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The Uranium Club: Big Oil's Involvement in Uranium Mining and the Formation of an Infamous Uranium Cartel

Michiel Bron *

Abstract: *»Der Uran-Club: Die Beteiligung von Big Oil am Uranabbau und die Bildung eines berüchtigten Urankartells«.* The diversification of "Big Oil" into uranium mining was a product of a long, entangled history of both the oil and uranium industries. By focussing on the story of the formation of an infamous international cartel allocating the uranium prices during the 1970s, this article explores the controversial role Gulf Oil Corporation played in the uranium mining industry. It argues that Gulf Oil's contribution to the cartel was mainly shaped by the geographical positioning of their uranium mines and the developing knowledge and technologies in the competing oil industry that helped create new economically viable uranium deposits. In this way, this article shows by combining Science and Technology Studies and Business History that the Western oil industry was not a one monolithic entity trying to "sabotage" the development of nuclear energy, but a mutually competitive market where new technologies and knowledge easily spilled over to other energy sectors.

Keywords: Uranium, nuclear energy, radioactive well logging, oil history, gulf oil, cartel, mining history.

1. Discussing the Uranium Cartel

"There is a single uranium market worldwide and the existence of a cartel, and it suggests that we are at least at the financial mercy of another foreign cartel like OPEC."[1] On August 29, 1976, James Harding, a former member of the international network of environmental organizations Friends of the Earth and assistant to the California Energy Commission in Sacramento, called a press conference to report the existence of an international uranium cartel. There, he blamed the cartel for causing an unprecedented hike in the price of the resource needed for the fast-growing nuclear industry. In the two

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1 James Harding, quoted in Richards (1976).

and a half years following the 1973/1974 oil crisis, spot prices of uranium had increased sevenfold. This shocked the nuclear fuel market and troubled actors responsible for the supply of uranium based on fixed contracts with buying parties. The cartel, composed of several non-United States companies and governmental organisations like the British Rio Tinto Zinc and the French *Commissariat à l'Energie Atomique* (CEA) and even American oil companies like the Gulf Oil Corporation, proved to be the perfect scapegoat for the price hike (Spar 1994, 88-92).

In the subsequent years, the cartel became a fiercely debated topic in political and economic debates. Also, the cartel became the centre of a long-lasting legal battle between two Pittsburgh-based companies: Westinghouse Corporation and Gulf Oil. In Washington, D.C., the House Subcommittee on Oversight and Investigations of the Interstate and Foreign Commerce Committee launched an investigation into whether the cartel had influenced the price hike of uranium in the United States. At the same time, Westinghouse was charged by 19 utility companies demanding that the company would repay them for the uranium it had failed to deliver because of the rising prices. Westinghouse, in turn, instituted legal procedures against several uranium companies participating in the cartel, including Gulf Oil, accusing them of increasing the prices by participating in the cartel to such an extent that Westinghouse could no longer afford to deliver on its contracts (ibid.).

In these debates, one question in particular gained attention: What were oil companies doing in the uranium business? Following the 1973/74 oil crisis, the comparison with cartels in the oil sector was easily made. As the quotes of James Harding already show, there was a fear that strategies employed in the oil industry that had been proven disadvantageous for the American people, like cartel formations, would also spill over into other energy regimes. Fuelled by rising gasoline prices, Gulf Oil's participation in the cartel and the subsequent, widely publicized lawsuits against the oil company quickly generated political and public theories about how the oil industry attempted to manipulate energy commodity prices across the board. The flamboyant Democratic senator James Abourezk of South Dakota became a prominent representative of the view that oil companies tried to stifle or even sabotage the development of nuclear energy by gaining a monopoly control over uranium recourses (Abourezk 1989). Historian Meg Jacobs (2016, 13) showed how the wider public shared Abourezk's suspicion that oil companies were gaining ownership of alternative energy sources in order to sabotage their development in favour of the existing oil regime. This view was also promoted in contemporary academic studies, such as John M. Blair's book on the power of oil companies (Blair 1976, 318). More recently, the view that "Big Oil" sabotaged nuclear energy has been a recurring theme both in popular culture, such as David Mitchell's *Cloud Atlas* (2004), and in academic literature, most prominently in Timothy Mitchell's *Carbon Democracy* (2011).

These theories were right in that oil companies had become big players in nuclear energy production during the 1970s. Since 1968, Gulf Oil exploited a large uranium mine in Canada, but also invested in the development of new high pressurized gas reactors, uranium milling, and reprocessing activities together with Allied Chemical and Royal Dutch Shell (Taylor and Yokell 1980, 14). At the same time, Gulf Oil was still primarily a major actor within the oil sector. Gulf was one of the Seven Sisters, the then seven largest international oil companies notorious for their collusion and influence over the oil market.[2] Also other oil majors were involved in uranium production. A 1976 Federal Trade Commission report found that oil companies owned or partly owned 12 of the top 25 uranium mining and milling companies in the US that controlled 95% of all US uranium reserves, including five of the top ten biggest uranium companies (Bureaus of Competition and Economics 1976, 684A). By 1981, "about 45% of all US uranium was produced by oil companies" (Baude and Wagner 1981, 5-28), sparking political debates about oil companies monopolising the uranium market. Republican Senator Bob Packwood joined with the Democratic Senator Edward Moore Kennedy in sponsoring a bipartisan amendment that would break up the power that "the oil companies now have in all fields of energy."[3]

Yet, the exact role of oil companies in the uranium business and the origins of their involvement have not been studied extensively. Especially the role of Gulf Oil in the uranium cartel is relatively unknown among energy historians. Although the uranium cartel has been a much debated topic among US politicians, economists and legal scholars, and the general public, this infamous episode has received relatively little attention from historians of nuclear energy, with the exception of Gabrielle Hecht's study of the South African mining company's (Nufcor) role as one of the founders of the cartel (Hecht 2012, 15).[4] Often, it is assumed that the diversification projects of the major Western oil companies into alternative energy sources during the 1970s were a short lasting product of the fear of losing access to oil concessions in the Global South, and are sometimes deemed as "bizarre, comic even" (Parra 2010, 212-3; Pratt and Hale 2013, 167-8; Sluyterman 2007, 155). This article argues, however, that the involvement of the oil industry was actually a product of longer entangled history of both industries dating back to the beginning of the 20th Century. This entanglement originated from shared geological properties of uranium and oil, which prompted the development of many later

[2] The label "Seven Sisters" was first coined by the Italian oil entrepreneur Enrico Mattei referring to Exxon, Mobil, Chevron, Texaco, Gulf, BP, and Shell. With this gendered frame, Mattei advanced the image of these "big oil" companies as a monolithic entity, working together as a family not willing to fully engage in competition (Sampson 1975).

[3] "News Release Bob Packwood" (October 20, 175). Robert W. "Bob" Packwood papers, Willamette University. WUA104, Box 655.

[4] For examples of legal scholars and economists studying the cartel, see Spar (1994, 90); Lunde, Sandberg, and Söderberg (2019, 2-3); Stewart (1981, 658).

technological spillovers between the industries.[5] These spillovers would set the stage for the later diversification into uranium mining by the oil majors during the 1970s and shaped the decision by Gulf Oil to participate in the uranium cartel.

Based on archival research in both national archives and the archives of French, Dutch, British, and American oil companies as well as an analysis on findings and discussions in early geophysics, this article focusses specifically on two technologies developed within the oil industry that would become dominant in the uranium business. First, the role of radioactive well logging in shaping the geophysical knowledge on what a "uranium deposit" is, and where it could be found. The development of this technology within the oil industry and the subsequent use within uranium exploration help show the historical contingency of the concept of "uranium deposits" and are a telling example of how technological innovation helped bridge the gap between two industries that are both highly dependent on furthering the development of geophysical, geological, and environmental knowledge. The use of radioactive active well logging techniques in both industries provided the basis for the diversification of oil actors into uranium mining. As part of this diversification, many other technologies, like the second studied technology, In Situ Leaching, also spilled over from the oil industry into the practice of uranium mining. These spillovers altered the already abundant uranium market, forcing exploiters of mines with high production costs and little enrichment capacity to employ new strategies, like the formation of the uranium cartel.

2. Developing Uranium Knowledge

In nature, three types of uranium can be found: uranium-234, -235, and -238. The numbers indicate the weight of the nucleus of each isotope, which is based on the number of neutrons and protons. Over 99% of all the uranium found in nature is uranium-238, with the rest being mostly uranium-235. Because uranium has a compulsion to combine with oxygen, natural uranium mainly occurs as either an oxide or a silicate. This constraint creates different types of uranium based on the combination with oxygen, including uraninite or pitchblende and carnotite. Since carnotite uranium does not intrinsically occur as a pure metal, its compounds can be found in small concentrations in both rocks and water all over the planet. The mineral occurs naturally a thousand times as frequently as gold and nearly as frequently as nickel and zinc (Moss 1981, 2; Mellor 2018, 30-1).[6]

5 For the terminology of "spillovers" I am indebted to Mody (2022).

6 See also World Nuclear Organization. Supply of Uranium. World Nuclear Organization. http://www.world-nuclear.org/information-library/nuclear-fuel-cycle/uranium-resources/supply-of-

However, natural processes can generate a process forcing the small concentrations to combine in a single site. Decaying organic matter such as trees or dead dinosaurs can collect the uranium from sandstone while decomposing and water streams can carry uranium and deposit it within beds of sedimentary rocks. If it is feasible to exploit these sites, they are classified as uranium deposits (Mellor 2018, 31-2). Because of uranium's tendency to form compounds, extracting the uranium can be a difficult, costly, and time-consuming process, especially in light of the fact that even "significant" concentrations of uranium ore often contain less than one percent pure uranium (Owen 1985, 26; Spar 1994, 94). Both these difficulties and the natural processes needed to produce a site make a "deposit" a highly historical contingent, political, technological, and geographical concept.

The exploration and ability to mine new uranium deposits hinged on the availability of the geographical knowledge and technology needed to find and mine the uranium. The available geographical knowledge on uranium deposits quickly changed during the decades preceding the formation of the uranium cartel in the 1970s. In 1955, the United Nations recognized three major types of uranium deposits during a conference of the United Nations in Geneva on the worldwide distribution of nuclear technologies. First, deposits originating from "warm fluids," such as the deposits in the Bancroft district and the Canadian Charlebois Lake derived from partial melting, from disseminations in migmatitic rocks like the deposit at Nipissing Lake in Canada, or deposits derived from veins in various rock types like Radium Hill in Australia, Port Radium and Ace-Fay-Verna in Canada, and the Shinkolobwe mine in the Katanga province of Belgian Congo. The second category included deposits associated with "old" sediments, or Proterozoic quartz-pebble conglomerates, like the deposits in the Canadian Blind River district and the Witwatersrand Basin in South Africa. Lastly, the United Nations categorized the deposits located within "normal" sediments, such as the sandstones in Wyoming and Colorado Plateau in the United States, and in black shale, coal and lignite, and phosphorites (United Nations 1956, 11).

In the following years, geologists regularly tinkered with this categorization based on new knowledge obtained from experiences gained in the growing uranium mining industry. Geologists such as Marcel Roubault (1958), Eberhardt W. Heinrich (1958), Albert Maucher (1962) and V. Ruzicka (1971) focused on deposits in the Western World, while V. I. Kazansky and Nikolay P. Laverov (1977) dealt with deposits in the Soviet Union (Roubault 1958; Maucher 1962; Ruzicka 1971; Kazansky and Laverov 1977, 349-424). These new classifications generally followed two alternative approaches, with geologists focusing either on descriptive features of the mineralization such as host rock type and orebody morphology, or on aspects of ore genesis. With

uranium.aspx (Accessed August 29, 2022); US Department of Energy. Nuclear Fuel Facts: Uranium. https://www.energy.gov/ne/nuclear-fuel-facts-uranium (Accessed December 22, 2023).

the uranium exploration boom starting in 1965, several new types of deposits with economic relevance were discovered, such as the vein, intra-intrusive and calcrete types, variations that were incorporated into new classifications as proposed by Valery Ziegler (1974, 661-77) and Franz J. Dahlkamp (1978, 83-104). Ziegler's authoritative categorization was based on the notion that the primary distribution of uranium is closely associated with the structural history of the sialic crust and hence with sialic magmatism. This meant that uranium exploration had to look primarily at structural elements of the continental crust (Ziegler 1974, 661-77; IAEA 2018, 11).

3. Radioactive Well Logging

An important technological contribution that made the growing body of knowledge on uranium deposits possible was the introduction of gamma ray logging. Radioactive well logging is conducted by means of sondes, tools that carry sensors which are lowered into the hole by a cable. Nuclear borehole logging techniques are either passive or active. The passive technique measures the natural radiation in the hole by an appropriate detector, while the active technique uses both a radioactive source and a detector placed in the borehole. The detector is an ionization chamber, a gas-filled enclosure made weakly conductive by the gamma radiation. Radioactive well logging techniques proved particularly useful for the exploration of uranium deposits. The gamma-ray log offers a measurement of the total natural gamma-radiation, emitted by the nuclides in the uranium and thorium. Because the variations in total radioactivity are almost entirely due to changing uranium concentrations, uranium explorers knew whether sufficient uranium was present to warrant mining by examining the well logs registering radioactivity. Use of this technique significantly expanded the amount of local uranium concentrations that were counted as "deposits" over the world.[7]

In the first half of the 20th century, it became increasingly clear that radioactive measurements could be used to search for different kinds of minerals, both oil and radioactive minerals. Based on the findings of Henri Becquerel and Marie Curie, and the studies of Ernst Rutherford and Frederick Soddy on radioactive decay, the Scottish geologist John Joly published his book on radioactivity and geology already in 1906. Joly focussed on determining the radium content of the surface materials of the earth, improving existing methods for measuring radium. He also devised a method for determining the

[7] La radioactivité dans les sondages, étude de Louis Migaux sur les manifestations de la fluorescene et de la radioactivité: note de laboratoire. Fondation Musée Schlumberger – Crèvecoeur-en-Auge (France/14). Henceforth referred to as AM-FMS. AM-347; Rayons gamma, analyse de experience d'utilisation de jalons radioactifs par W.B. Steward: rapport. FMS. AM-834; Allaud and Martin (1977, 268); Killeen (1983, 231-2).

amount of thorium in rocks by estimating the radioactivity of this element in rocks (Allaud and Martin 1977, 268; Wyse Jackson 2006, 237-8; Royal Society 1934, 268-9). In 1921, Richard Ambronn used Joly's studies to measure the radioactivity of cores taken in an oil well at Celle, near Hanover, Germany. In his articles on the exploration different minerals, like potash and petroleum, Ambronn brought together his different findings on radioactive measurement and tried to establish the field of "applied geophysics" (Ambronn 1928, 433; Egloff 1955).

The findings and studies of Joly and Ambronn sparked the interest of several pioneers in the oil sector during the following two decades. Before the start the Second World War, Russian geophysicists had built a logging device based on gamma rays but failed to publish any results (Allaud and Martin 1977, 268). Another attempt was successful and published, however. The French family-run oil prospecting company Schlumberger succeeded in designing an apparatus to record natural radioactivity. Geophysicist Conrad Schlumberger, along with his brother Marcel Schlumberger, the founder of Schlumberger, had been interested in the idea of using radiation for oil exploration since the early 1920s.[8] Especially gamma logging, the technique used to register the gamma-quanta of high energy generated by some natural radioactive elements located in magmatic and sedimentary rocks, was helpful to discover sand containing oil or water within clay beds, which generally contain more natural radioactive nuclides, by measuring the thickness of layers containing uranium or potassium (Reinhardt and Gast 1995, 703). In 1938, the research conducted by Schlumberger eventually led to the first gamma ray logging, performed in Oklahoma by the American subsidiary Well Survey Company, who would commercialize it one year later by promoting the technique for its accurate perforating (Luthi 2001, 12-25; Allaud and Martin 1977, 268).

4. Introduction of the Oil Industry in Uranium Mining

After the introduction of the radioactive well log, the technique immediately proved useful for the oil industry. Since gamma rays penetrate the casing, the new logging technique made it possible to analyse rock characteristics and boundaries of beds in cased holes that the predominantly method of electric well logging could not show. In this way, it became possible to see if there was still oil available in previous depleted reservoirs and to locate new oil reservoirs in specific geological structures like sands and sands with small amounts of calcite cements (Hilchie 1977, 212).

8 Carottage radioactive, instruction d'utilisation pour les sondages de gisements pétroliers: note technique. Archives Marcel Schlumberger. AM-FMS. AM-349; Bowker (1994, 39).

Several companies started working on radioactive well logging techniques after Schlumberger's breakthrough. In June 1942, the geophysical laboratory of the Texas Company in Houston published a report concluding that the equipment was very useful.[9] In addition, the Shell Group decided to introduce the new method in the years shortly after Schlumberger's experiments (Forbes and O'Beirne 1957, 206-7; Rabe 1957, 65-7). At the American oil company Tulsa, the Italian nuclear physicist, and later notorious spy, Bruno Pontecorvo would work on a design for new nuclear well logging technologies (Turchetti 2012, 39-68; Bonolis 2005, 487-99; Close 2015). After the war, also other oil companies like the Lane-Wells Corporation started working on this technique (Bush and Mardock 1951, 191-8; Widmyer and Wood, 57-60). Socony, later Mobil, invested in particular in new research on radioactive well logging methods. In the decades following the invention of Schlumberger, Socony worked on gamma-ray devices that picked up the presence of radioactivity emitted by uranium to see if there were new oil reservoirs to be found. In the 1970s, this research led to a new invention by Mobil's Dallas Field Research Laboratory, called a Delayed Fission Neutron Log, which was able to measure the amount of uranium in the ground electronically. Under Mobil's license, the device quickly became popular in both the oil and uranium industries.[10]

The knowledge gained on the radioactive well logging techniques in the oil industry was recognized as particularly useful in the search for uranium for the emerging nuclear industry in the decades following the Second World War. In the United States, the American Atomic Energy Commission (AEC) was tasked with finding uranium reserves for the production of new atomic weapons, and later nuclear energy production. To find new deposits, the AEC established an advisory committee including many prominent oil actors with a background in geophysics and oil exploration, like Wallace E. Pratt and Everette L. DeGoyler (Salvador 1982). In addition, the AEC opened the uranium market by allowing private actors to do the uranium exploration and mining and promising to buy all the uranium found, attracting various representatives from the oil sector during the first uranium booms in the 1950s. Many oil entrepreneurs, like Charlie Steen, Bob Adams, and Stella Dysart, and companies, like Kerr McGee, Getty Oil, and Philips Petroleum, involved in this first uranium boom were already involved in the oil industry before entering the new uranium market (Amundson 2002, 24-6; Ringholz 2002, 13, 60).

The entering of Kerr-McGee into the uranium business in 1952 offers one of the best examples of the success of the radioactive well-logging method

[9] Radioactivité dans les sondages, expérience d'application de la Texas Company: rapport. AM-FMS. AM-835.

[10] For Uranium, the Future is Now. Mobil Overview 2, 1 (1978), 6. ExxonMobil Historical Collection. The Dolph Briscoe Center for American History. The University of Texas at Austin. Henceforth referred to as DBCAH. Box 2.207/F120.

directly transferred from the oil industry to the uranium sector. Together with Buffalo Kennedy, geologist Dean McGee, one of the founders of the Oklahoma-based oil company, decided to focus more on the uranium industry. McGee appointed several company geologists, previously working on oil exploration, like Marion Bolton and Leo LeBron, to search for new uranium sources. The company embarked on a search that extended from Arizona to as far north as Utah and Wyoming, where some 1,275,180 acres were leased by early 1953. Because the engineers found that it was too expensive to "start trying to feel your way around by drilling and blasting and mining to do your exploration work," Bolton and a colleague in the seismographic business came up with the idea to use a "shothole," or seismograph rig, to quickly drill more small holes close to each other and in this way find the uranium beds that were small and easily missed. To accommodate for the analysis of the boreholes, geologist Virgil Janeway built what was probably one of the first portable logging instruments in the uranium business – a Geiger counter with a probe on a cable reel. In this way, he permitted Kerr-McGee to successfully map all the drilling holes and make possible profitable finds in New Mexico and Wyoming.[11]

Outside the United States, governments interested in finding and accessing new uranium deposits made use of the available geographical knowledge in the oil sector too. In the Netherlands, a special advisory committee to the department of nuclear energy in the ministry of economic affairs was established to research the possibility for uranium deposits in the Dutch colonised countries, like Surinam and the Dutch Indies. Herman Schürmann was a former geologist at the Royal Dutch Shell Group and was responsible for the training of recently graduated physicists as geophysicists. He also was the founder of the Dutch isotope-petrology institute in Amsterdam.[12] Because of his experience at Shell, the Dutch government included him in their advisory committee. The company Shell, too, was regularly asked to join in new uranium exploration projects. In 1970, the company turned down several requests to start a uranium mining project in Niger together with the French CEA.[13]

In 1970s France, oil company *Compagnie Française des Petroles* (CFP, later Total SA) was heavily involved in uranium mining enterprises in former

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[11] John A. Hermann and P.C. Ellsworth, Selection and Construction of Gamma Ray Probe Curve for Estimation of Pacific Uranium Orebody (Kerr-McGee Oil Industries Inc, 1957), 3. Dean McGee Papers. University of Kansas – Kenneth Spencer Research Library. Box 48, folder 6; Ezell (1979, 212-4).

[12] Nota: Instelling Commissie voor onderzoek aanwezigheid splijtbare materialen in Nederlands-Nieuw-Guinea en Suriname. 1956. Archives of the Directorate of Nuclear Energy of the Ministry of Economic Affairs, National Archives, The Hague. 2.06.101, box. 735; Dozy (1979, 289-90).

[13] Shell Kernenergie N.V. 1970. Uraniumexploratie in Niger (June 16). Archives of the Directorate of Nuclear Energy of the Ministry of Economic Affairs, National Archives, The Hague. 2.06.101, Box 738.

French colonies like Mauritania and Senegal, but also in mining projects in Colombia and Australia. By means of subsidiaries like *Total Compagnie Miniere et Nucleaire* (TCMN) and *Societé Centrale de l'Uranium et des Minerals et Metaux Radioactifs* (SCUMRA), CFP invested both in the exploration and extraction of radioactive minerals and in developing technologies and methods to further improve the uranium mining industries.[14] An involvement following a long tradition of French oil engineers that shaped the development of the French early nuclear industry (Hecht 2009, 82).

In 1968, the American AEC actively tried to increase the involvement of the oil industry in uranium mining by requesting several American oil companies to aid in a "hunt for scarce and vital uranium," including Lane-Wells Company, General Petroleum, Gulf Oil, and Mobil. Three professional societies of earth scientists developed a five-point program to ferret out radioactive minerals while the oil industry's "10,000-man army of scientifically trained explorers" searched for crude oil. The 4,000 test holes with an average of 75 to 100 feet in depth, drilled each day by oil industry explorers in the United States and Canada, should have follow-up crews check the material excavated for radioactivity by using gamma ray logs according to the plan proposed by General Petroleum and Lane-Wells Company.[15] The request of the AEC, based on the geographical knowledge needed to find both oil and uranium, proved the starting point of a new uranium boom, with this time also bigger oil companies joining the uranium market. In the following decade, this involvement would grow towards a 45% share of all US uranium produced by oil companies by 1981 (Bauder and Wagner 1981, 5-28).

5. In Situ Leaching

The involvement of oil companies in the uranium market made several new inventions possible in uranium mining based on the overlaps between the geographies of oil and uranium, which in turn would partly shape the decision by Gulf Oil to participate in the uranium cartel. The most important of these inventions was In Situ Leach mining, or ISL. ISL dissolves the minerals with chemicals and pumps the solution out of the ground. The technique can be used for the recovery of copper, nickel, gold, iron, phosphate, salt, potash, and uranium. In general, uranium mining involves two steps: first, digging or extracting the ore with an underground or open cut mine, and then processing of the ore with a chemical mill to leach the mineral from the bulk of the ore. With In Situ Leaching, the chemical leaching solutions are directly circulated through the ore zone in the ground and then the solutions are

[14] Accord de Transfert. Total S.A. Archives. Box. 50ZZ520. Folder 6. Paris.
[15] Double-Duty Prospectors, 19. ExxonMobil Historical Collection, DBCAH. Box 2.207/F120.

recovered to extract the minerals of interest. Compared to earlier often-used mining techniques, like open pit and underground mining, the process of ISL is much cheaper because no excavation of ore is required and it reduces the handling of large volumes of ore materials, making previously unprofitable sites economically viable especially with lower uranium prices (Mudd 1998, 11).

The first serious experiments with In Situ Leaching in uranium mining were conducted starting in the mid-1960s in the United States. However, the major oil companies further developed this technique and deployed it on a large scale in the 1970s. The oil companies had an edge since the leaching technique draws on the same engineering principles that are used in oil production. Dissolving uranium with chemicals and then pumping it up is similar to the technique of chemical waterflooding that was used to increase recovery of oil. The experience with this technique in producing oil gave the scientists within oil companies, such as the researchers at the Mobil Research and Development Corporation labs in Dallas and Princeton and the engineers at Mobil's Exploration and Producing Division, a head start in further developing the leaching technique in the uranium sector.[16]

From 1968 onwards, the scientists at Mobil spent several years to finetune the leaching technique in several pilot plants, such as the Bruni pilot plant, before starting the construction of commercial plants. In the ten years following the entry of Mobil in the uranium market, the company spent $36 million dollars on the exploration on uranium and built up a resource base of some 50 million pounds located in south Texas and New Mexico. This is the equivalent of nearly two year's supply for the US consumption in 1978, with about $11 million for domestic exploration budgeted for exploration per following year.[17] Most of Mobil's uranium mining plants were leaching plants, located in regions where the uranium deposits were suitable for ISL. These deposits were mainly located in permeable sand or sandstones below the water table, crammed in between impermeable strata.[18]

In this way, the development of leaching made new uranium deposits located in the US economically viable and added new resources to a market already dealing with oversupply, posing a threat for the future production of uranium deposits not suitable for the cheaper method of leaching. During the first years, leaching was mostly applied on uranium deposits located in the sandstone sediments on the Colorado Plateau. Over the next few decades, however, the leaching method would become one of the most used

16 For Uranium, the Future is Now. 1978. Mobil Overview 2, no. 1, 6-8. ExxonMobil Historical Collection, DBCAH. Box 2.207/F120.

17 Mobil Energy Minerals Division. Leaching: Mining Uranium in Nature's Way, 1. ExxonMobil Historical Collection, DBCAH. Box 2.207/F120.

18 World Nuclear Association. In Situ Leach Mining of Uranium, World Nuclear Association. https://world-nuclear.org/information-library/nuclear-fuel-cycle/mining-of-uranium/in-situ-leach-mining-of-uranium.aspx (Accessed June 27, 2022).

techniques to extract the mineral. In 2020, around 57 percent of the uranium mining projects worldwide made use of this technique, putting uranium deposits only possible to mine with more traditional techniques out of commission.[19]

6. An Abundant Market

The oil companies joined a uranium market that was dominated by the holders of the uranium enrichment facilities. Before uranium can be used as fuel for a nuclear reactor, it needs to undergo a process of conversion, enrichment, and processing. When the ore is extracted from the earth during the mining process, the uranium is crushed, pulverized, and ground into a fine powder, and then chemically extracted and concentrated. After this so-called "milling," the pure uranium undergoes a process of conversion where it is turned into uranium hexafluoride (UF_6) gas before it is sent to an enrichment plant. There, the individual uranium isotopes are separated to produce enriched UF_6, which has a 3% to 5% concentration of U-235; the special type of uranium that can be used in the nuclear power plants that became the most common since the 1960s. The necessity of these phases in the production of nuclear energy means that companies active in uranium mining have to reach a price agreement for the purchase of their uranium with the companies or organisations active in the processing or enrichment of the uranium (Hyett 1984, 162-90; Price 1984, 150-2).

When the members of the cartel first met in 1972, the US Atomic Energy Commission (AEC) was almost a monopolist within the field of uranium enrichment in the Western nuclear industrial countries. With US light-water reactors, which depend on enriched uranium for fuel, as the most dominant type of reactor at the beginning of the 1970s, and an unparalleled weapons program in the United States, the need for enriched uranium was rapidly growing. With their three big uranium enrichment plants located in the United States, the AEC had by far the most capacity to make enriched uranium. Outside the United States and the Soviet Union, only France and the United Kingdom had small enrichment plants by the late 1960s, which were mainly used for the production of enriched uranium for their respective nuclear weapon industries (Pringle and Spiegelman 1983, 344). Furthermore, the Netherlands, Germany, and Britain were working on their own experimental plant, although this plant would not become productive until the late 1970s (Schrafstetter and Twigge 2002). The enrichment plants in South Africa, Japan, and the one in Pakistan that would start running in the late 1970s were

[19] World Nuclear Association. Former Australian Uranium Mines. World Nuclear Association. https://world-nuclear.org/information-library/country-profiles/countries-a-f/appendices/australia-s-former-uranium-mines.aspx (Accessed July 23, 2021).

only in a conceptual stage at the time or were not yet worked on (Laughter 2007). In this way, countries outside the United States seeking to establish a nuclear industry were dependent on US supplies and prices of enriched uranium, enabling the AEC to exert great influence over crude uranium prices in countries all over the world outside the Soviet Union as a buyer (Stewart 1981, 659-61).

Already since 1939, the uranium market in the world outside the Soviet sphere was extremely volatile and marked by a series of dramatic price falls that have often forced the closings of once-booming mines and have transformed mining communities, particularly in Canada, into ghost towns (Spar 1994, 96; Amundson 2002, 17-36). At first, uranium was foremost a sellers' market where governments, especially the US government, were desperate to get uranium and willing to pay almost any price for it. After the Second World War, however, the critical shortages gave way to an oversupply of uranium with a boom of new producers trying to profit from this new market. Existing mines were expanded throughout the 1940s and 1950s, and hundreds of prospectors attempted to join. By the mid-1950s, the industry was already experiencing overexpansion, enabling governmental organisations like the AEC to dictate the terms of trade with their suppliers (Radetzki 1981, 39; Spar 1994, 96-7; Amundson 2002, 26).

In 1964, the United States imposed a uranium embargo on all imports which would not be dropped until the end of the 1970s. Next, in 1967, the AEC declared that it would sell enriched uranium at a fixed price, a decision that would effectively fix the price of raw uranium at $6 per pound (Stewart 1981, 660). This was hugely disadvantageous to countries outside the United States, such as South Africa, Australia, and Canada, which had made big investments in uranium mining in the 1950s to meet the expected growing US demand. When this expected increase turned out to be disappointing because the growing uranium production started to exceed the demand of the weapons program in the United States, many countries had already had to scale back their uranium production. With the price at $6 per pound, the uranium still mined was sold for half the market value it had in the mid-1950s, making the investments in uranium production even less profitable (ibid., 659-60).

A joint OECD/IAEA report from 1983 showed that over three-fourths of the world's Reasonably Assured Resources existed in only five countries: Australia, Canada, South Africa, Sweden, and the United States, and another three-fourths of the world's Estimated Additional Recourses were thought to exist in Canada and the United States (OECD and IAEA 1983, 9-13; Spar 1994, 94-5). The countries that had producing uranium mines in 1972 were Uzbekistan, Kazakhstan, Ukraine, Russia, Czech Republic, East Germany, South Africa, the United States, France, Canada, Australia, and a selection of other countries with smaller uranium deposits like Gabon. The mines in Niger were slowly starting to produce at the beginning of the 1970s, and the mines in

Namibia were already explored but still had to start their full-scale production. Since the production in Russia, Uzbekistan, Romania, Kazakhstan, Czech Republic, Ukraine, and East Germany was part of the relatively closed nuclear fuel cycle within the Soviet Union, the deposits producing for the world uranium market were fairly concentrated, especially considering that three of the remaining countries mostly sold their uranium through the state agencies of their former colonizer: either France, in the case of Gabon and Niger, or the state agency of South Africa, in the case of Namibia.[20] The governments of many of these countries would eventually form the cartel.

In 1971, the prices in this market dropped even further to a price of $4.50 per pound outside the United States. This meant that the costs of production were higher than the gross profits in most mines (Gillespie 1977). This situation was exacerbated because of new the "creation" of new uranium deposits. In Australia, several unusually rich uranium deposits were discovered in the 1960s and 1970s. In 1969, the Ranger mine in Northern Territory was discovered and was to be put into operation in 1980. The Ranger Mine was joined by the Naberlek (commenced in 1979) and Southern Alligator (commenced in 1975) mines in Northern Territory. A large amount of uranium was also discovered in 1969 in South Australia, and new uranium extraction techniques, like In Situ Leaching, promised to make the mining of new uranium deposits on the US Colorado plateau viable in the future.[21] These mines, because of their relative richness in usable uranium, would likely have relatively low production costs that would push other mines out of the market.[22] Also in Canada, one of the largest uranium mines ever to be found in the Western world was discovered at Rabbit Lake in Saskatchewan. This mine, which was found by use of radioactive well logging techniques, was scheduled for production in 1975 and became Canada's biggest single producer of uranium ore.[23]

Since it takes several years before a mine is put into operation after uranium is discovered, a reasonable prediction could be made by the various producers about the uranium price development (Williams 1984, 124-36). Already at the first meeting of the cartel in 1972, the French CEA would point out that in the medium term, uranium production would probably continue to exceed

[20] Austin, J. Memorandum: Meeting of International Uranium producers in Paris April 21-25, 1972. IUC Hearings, 496; see also Adamson (2021, 325); Hecht (2012); World Nuclear Association. 'World Uranium Mining Production. https://www.world-nuclear.org/information-library/Nuclear-Fuel-Cycle/Mining-of-Uranium/World-Uranium-Mining-Production.aspx (Accessed July 23, 2021).

[21] World Nuclear Association. Former Australian Uranium Mines. World Nuclear Association. https://world-nuclear.org/information-library/country-profiles/countries-a-f/appendices/australia-s-former-uranium-mines.aspx (Accessed July 23, 2021).

[22] Energy: The Uranium Cartel's Fallout, Time (November 21, 1977), 96.

[23] The Rabbit Lake Operation. 1979. Gulf Oil Corporation Records. Heinz History Center - Detre Library and Archives. Box B, folder 14; Stewart. Canada's Role in the International Uranium Cartel, 665.

demand if no mutual agreements were reached among the various countries. According to the French, demand would reach a maximum of 26 thousand tons by 1977, while production capacity, even without the mines in Australia and Canada, would already reach a hundred thousand tons.[24]

7. The Formation of the Uranium Cartel

The 1970s not only were the age of multiple oil crises, but also experienced a disruption in the price development of alternate resources. Other fossil fuels, like natural gas and coal, almost doubled in price in 1973/1974. The sharpest increase in spot price, however, was the uranium price hike. Whereas the spot-prices of uranium had been declining steadily since the mid-1950s and reached a point of about 76 US dollars (adjusted to 2022 dollars) per kilogram of uranium (or US$/kgU) around 1973, spot-prices reached a high of 301 inflation-adjusted US$/kgU in 1976 ($114/kgU in contemporary US dollars) an increase of more than 500 percent in two years. That peak would persist until 1979, after which prices would soon return to their former level (Rothwell 2016, 10-1).

Shortly before the remarkable uranium price increase in the 1970s, a first meeting took place of different parties unhappy with the steadily decreasing, and already low, prices for raw uranium before the 1970s. On February 1, 1972, delegates from Canada, Australia, South Africa, and France as well as producer representatives from these countries and Britain met at the headquarters of the French CEA in Paris. Already before this first meeting, the seeds of the uranium cartel were planted. Business historian Debora L. Spar located the first initiative with the multinational mining company Rio Tinto Zinc harbouring the idea of international cooperation without having the political and institutional means to implement the official arrangements needed, and the Canadian policy entrepreneur Jack Austin using his powers to set the cartel in motion (Spar 1994, 99). Other stories attribute the first initiative to the French energy minister and former oil entrepreneur André Giraud who feared a monopoly in the uranium market of “Seven Brothers,” as a counterpart to the “Seven Sisters” in the oil sector and wanted to position the CEA as the “Shell of the atom” (Pringle and Spiegelman 1983, 332-45). It is certain that the first meeting, supervised by André Petit of the CEA International Division, was already used by the French to set the program to determine prices and quotas.[25] During the next five months, various negotiations followed, first in Paris and a final summit meeting in Johannesburg, South

[24] Statement Albert Gore, Jr. IUC Hearings, pt. 2, 2.

[25] Statement Albert Gore, Jr. International Uranium Cartel: Hearings before the Subcommittee On Oversight and Investigations of the House Committee On Interstate and Foreign Commerce. 95th Cong., 1st Sess., pt. 2. 1977, 2. Hereafter cited as IUC Hearings.

Africa, in May 1972. There, the uranium cartel was officially established. The countries involved would call themselves the "Club of Five," or more simply "the club."[26]

The participants in the cartel fixed precise percentages and established a bid-rigging procedure. The total world uranium market, excluding the United States and the Soviet Union, was allocated to each of the members of the Club of Five for the remainder of the 1970s. The new cartel price was fixed on a new floor price, below which no one bid, of $6.25 per pound. This price escalated slowly, based on an agreed formula. The central secretariat, based in the headquarters of the CEA, decided whose turn it was to get a new contract when an opportunity was announced outside the United States, and then that company would put in a bid at the floor price. Another member of the club would then be appointed as the "runner-up" and would be obliged to put in a higher bid for the contract (Stewart 1981, 667).

Although the initiating governments were closely involved in the club, the various mining companies would eventually participate within the cartel. The main player was the British mining company Rio Tinto Zinc (RTZ) with subsidiaries in Australia, Namibia, and Canada, which alone owned more uranium reserves than most world powers, controlling almost a fifth of the world's uranium deposits outside the United States (Pringle and Spiegelman 1983, 336). From France, the French company Uranex participated, from Germany Uranerz and Urangesselschaft, from Australia Mary Kathleen Uranium Limited, Ranger Export Development Company, and Queensland Mines Limited, and from South Africa Nuclear Fuels Corporation (Nufcor). From Canada, several companies took part, such as Rio Algom (subsidiary of RTZ), Agnew Lake Mines, Eldorado Nuclear Pyramid Gold Mines, and Denison Mines. Gulf Oil's Canadian subsidiary, Gulf Minerals of Canada Limited, also joined in 1972.[27]

These companies were selected because they already had mining properties in the different countries. The French and South African production of uranium was already centralized with no legal obstacles to further regulation, making it easier to set prices or allocate market shares. In Australia, the uranium industry was relatively new, so the government was able to impose operating procedures already in line with the cartel agreements (Spar 1994, 104; Hecht 2012, 70-3). Canada encountered more problems, however. Even though some of the largest producers were national companies, most others were private concerns. Energy Minister Jack Austin had to convince the other members of Pierre Trudeau's cabinet to agree to Canadian participation in international discussions on the subject of export markets and floor prices. This decision enabled him to authorize the Atomic Energy Control Board to

[26] IUC Hearings, 342.

[27] These are at least those companies that have contracted or offered to contract with the utilities of the United States. Statement Patrick McLain. IUC Hearings. Note 4, 340.

deny export permits when the prices and quantities were not in the "public interest." In this way, the private companies were forced to comply with the cartel agreements while at the same time preventing those companies from being persecuted under Canada's antitrust law (Stewart 1981, 664; Spar 1994, 104-5).

One company needed more convincing, however. The US-based Gulf Oil Corporation, contacted via their Canadian subsidiary, worried that they would be liable under US law for participating in a cartel via Canada, and stated that participation in a formal arrangement was not necessarily in their best interest and that any action undertaken by their Canadian subsidiary should be in compliance with the US antitrust laws.[28] In the end, the Canadian government succeeded in overcoming Gulf Oil's worries by creating a legal trail that would demonstrate that Gulf had been forced by Canadian law to join with the other uranium producers. In a memorandum from Roy D. Jackson to I. W. Coleman attached to the hearings, Jackson concluded that both the economic pressure of threatening Gulf Oil with limiting the accepted ownership of foreign companies to 33 percent being exerted by the Canadian government, and the internal reasoning within the oil company that participating would in fact not violate the US antitrust laws, played a role.[29]

This article, however, argues that the constraints imposed by the geographical properties of uranium deposit owned by Gulf were an important additional factor in the decision made by Gulf Oil to join the cartel. Gulf joined on May 9, 1972, along with the other Canadian firms in signing an aide-memoire agreeing on the desirability of a market arrangement designed to "to stabilize the present chaotic market situation and to avoid a further acceleration of the present price war."[30] Their most pressing concern was to make their uranium mining enterprise profitable. Explored by the company in 1967 by means of several well logging techniques, the Rabbit Lake mine would open in 1975. The ore in the Rabbit Lake uranium mine, operated by Gulf Minerals of Canada Limited, was mainly located in metasediments of the Aphebian Wollaston Group, forcing the operators to go for the more expensive open pit mining and milling techniques instead of the cheaper leaching techniques. This more expensive way of mining uranium would only be economically viable with higher uranium prices, unlike the uranium deposits mined with leaching that could still be profitably mined even with a lower uranium price (Tremblay 1982, 12-4). The expectation that, after the Rabbit Lake mine opened in 1975, prices would soon fall even further with the addition of the

[28] IUC Hearings, 135. See also Gulf's File Note on the April 19, 1972, Paris Meeting of Canadian Producers. IUC Hearings, 484-7.
[29] Memorandum from Roy D. Jackson to I. W. Coleman, April 28, 1972. IUC Hearings, 488.
[30] Aide-Memoire Accepted by the Undersigned Canadian Uranium Producers on May 9, 1972. IUC Hearings, 528.

various leaching plants in the United States, would prove an additional reason for Gulf Oil to accept the proposal to participate in the uranium cartel in 1972.

8. Concluding Observations

This article showed that oil companies, like Gulf Oil, did not join the uranium business out of a will to sabotage this industry. Instead, they entered a market that was closely linked to the oil sector and used their technological expertise to become a competitor. In their willingness to gain a foothold on the uranium market, many oil companies were willing to employ some of the far-reaching and legally risky strategies, like cartel formation, that were also common in the oil industry. In a way, James Harding was therefore right in comparing the uranium cartel with OPEC in his 1976 press conference publicly exposing the existence of the cartel. Like OPEC, the uranium cartel was a collaboration of many of the producer countries. Where the OPEC-countries started their cooperation to get more influence over the Western oil companies that used their dominance over the refineries and tanker fleets to set the prices and alter the low prices, the original members of the uranium cartel were unhappy with the dominant position of the AEC as the main exploiter of uranium enrichment facilities and wanted to counter the declining uranium price development. Both cartels were by no means meant to sabotage the market they wanted to profit from. They were founded to shift a bigger share of the profits, and for many countries also the associated technopolitical power, to the producers (Garavini 2019; Harald Claes and Garavini 2020).

One of the differences with OPEC, however, was the role of an American company in the cartel. Gulf Oil, in the story of the rise of OPEC often framed as one of the actors losing influence in the oil market, joined the uranium cartel as a producer facing difficulties with making their uranium mining projects profitable. Although the US House hearings already ended in 1977, and the cartel stopped existing after 1978, the lawsuits between Westinghouse and Gulf Oil continued until 1983. In the end, Westinghouse and Gulf Oil reached a settlement on some of the lawsuits brought by Westinghouse. It was agreed that Gulf Oil would remit $25 million dollars to Westinghouse, that Gulf Oil would drop the counterclaim that Westinghouse used unlawful tactics to squeeze competitors out of the market, and that Gulf Oil would supply 13 million pounds of uranium with a market value of $350 million at the time to six of Westinghouse's utility customers (Pikna 1980, 591). In this way, the saga of the uranium cartel ended, although tensions between the governments of the United States and the participating countries remained for some time, as did the public and academic debates on the actual role of the members.

In this debate it is important to remember that the uranium market in which the cartel operated was largely shaped by the geophysical qualities of the resource the market was built around. The ways in which the uranium mineral amasses in specific geological layers determined the locations of the various uranium deposits. The uranium deposit in itself was a historically contingent concept, shifting over time based on the knowledge and investing capabilities available to get the uranium out of the ground. This geophysical knowledge, needed for the exploration and extraction of the resource, was largely based on technological spillovers from the oil industry.

The knowledge needed to get the uranium out of the ground and the overlapping geographical characteristics of both uranium and oil, made it possible for many oil actors to join the uranium industry. Already since the early development of the uranium industry, oil actors were involved in the exploration and extraction of uranium. Oil entrepreneurs as Charlie Steen and Bob Adams moved from the oil industry to uranium exploration and companies like Kerr McGee and Philips Petroleum diversified their businesses during the uranium boom in the 1950s. From 1968 onward, on the request of the American AEC, "Big Oil" companies, like Mobil and Gulf Oil, became involved in uranium mining by reusing their boreholes to search for the mineral. The radioactive well logging and the In Situ Leaching technique in particular provided a helpful edge for oil actors in the rapidly growing uranium market, making it cheaper to find and mine uranium.

Especially the In Situ Leaching technique, used by American oil companies to mine previously economically unviable deposits, threatened the exploiters of non-American uranium mines with an influx of ever-cheaper uranium in a market already dominated by the monopolist in uranium enrichment, the American AEC, as the main buyer. This threat proved to be an important reason for the owner of the Canadian open pit mine at Rabbit Lake, Gulf Oil Corporation, to join the international uranium cartel and to try to keep their enterprise economically viable.

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