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From the beginning of oil and gas industry to carbon reverse engineering: implications for mining and petroleum-engineering education

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ABSTRACT: Transitions have based on historical episodes, including the ownership of mining rights, and the recent shale-oil and gas revolution. The evolution of the oil and gas industry from the 1870s, represented by Rockefeller, and the transition to a low-carbon society, is the focus of this article. The lives of three great entrepreneurs, Rockefeller, Edison and Ford, are important in the formation of major industries in the early 20th Century. The Japanese oil industry and market had a relationship with the global oil business from the 1920s. Mineral and energy resources have enriched human lives and become the basis for many industrial sectors. However, there is a growing fear that excessive fossil-fuel consumption and burning may cause global warming and climate change. The necessity to establish a new concept that integrates the terms, resources and environment is proposed to maintain global sustainability. Future curricula should focus on carbon reverse engineering required in mining and petroleum-engineering education.

Keywords: Mining, petroleum, engineering education, transition, mineral and energy resources, history, episodes, sustainability, carbon reverse engineering

INTRODUCTION

The movie *Promised Land*, which was released in 2012 depicts issues between residents and a natural gas company in a small town [1]. The author was fascinated by the movie because its subject was shale gas, of great concern at Kyushu University, Japan. The film depicted the conflict between company employees who negotiated with residents in a small country town, where natural gas reserves were discovered but required investigation. In this movie, the lifestyle in a small town, the mineral resources business, corporate logic and the environmental protection movement in the USA were treated neutrally. USA crude oil production in 2018 surpassed Saudi Arabia and Russia. Consequently, the USA returned to its position as global top crude oil producer after 45 years [2]. This outcome was an *energy revolution* and crude oil production was an issue in the 2020 US presidential election.

Mineral Resources

Gas and crude oil trapped in a hard rock layer (such as a shale layer) in deep underground formations, can be extracted by the injection of liquid under ultra-high pressure (hydraulic fracturing or *fracking* as it is termed in the USA) [3]. This triggered the *shale revolution*. The liquid that is used for this hydraulic crushing is a chemical solution that is provided by Japanese chemical companies, using steel pipes made by Japanese steelmakers. Japanese companies have contributed directly to the shale revolution. The capacity was doubled in July 2016 for liquefied natural gas (LNG), processed from shale gas in the USA to be transported to Japan [4]. LNG is transported to Japan within 29 days, much quicker than via the Middle East, which is 42 days [4]. Hence, shale gas provides direct benefits to the lives of the Japanese people.

The Law and Mineral Resources

The USA mining laws are similar to those of many other countries (i.e. state laws that are enacted under federal guidance); however, the landowners' rights are respected, and the lease contracts of the land and mining rights must be purchased [5]. In contrast to Europe and Japan, where the state designates minerals (statutory minerals) by law and mining rights (i.e. exploration, development and production; right to mine, acquire and dispose of products) and mineral mining areas and based on licenses (i.e. areas registered for exploratory drilling and mining), loyalty and environmental conservation laws (e.g. mining law). This system has been adopted in many countries. However, in the Middle East, crude oil resources belong to the sovereign king.

An historical episode related to oil exploitation in the Middle East that highlights land rights in this region involves Taro Yamashita (1889-1967), who was a Japanese businessman and visited Saudi Arabia and Kuwait after World War II [6]. He negotiated with the kings in both countries, and in 1957, he acquired a 40-year oil-exploration license from the offshore Kafuji oil field in the neutral zone that belonged to both countries as a Japanese self-developed oil field. He established the Arabian Oil Co. Ltd. (1958-2003) and produced crude oil with a peak of almost 300,000 barrels/day [7].

Japan's Oil Production

The total oil export of 4 million barrels to Japan was an outstanding achievement. In 1961, when oil production in the Kafuji oil field was stabilised, Yamashita was invited to a party hosted by the Rockefeller Foundation in New York to honour his success in the oil business. At this event, John D. Rockefeller III (1906-1978) stated that the latter half of the 20th Century was the age of oil, and humanity floats on oil. Yamashita replied to Rockefeller III, *if we burn and exhaust the finite treasure of the earth… human beings in the twentieth century will mourn [the loss]*. In response, Rockefeller III agreed to Yamashita's comment, and said *We have to open up the energy sources of the next era, including the use of nuclear energy etc, otherwise, we will be judged by God*. When Japan finally embarked on the development of oil resources after World War II, it was already looking ahead to alternatives to oil. This highlights the frontier spirit that is the driving force for creating the new world. The oil-exploration licences of the Kafuji oil field were retracted in 2000 and 2003 when contracts ended [8].

Mineral resource ownership by landowners, countries or kings depends on the country. In an episode that highlights Japanese rights, when crude oil appeared at the surface of a private residential garden in Niigata City, the resident had to pay for the cost of disposing the oil as an industrial waste in 2013 [9], because the collection and selling of oil to an oil refinery without mining rights is illegal under Japanese mineral law.

THREE GREAT BUSINESSMEN

History records a series of social, economic and business changes, e.g. the shale gas and oil developments mentioned above. Utilising new resources and materials begins with the practical realisation of new inventions. This can be seen with shale gas and oil but also with the Bronze Age and Iron Age of ancient times. In modern times, during the last 300 years, the industrial revolution (1760s to 1840s) brought about the development of the steel industry by establishing coking technology and the use of coal for steam engines. Another revolution was the century of oil in which stable and reliable refining technology was developed to produce kerosene from crude oil [10]. This era was dominated by John D. Rockefeller (1839-1937) [11], who was the first billionaire. The demand for kerosene increased because of an increased demand from homes as people began enjoying night entertainment using oil lamps.

Example of Great Developers

The Standard Oil Company [10], which was established in 1863 by J.D. Rockefeller, expanded their sales using the promotion of a safe and standard kerosene for oil lamps. The company became a typical large company. However, there was a time when its business viability was uncertain because of oil lamps being replaced by electric lights. This decrease in demand occurred after Thomas Edison (1847-1931) invented the electric light bulb and established the Electric Power Company in 1878 [12].

Henry Ford (1863-1947) started automobile mass-production from 1903 using an assembly line to produce Ford Model-Ts with gasoline (petrol) engines for private use in America [13]. This production triggered the start of the motor era, and the Standard Oil Company could shift to selling gasoline for automobiles. As shown in Figure 1, these three great entrepreneurs played an important role in promoting major industries of energy, power and transportation, in the early 20th Century.

The Standard Oil Company became a monopoly in the oil business. The US Federal Court ruled that the company was an illegal monopoly and the Standard Oil Company was divided into 34 separate companies in 1911. An antitrust law was enacted in 1914 to promote competition for the benefit of consumers.

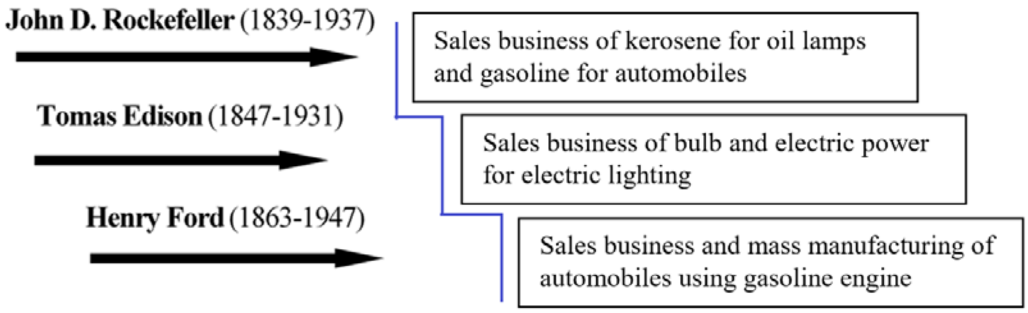

Figure 1: Three great entrepreneur in the early 20th Century.

Recently, the sale of automobiles using gasoline has been affected by the decarbonisation movement. Major oil companies such as ExxonMobil and Chevron, which were once part of the Standard Oil Company, have started to invest in LNG (liquid natural gas), hydrogen, and other renewable energies.

JAPANESE CRUDE OIL BUSINESS BEFORE WORLD WAR II

News of the great oil geyser at the Kurokawa oil field in Akita, Japan [14][15], was shared globally in 1907, when Japan was also a kerosene customer of the Standard Oil Company. However, the reserve was not as large as that of the USA oil fields and could not meet Japanese demands.

In 1924, after the Great Kanto Earthquake in 1923, J.D. Rockefeller, Jr. [16], donated funds to reconstruct the University of Tokyo Library, which was destroyed by the earthquake and fire [17]. This gesture was an act of philanthropic charity and investment financing. US and Dutch oil companies were interested in the Japanese oil business, and they were competing with Japanese domestic companies because increases in petroleum demand after World War I put oil-fuelled weapons, such as tanks and airplanes, to practical use. The Japanese petroleum demand and supply during the 1870s to 1910s was reviewed by Redfield [18]. Figure 2 shows that imported oil increase from 1921, which indicates an increase in annual domestic oil production and imported oil in Japan from 1913 to 1939 before World War II [19]. After 1924, imported oil volumes surpassed domestic crude oil production, and Japan imported ~90% of crude oil from overseas in 1937.

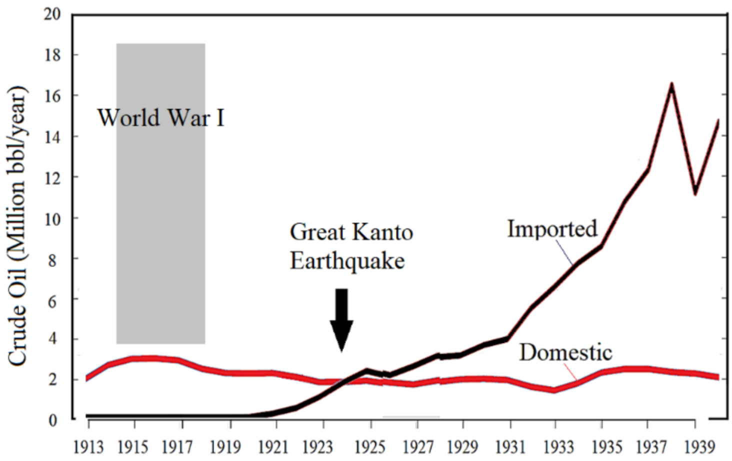

Figure 2: Annual domestic crude oil production and imported oil in Japan during 1913 to 1939 [19].

MINERAL RESOURCES AND TECHNOLOGY

Mineral resources are solid or liquid substances. However, their abundance and depth in countries differ. Some resources are mined and refined as mineral products and sold in markets, whereas others are left in rocks and geological formations. When a society recognises an ore's economic value, it is treated as a mineral resource. Oil and natural gas in shale layers was not significant in the absence of an economic exploration technology. The development of fracking technology provided a breakthrough to new petroleum resources and provides an example of the relationship between technology and mineral resources. However, no reports of successful commercialisation using fracking technology exist in Europe and Asia, where similar shale layers exist. It is unclear whether USA companies have risked releasing the technology because of geological differences or falling oil prices.

Exploitation of Mineral Resources

As for mineral resources, the demands, economic value and targeted usage of the resource changes. For example, a substance under the seabed or on the moon may serve as a new resource when economic mining or transportation methods and applications are developed. Some countries show an interest in mineral resources prospects that are available on other planets because it may be possible to use these to develop new materials and initiate a new resource era. Conversely, a reduction in coal usage to combat climate change could make coal obsolete. In the Canadian province of Alberta, tar sand layers contain extra-heavy oil (bitumen), and is equivalent to approximately 9% of the world's proven oil reserves. They are buried at a relatively shallow depth below the surface [20]. During 2008 to 2015, when the oil price was roughly US$100 per barrel, a considerable investment of USB$70-100 was made [21]. However, the future of this industry may be jeopardised by the fall in crude oil price and the decarbonisation of the world economy [22].

Platinum, which is a rare metal, traded at approximately twice the price of gold in 2007 (~US$67-70/g). In 2020, when industrial demand declined, especially for automobiles that were equipped with diesel engines, platinum value fell to approximately half that of gold. The survival of top-producing South African platinum mines was in doubt. However, the mines continue to mine platinum because of the declining local currency and soaring palladium price, which is 1.3

times the gold price. Furthermore, other platinum by-products are used in exhaust gas treatment devices for gasoline engines [23].

The significance of resources changes based on societal and industrial economic demands. A recoverable reserve depends on the global market. Recently, many resource-holding countries have restricted mining rights and prohibited raw mineral ore export with an emphasis on the country's economic sustainability, environmental conservation and biodiversity. For example, Indonesia announced a policy to ban from January 2022 on the export of untreated raw mineral ores that have not been smelted or refined [24].

Major investment institutions worldwide have selected investment destinations based on policies that emphasise sustainability and governance of the environment, which has a significant impact on resource development projects of major mining and oil companies globally [25].

MINERAL RESOURCES AND THE ENVIRONMENT

In an introductory lecture on mineral resources to high school students and freshmen at Kyushu University, the author used a picture of a goldfish growing in a fishbowl (Figure 3). In this analogy, a *resource is the entrance, and the environment is the exit.* The *goldfish (human beings)* cannot grow without *feed (resources)*. However, when excessive feed is provided, the *water (global environment)* becomes polluted because of emissions, and the goldfish die from diseases. The story was developed based on a manual on goldfish upkeep that is provided when children win goldfish at popular Japanese festival scooping games. The critical issue is to provide the required feed. Young people's engagement in global environmental issues and awareness, represented by Greta Thunberg, based on the recognition of *the earth is finite and irreplaceable*, predicts the future of the world and all living things.

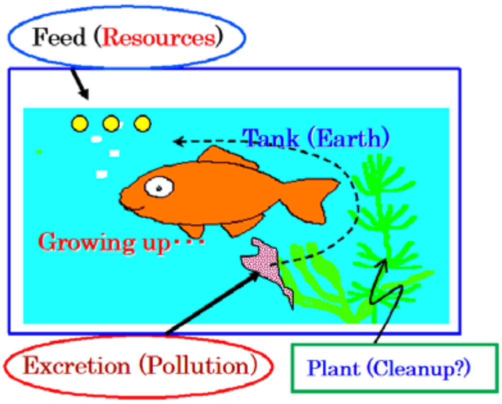

Figure 3: Earth is like a goldfish tank with limited resources.

DE-CARBONISATION AND ENVIRONMENTAL SUSTAINABILITY

The conflict between residents who expect that the town will be saved and those worried about environmental destruction in the movie, *Promised Land*, presents a societal microcosm where human hopes or desires and anguish are mixed and overlap. The balance of economic resource utilisation and environmental conservation is an issue that has caused conflict in Japan and globally. This conflict has parallels with those focused on establishing geological disposal sites for radioactive waste that is generated by nuclear power plants and controlling Covid-19 versus promoting economic activities. The process towards making a final decision in these conflicts is not straightforward in democratic countries.

PETROLEUM-ENGINEERING EDUCATION AND SUSTAINABILITY

Coal and oil use has been supported since the Industrial Revolution. Mining engineering (including petroleum engineering) has been a source of fundamental engineering since the middle ages [26] and has been instrumental in bringing underground hydrocarbon resources to the surface for human consumption. As a result, ten billion tons of carbon dioxide have been generated annually into the atmosphere from underground strata. Figure 4 shows the schematic system of carbon circulation and carbon balance between below and above ground. The annual increase in global average atmospheric carbon-dioxide concentrations is 2 ppm [27]. The amount is ~1% of global carbon circulation on the earth [28]. This small change in global carbon circulation and carbon balance below and above ground on the earth are thought to have been the cause of recent climate changes and global warming.

Curricula Requirements

Present curricula in mining and petroleum engineering have taught how to excavate efficiently and safely solid or liquid resources, such as coal, crude oil and natural gas, in consideration of market prices. From now on, it is necessary to evaluate energy consumption and CO_2 emissions. There is a need to achieve minimum CO_2 emission and maximum sustainability. The author would like to propose curricula to promote sustainability.

The important goal is to achieve 10 to 20 billion tons of carbon dioxide underground using so-called *carbon-dioxide geological storage* [29]. This demonstrates that the knowledge that mining and petroleum engineering possess, is professional knowledge related to crustal geology, including aquifers or targeted reservoirs.

Education in engineering should include curricula that incorporate the carbon reverse engineering and its contribution to sustainability in human society.

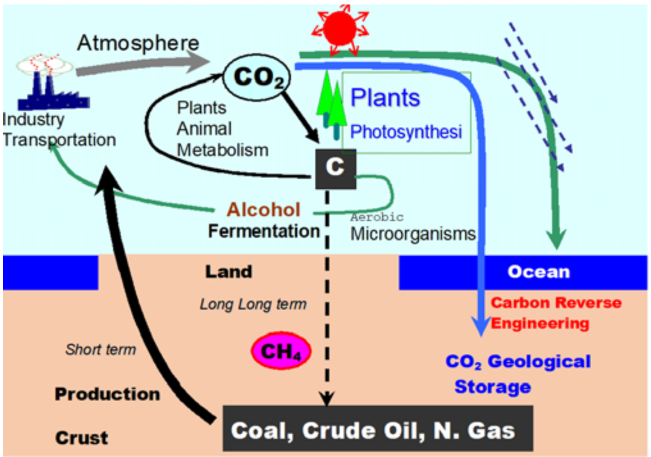

Figure 4: Carbon circulation and carbon balance between below and above ground [27][28][29].

CONCLUDING REMARKS

Mineral and energy resources enrich human lives. Humans cannot flourish without resource and energy. However, concerns exist that excessive consumption and the burning of fossil fuels may induce changes in the climate. Therefore, it is necessary to integrate resources and the environment, while considering global sustainability.

In engineering education, and especially in mining and petroleum engineering, the curricula should incorporate *carbon reverse engineering* to consider the global carbon balance below and above ground, which contribute to sustainability.

The use of resources will continue, and along with that solutions will continue to appear.

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BIOGRAPHY

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