterioration of those remnant pillars. Gob (void space or that filled by caved material after extraction of ore body) has high risk of spontaneous combustion and water inrush. Moreover, increase of cover depth gives rise to many problems in practice. Large ground pressure and severe roadway deformation are big challenges for safe mining as dynamic disasters such as rock bursts are related to depth. Some technologies have been proposed for deep mining and recovery of residual resources. Split-level longwall mining is an emerging mining method suitable for coal, trona, potash, etc. and is widely spread in China, Australia, etc. to cope with difficulties in deep mining [20]. Fluidized mining mentioned earlier is also a very promising mining method for deep resources [17].

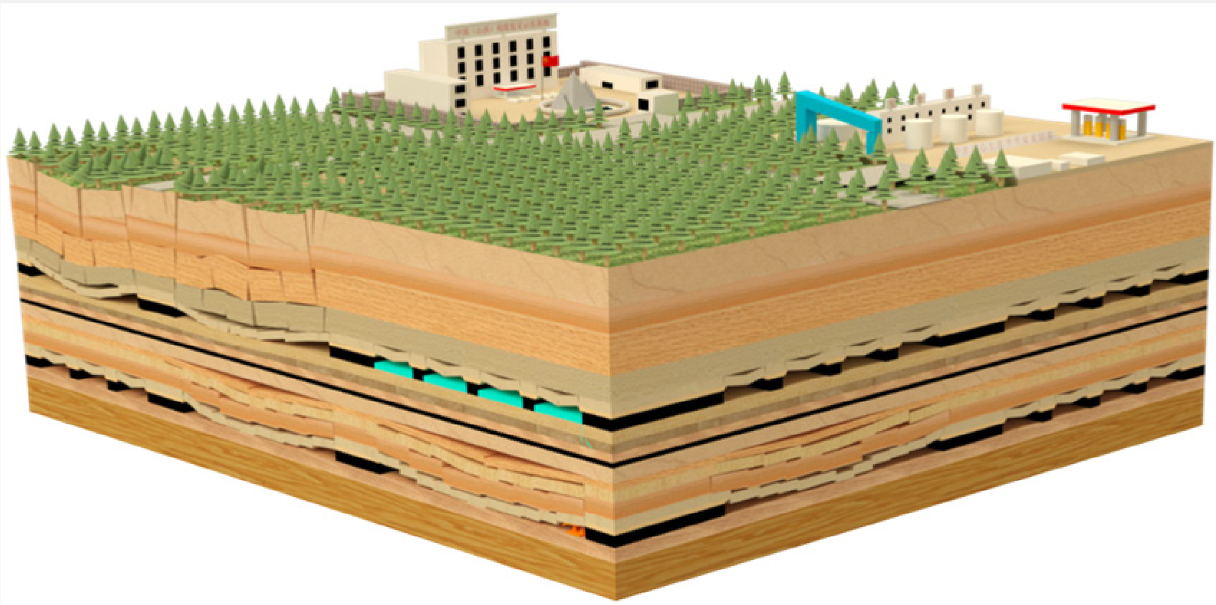

Figure 4: Schematic of Unmined Remnant Coal, Gob Threat and Destruction of Land.

To ensure safety, mining without a person in site or unmanned mining is a promising trend. The U.S. is well known for their small number of personnel working in mines. China now has several underground mines where no people can be seen at the working

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face. Thanks to the development of artificial intelligence and manufacture of machines, by constructing real-time network accompanied with remote sensing system covering whole mine, accurately controlling mining machines in the office is possible. With the depletion of conventional fossil energy resources such as oil, coal, natural gas, some unconventional, alternative and emerging energy resources such as shale gas, geothermal energy and nuclear energy are more popular. As mines go deeper, geothermal energy, a type of cutting-edge renewable energy, is gaining increasing attention. Scientists are endeavoring to use deep geothermal for generating electricity, heating and cooling buildings, etc. since it is clean and sustainable. Another concern of depletion of reserves is that the number of abandoned mines is larger. Some researchers developed methods to recover residual resources in abandoned mines [21]. Some on the other hand proposed to reuse them for tourism, refuse disposal, underground storage of water and energy, even building underground cities, etc. as well as develop ecological restoration plans for reclamation [22-25]. In addition to resort to deep deposits underground, resources deep inside the Oceans are also a promising direction. Methane clathrate, for instance, is gaining significant attention. One cubic meter of methane clathrate releases about 160 cubic meters of gas making it a highly energy-intensive fuel. South China Sea claimed that methane clathrate had been produced continuously for 60 days, the output was over 300,000 cubic meters with 99.5% methane.

Apart from the sea, the future resources may also come from outer space [26,27]. The moon's vast Aristarchus Crater may hide minerals that could be harvested by astronauts for oxygen and fuel [28]. Among the moon's riches: gold, cobalt, iron, palladium, platinum, tungsten and Helium-3, a gas that can be used in future fusion reactors to provide nuclear power without radioactive waste [29]. Space mining was given great attention on July 19, 2015, when an asteroid-2011 UW158, which passed about 1.5 million miles from the Earth, might have carried as much as $5.4 trillion worth of precious metals and minerals. NASA's OSIRIS-REx is on its way to get a sample of an asteroid and bring it back to Earth [30]. The House passed The U.S. Commercial Space Launch Competitiveness Act. It will foster the development of advanced space technologies, facilitates a pro-growth environment for the developing commercial space industry by encouraging private sector investment, creating more stable and predictable regulatory conditions, and improving safety, enables U.S. private sector exploration and use of celestial resources. Angel Abbud-Madrid, director of the Center for Space Resources at Colorado School of Mines, and Christopher Dreyer, a professor of the center is carrying out research on mining of using sunlight to break apart rocks with sunlight and extract the water and even precious metals. They also will launch a first-of-its-kind graduate program in space resources—the science, technology, policy, and politics of prospecting, mining, and using those resources. The multidisciplinary program would offer Post-Baccalaureate certificates and Master of Science degrees. With the fast development and combination of space and mining technologies, resources from outer space is expected to be exploited in the next decade or so [31,32].

Conclusion

From the development of the mining history we can conclude that in the future, the mining technology is going to be safer, more intelligent, comprehensive, interdisciplinary and environmentally friendly. The mining objects will shift from traditional reserves to unconventional resources such as geothermal energy, methane clathrate, etc., from the Earth's crust to deeper core, the ocean and even outer space (Figure 5).

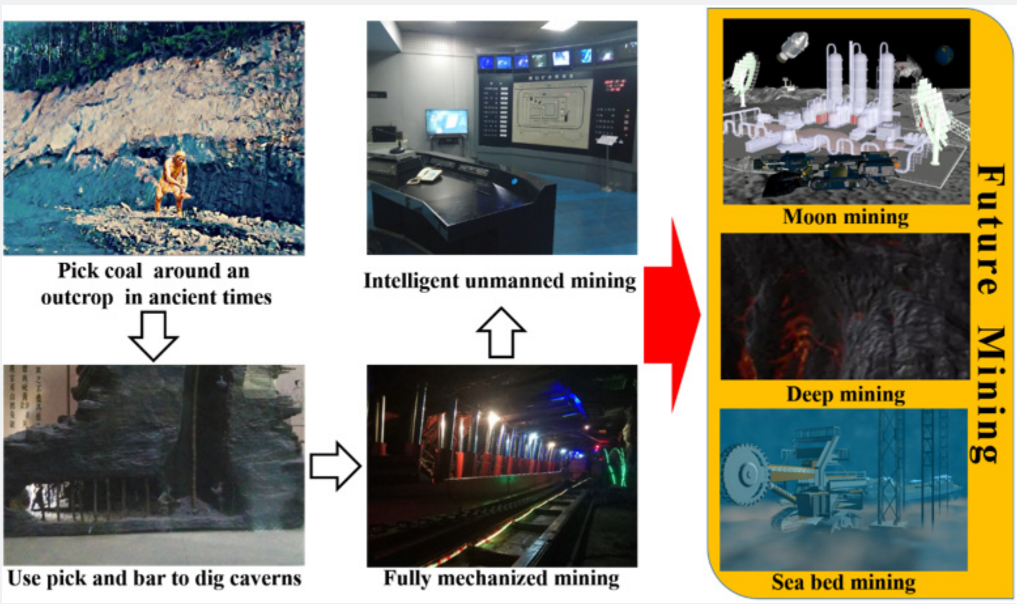

Figure 5: Mining Development and Its Future.

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To meet the requirement of environment and increasing demand of mineral resources for the time being and near future, many countries are developing policies as well as technologies. For instance, China is now implementing rehabilitation and restoration of mine geological environment, advocating green exploration, and comprehensively advancing the construction of green mines. China has clearly defined four support policies - mining right policy, land use policy, fiscal policy and financial policy, and established a series of typical models of green mine construction to protect our planet. In the future, the intensified competition between countries on resources in the deep underground, the ocean and even outer space will expedite the advance of new mining technologies and legislation for the United Nations to keep good environment of competition for this world.

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