CHAPTER TWO

Geosocial Formations and the Petroleumscaping of Singapore

Underground Landscapes as Infrastructural Territories

ANDREW TOLAND

A hundred and thirty meters below an artificial inlet set into an unnaturally shaped island just off the southern coast of Singapore lies a vast array of gigantic artificial caves called the Jurong Rock Caverns. The caverns are filled with various forms of liquid hydrocarbons and derivative products. This massive piece of infrastructure, like the larger national petrochemical facilities of which it forms a part, is a central node in the global fossil fuel economy. Singapore hosts the largest oil bunkering facilities in the world (MPAS n.d.), where oil is stored to refuel the ships that cycle endlessly between the manufacturing centers of East Asia, the consumer markets of Europe, and much of the rest of the world—an endless armada passing to and fro through the Strait of Malacca, west of Singapore.

The Singaporean government constructed and is continuing to expand the Jurong Rock Caverns both to bolster Singapore's petrochemical industry—it is reportedly the world's third-largest oil refining center (Tan 2017) and the world's third-largest oil trading hub (ITA n.d.)—and to underwrite its continued strategic importance for global maritime trade. In spite of extensive coastal reclamation, Singapore's scant land resources on the surface have impelled government and industry to view the subsurface as a new frontier for infrastructural development. However, the significance of the Jurong Rock Caverns goes far beyond the economic. Certainly, the caverns exemplify the roles of large-scale, state-sponsored infrastructure and of the transport and logistics industries in the story of Asia's modern development. But the caverns can also be read in other ways: they reveal the history of value judgments about landscapes and the construction of national territory; they bind narratives of national identity to economic and material transformations; and they operate as an assembly through which the circulation of fossil fuels, technological imaginaries, and economic life come together with the implacable realities of geological time, the processes of matter, and the geochemistry of climate.

Part of the national discourse of Singapore since independence is that it has been engaged in an ambitious and determined game of catch-up with the rest of the developed world, which it has now surpassed on many measures.[1] Now that

Singapore has overtaken much of the rest of the world, the stated objective of its government is to stay ahead, in what government discourse tends to characterize as a cutthroat struggle for global economic survival.[2] The Jurong Rock Caverns have been cast as one of many examples that instantiate this national discourse.

This chapter shows how the caverns also represent an opening onto myriad other dynamics—national and international, historical and projective, material and representational, technological and environmental—that we might fruitfully begin to probe in order to understand the deeper currents in the history of infrastructure and modernity in Asia. I argue that the Jurong Rock Caverns are just one part of the national terraformational project of Singapore: not only engineering and economic achievements, they are also a geosocial project that discursively constructs Singapore's transformation from a landscape with no natural endowments to one that can create innovation, value, and advanced knowledge at will.

Scale is an important factor here. The caverns project is not merely driven by the engineering imperatives associated with large-scale infrastructure; it also serves the Singaporean government's rhetorical strategy of forever renewing the superlatives that can be attached to the small nation. And not just physical scale is at play here. So is a more immaterial contrast of scales, constantly repeated for the benefit of both domestic and international audiences to burnish the technocratic and visionary credentials of the ruling People's Action Party. In the case of the Jurong Rock Caverns, it is petroleumscaping in particular that effects this heroic construction of artificial grounds and undergrounds, transforming, in the words of Lee Hsien Loong, Singapore's prime minister, seven small offshore islands into economically and socially lucrative "thinking space, international space, and development space" (Lee 2014).

A Light at the End of the Tunnel

On February 8, 2007, Singapore's minister for trade and industry stood in front of a large papier-mâché rock face and set off a mock explosion with a cardboard detonator. Through the magic of stagecraft, this blasted a hole in a wall of styrofoam rocks, which theatrically tumbled down to reveal the interior of a dramatically lit cave. This rather overblown piece of theatricality marked the climax of the groundbreaking ceremony for the Jurong Rock Caverns development (*Straits Times* 2014).

In his speech for the occasion, the minister, Lim Hng Kiang (2007), reiterated many of the talking points that have long characterized Singapore as an ambitious developmental state: the project was a "first" of regional significance; it contributed to Singapore's consolidation as "a global [oil and] chemicals hub"; it was part

of the Singaporean government's commitment to give "current and future investors in Singapore" certainty about industry prospects; it was a manifestation of Singapore's "spirit of constant innovation" as well as "hard work, imagination, and perseverance"; and it demonstrated Singapore's determination to maintain its "competitive position" and stay ahead in a "fast-changing and dynamic competitive environment."

At the same time, Lim's speech revealed certain things about the way geology, land, and space are brought together within the project of Singapore's developmental state and in its political economy and political ecology. And it revealed a series of both emphases and elisions in the state's official discourse about the materials, processes, and systems mobilized for the project: capital, geotechnical knowledge and construction methods, global petrochemical trading networks, and the labor of construction workers (mostly migrants in Singapore on short-term visas). Other historical legacies, equally absent from the official narrative, also came along with the project as its inevitable stowaways: histories of land modification in Singapore, the island's long role in the global trading system, its perennial discourse of resource and land scarcity, the social engineering of the People's Action Party, and the country's perpetual geostrategic recalibrations in the face of shifting regional and international power dynamics.

When the project formally opened in 2014, Singapore's prime minister, Lee Hsien Loong, officiated. This time there was no choreographed blasting open of ersatz rock. Instead, Lee stood behind a large, altar-size slab of actual rock alongside three other officials. They each pressed four oversize buttons attached to the rock's surface. The buttons lit up, and (one was meant to assume) the first flows of liquid hydrocarbons into the underground chambers of the caverns were set in motion. Lee's accompanying speech repeated many of the same tropes that Lim's speech seven years earlier had featured, but it also contained some interesting asides, as well as broadening the claims about what this instance of underground infrastructure might represent for Singapore. Lee introduced the project by going straight to one of the organizing narratives of Singapore since independence—a narrative that had been passionately and frequently articulated by his father, Lee Kuan Yew, the country's founding father and long-serving prime minister—that the nation was a territorially constrained and land-scarce city-state with no endowments of natural resources, constantly in search of a means of existence for its people. Lee Hsien Loong began:

> Ladies and gentlemen:
>
> I am delighted to be here this afternoon to open the Jurong Rock Caverns. This is Southeast Asia's first commercial underground liquid hydrocarbons storage facility and we got it here in Singapore.

> In land-scarce Singapore, we are always trying to create new space—to support growth, to create jobs, and to build homes for our people.
>
> Two months ago, I met the Board of Halliburton. They were having their board meeting here. They asked me this same question—how is Singapore going to expand our physical land area [*sic*].
>
> I explained to them that Singapore's land constraint is a little bit like Peak Oil. It exists, there is a theoretical limit. But with ingenuity, determination and technology, that limit can be quite a way off! And as you approach it, hopefully we can push it even further off in the future.
>
> Take Jurong Island, where we are at now. (Lee 2014)

The anecdote about Halliburton's board seemed intended to encode a number of further messages. First, it demonstrated Singapore's leading status in the global petrochemical industry, and in the global economy more broadly; the world's leading oil services company could just as legitimately hold its board meeting in Singapore as in Houston.[3] Second, it offered an opportunity for Singapore, the scrappy Asian upstart, to school a global corporate behemoth; both were facing the constraints of a finite resource, but with "ingenuity, determination and technology," a future crisis might be indefinitely deferred.

Lee was subtly continuing a favorite theme of his and his father's "Asian values" discourse (e.g., Barr 2007). In this context, Jurong Island and the underlying Jurong Rock Caverns project come to stand for broader formations of Singaporean national identity, as well as for the social and cultural engineering necessary in the pursuit of long-term national economic strategy. These are the very themes distilled in the goal statement that opened Singapore's 2010 strategic economic planning document: "high skilled [*sic*] people, innovative economy, distinctive global city" (Singapore Ministry of Finance 2010). In the discourse of the Singaporean government, the Jurong Rock Caverns are promoted as a signal example, mobilizing imaginative (even fantastical) infrastructural and technological creativity; significant financial and intellectual capital; deliberate reconfigurations of material realities; and an astute, carefully calibrated positioning of the country within regional and global economies and resources.

In addition to peak oil and peak land, Lee's speech also touched on the threat of another sort of limit: "JRC [the Jurong Rock Cavern development] shows that we are determined to develop the petrochemical industry here, despite our land constraints, and also despite the potential impact on our petrochemical industry of a United Nations Framework Convention for Climate Change agreement on carbon emissions which is presently being negotiated by the countries of the world" (Lee 2014). Ostensibly, this statement seemed intended to reassure investors and

to signal certainty in the face of the impending Paris Agreement, affirming the stability and continuity of government policy in an unpredictable international context. Lee then noted that the petrochemical industry accounted for a third of Singapore's manufacturing output—signaling that Singapore had as much skin in the game as any private investor.

At the same time, the statement offered no concrete indication of how the risk of climate change and the need to limit carbon emissions might be managed. Instead, it seemed to signal an implicit bet: that the region's demand for oil and petrochemical products would always prevail against any international agreement on carbon emissions reductions, and that self-interested realism would always trump idealism in international relations and multilateral frameworks. One might interpret this as a bet on the teleology of Asian modernity (the ultimate metaphorical light at the end of the tunnel): that it is an inevitable trajectory built on the demands of ever-increasing material standards of living, and serviced by a state-mobilized infrastructural imaginary of ever-increasing productive capacity, logistical efficiencies, and technological innovations. Nevertheless, the Jurong Rock Caverns project offers a curious instance of this infrastructural imaginary's rubbing up against the exigencies of anthropogeological forces moving inexorably in the opposite direction.

An (Un)Natural History of Politics: Singapore as a Terraformational Project

Even before discussions about the Anthropocene emerged, first in the sciences and humanities, and then in broader discourse, geologists had begun to speak of anthropogeomorphology—the association of geomorphological conditions with the anthropogene, or the landscape as modified by humans, especially in urban contexts (Coates 1984). One of the early studies in this field was Avijit Gupta's 1987 "Urban Geomorphology in the Humid Tropics: The Singapore Case." Even then, the "Singapore case" offered a rich example of just how much a natural geomorphology could be altered in the service of urbanization and economic development. More recently, "political geology" (Bobbette and Donovan 2019) and the slightly earlier "geosocial formations" (Clark and Yusoff 2017) have offered ways in which social and political-economic dynamics may be read as imbricated with geological phenomena, and vice versa. This corrective to the blander discourse of the Anthropocene allows geophysical, biopolitical, and social conditions to be considered in terms of "geologic capacities" and "geologic subjectivities," tying together fossil fuels and the modes of existence under late capitalism that the energy source underpins in what Kathryn Yusoff (2013, 780, 791) calls "geologic life."

The Jurong Rock Caverns, and the larger terraformational project of Singapore of which they form just one part, can be interpreted as an expression of such geosocial formations. In both the colonial and modern periods, Singapore has always been geosocial, insofar as the habitation and identity of the island was always dependent on geographic and geological contingencies: its geophysical status as an island separated from the Malay Peninsula, its geostrategic location in relation to the Strait of Malacca, and its shortage of buildable land. The Jurong Rock Caverns can be thought of as a contemporary extension of this history, a new phase in the geosocial life of the territory.

When the British commenced the formation of Singapore as part of their colonial project, the geosocial life of fossil fuels was only in its infancy. Britain's geostrategic maneuverings in the region were focused on the Strait of Malacca as a choke point on the trade routes of the global spice economy and of the India–Southeast Asia–China commodity trade, in which the British competed with the Dutch as well as with local powers. In many ways, this was simply a continuation of the strategic trade role that the strait had played since at least the first millennium CE under the (partial) control of the Srivijayan Empire, and under the later overlapping structures of the Islamic-based trade system.[4]

By the middle of the nineteenth century, however, reorientation was well under way: both toward fossil fuels (first coal and later oil), and toward the evolution of the Western colonial trade system into the present globalized economy, in which carbon-based energy plays such a major part. Singapore's strategic role straddling East Asian and European trade continued to strengthen with the technological shift to coal-powered steamships, whose use both cut travel times and increased volumes (Clarke 2006).

As noted above, the conventional narrative of the history of Singapore's land reclamation projects is built on a discourse of land scarcity. But another approach to the issue is to consider this history in relation to the formation of global transportation infrastructures. Port cities tend to experience some of the most intensive land transformations because they reshape coastal or river edges and floors to suit the needs of shipping, and reconfigure adjacent land in the service of the associated warehousing and logistics (Graf and Chua 2008). Within three years after Britain established the colony of Singapore in 1819—founded with the strategic intention of challenging the predominance of Dutch ports in the region—the British had begun clearing "impenetrable forest" and demolishing hills in order to fill in the mangrove wetland on the south side of the Singapore River and create Boat Quay. The north bank was occupied by the local Malay *temenggong*'s (viceroy's) compound and the village under his jurisdiction (Dobbs 2003, 19–20). By the 1860s, the port activities of Singapore had outgrown the original site at Boat

Quay, as the British settlements in the strait grew and their trade within the British colonial system increased—a change boosted by the opening of the Suez Canal in 1869. From the second half of the nineteenth century onward, the entire southern coastal edge of Singapore underwent successive transformations until the land area of the island had been increased by a quarter of its original size (figure 2.1[5]).

Retrospectively, these developments tend to be described as driven by the imperatives of land scarcity in the face of a growing population, but a careful reading of successive reclamation schemes reveals that these were as much social engineering projects as infrastructural ones. These colonial reclamation projects were driven by a desire to spatially order the settlement in such a way as to keep the Indigenous Malay and the growing Chinese immigrant populations in check, while constantly working to improve infrastructure for the British merchants and to facilitate trade and commerce. The focus on developing port infrastructure did not just entail reconstructing the waterfront edge: opening up new port areas demanded reconfigurations both of the commercial districts that serviced them, and of the transportation links that connected them. When a new port at Tanjong Pagar was established and the Singapore River docks were expanded with additional reclamation at Telok Ayer, the intervening hill ranges of Mounts Wallich and Palmer needed to be reshaped to allow the construction of direct roads linking the original commercial district and port with the new port at Tanjong Pagar.

This pattern was repeated throughout Singapore's colonial and postcolonial history: the development and consolidation of Singapore's internationally oriented economic ambitions necessitated continuing development and consolidation of its landforms and spaces, as well as the intensification of its use of land and the land's productivity. In the period after independence, the most notable example is the vast thirty-year East Coast Reclamation Scheme initiated by the Housing Development Board, which transformed a "bare expanse of new coastal land" into a "new skyline" for Singapore, with new "commercial centres, hotels and luxury apartments, low and high density housing" and "miles of beaches and acres of parkland" (Campbell 1971).

The formation of Singapore since independence has been an ongoing project, not just to reengineer space, but also to reorder other elemental conditions of life (air, water, and food)—not to mention its human subjects (Wilkinson 1988). Joshua Comaroff (2017) has shown how Lee Kuan Yew attempted to engineer the very air of Singapore (he believed that the optimal temperature for a vigorous and productive life was twenty-two degrees Celsius). Similarly, Mark Usher (2018, 331) has tracked how Singapore's water infrastructure encodes a "lively" biopolitics of fluid assemblies of bodies, infrastructure, and natural systems in service of the

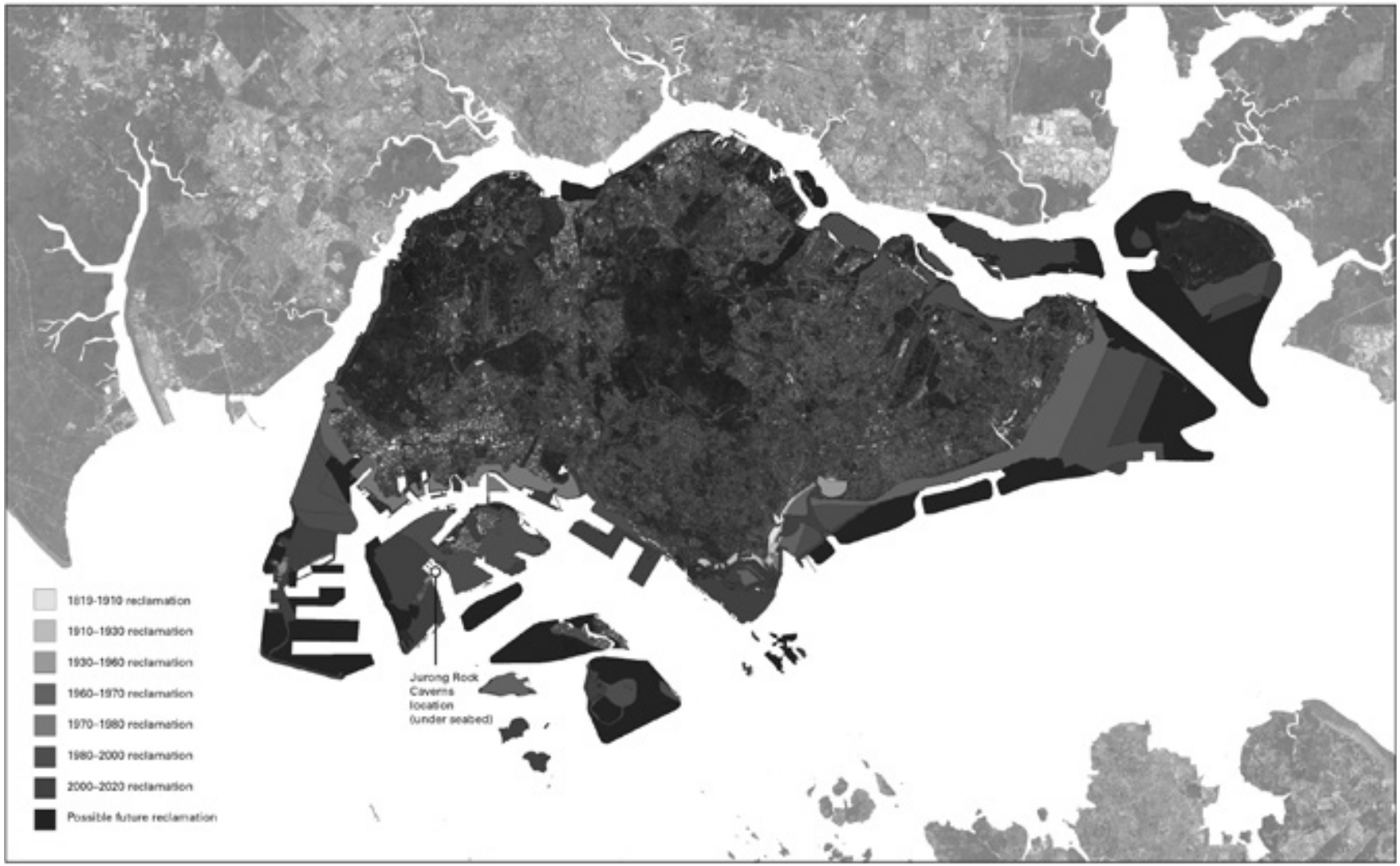

Figure 2.1. Singapore's history of land reclamation. (Map by Andrew Toland and Daniel Rooke.)

shifting objectives of Singaporean modernization. But precisely where and how the terraformation of new spaces should take place in Singapore has depended on long histories of cultural meanings assigned to land and environments, as well as to the Singaporean state's reading of international trade and economic dynamics.

Petroleumscaping Singapore

Carola Hein (2018) has advanced the notion of "petroleumscape" to speak of the global network of spaces, physical and financial flows, representations, and cultural imaginaries that have been mobilized by powerful state and private actors to shape a vast fabric of landscapes, cities, buildings, infrastructures, and the very modes of life in urban and nonurban territories alike. As she (2018, 888) notes, "connecting the actual places where oil has a hold with the *representation* of these spaces and of the *practices* of petroleum products . . . points to a better understanding of the ways in which oil shapes behaviors and secures continuous production and expansion of its spaces, thus creating a feedback loop."

To understand the infrastructure of Singapore's Jurong Rock Caverns as a petroleumscape requires realizing that an important dimension of Singapore's historical formation is related to the history of the global fossil fuel economy. The story of the Jurong Rock Caverns is not just the story of the construction of a vast underground oil storage facility: the caverns are only the latest expression of the reshaping of Singapore in the service of the global oil system.

As Singapore's strategic significance as a regional oil hub grew, the topography of the entire southwestern coast of the territory and its outlying islands was literally reshaped in the service of that growth. In the narrative presented by the Singaporean government, Singapore's participation in the global oil economy allowed the transformation of "barren rock" (Goh 2000) into productive land. Just as reclamation allowed the land of Singapore's urban areas to be consolidated and expanded in the service of colonial trade, and ultimately transformed into a new globalized skyline, the reclamation of Singapore's southwestern coast and islands allowed the consolidation of colonial energy resource systems and independent Singapore's post-war petrochemical industries. The most recent iteration, the Jurong Rock Caverns, operates as an underground analog to the intensification of land use and productivity offered by the contemporary skyscrapers of Singapore's new commercial and residential developments.

The first petroleum depot was established in Singapore in 1891 on the island of Pulau Bukom Besar (now Pulau Bukom) by M. Samuel and Company, Limited, a London-based trading company. Founded in 1832 by Marcus Samuel with a focus on trade with the Far East, the company realized early the global potential of the

oil trade, and in the 1880s it began shipping case oil (five-gallon tins packed as pairs into wooden crates) from the Black Sea oil fields of Russia to rapidly industrializing Japan. By 1888, this venture had become so successful that the company commissioned three custom-designed ships, the world's first oil tankers, to transport oil in bulk: the *Murex*, the *Clam*, and the *Conch* (named after the shells that were the most successful early imports of Samuel's London antique shop).[6] M. Samuel and Company's Singapore depot was established as a regional hub and distribution center as part of the company's trade in Russian kerosene (Moey 1991, 27–28).[7] The Singapore storage facilities formed part of the company's network of oil trading infrastructure across Asia, which was linked to other facilities in Kobe, Hong Kong, Shanghai, Saigon, Bangkok, and Jakarta.

In the period of around a decade at the start of the twentieth century, the use of oil and oil derivatives rapidly shifted from urban and industrial lighting fuel to fuel for internal combustion engines in transportation and industry, completely reconfiguring the geography of resources, mobility, and territories, and causing demand to explode. The first diesel-powered ships were launched in 1903, and by 1912 the British Admiralty directed that all warships be converted from coal to oil. This transition consolidated Singapore's strategic position in the global fossil fuel system, and Singapore became the base for Britain's Far Eastern fleet. The Singapore naval base at Sembawang, constructed between 1923 and 1938 on the northeast coast of Singapore, stored enough oil reserves to fuel the fleet for six months (Murfett, Miksic, and Farell 2011, 155). While the British Navy built its vast oil storage infrastructure on the north of the island, on Pulau Bukom, off the southern coast of Singapore, the Asiatic Petroleum Company continued to develop and expand its facilities, principally through ongoing reclamation. By 1942 the island housed sixty storage tanks and five wharves, setting in place the basis for Singapore's post-war and post-independence petrochemical economy. Although many of these facilities were damaged during the war, what remained was a terrain that was sufficiently petroleumscaped (with reclaimed and leveled islands, cleared sites, and strategically developed port infrastructure) such that the industry could be rapidly revived after 1945, and especially after independence in 1965.

The process of reclaiming and developing seven separate natural islands to form Jurong Island began during the rapid expansion of Singapore's petrochemical industry in the period immediately after independence. In 1968, the minister for law and national development announced to Parliament that the government had acquired the whole of the island of Pulau Ayer Chawan, and that the Jurong Town Corporation had negotiated the lease of that island to Esso for the development of an oil refinery costing SGD 200 million (about USD 65 million). The refinery's development required the creation of an additional 332 acres of land by reclamation,

which was undertaken and paid for by Esso (Parliament of Singapore 1968). This pattern was repeated on Pulau Ayer Merlimau, leased to Singapore Petroleum Co. (Pte.) Ltd., and on Pulau Pesek, leased to Mobil and other oil companies in 1971 (Parliament of Singapore 1971a, 1971b).

The most ambitious scheme, first conceived in the 1980s and aimed at focusing even more of Singapore's manufacturing strategy on the petrochemical sector, was a proposal to construct a thirty-two-square-kilometer artificial island by consolidating and reclaiming the area around the seven existing islands off the southwestern coast of Singapore: Pulau Seraya, Pulau Ayer Merbau, Pulau Sakra, Pulau Pesek Kecil, Pulau Pesek, Pulau Ayer Chawan, and Pulau Merlimau—in other words, binding all the islands of the different multinational oil companies into a single mega-island (figure 2.2[8]). On October 14, 2000, Goh Chok Tong, then Singapore's prime minister, officially opened Jurong Island. In narrating the story of its development, he described the seven original islands as "seven pieces of barren rock," and he noted that visionary feats of geotechnical engineering and marketing had "convinced over 60 leading petroleum, petrochemical, specialty chemical and supporting companies to hub on Jurong Island" (Goh 2000). The achievement was not only the creation of land out of empty seawater and barren rocks, but also the selling of it: "Selling stretches of seawater, with only the promise of land sometime in the future, must surely be more difficult than selling ice cream to Eskimos!" (Goh 2000).

As the petroleumscaping reclamation of Jurong Island has progressed and been augmented with the addition of the Jurong Rock Caverns, the site has come to figure prominently in the Singaporean state's discourse of national economic achievement, making the prefix "Jurong" itself a metonym for such wizardry. In his speech at the opening of the Jurong Island Road Link, Lee Hsien Loong (2000), then deputy prime minister, said:

> The name, Jurong, has become synonymous with national entrepreneurship. . . . Jurong was associated with our bold move, starting in the 1960s, to industrialise the economy. We transformed the swamps of Jurong into industrial land and the Jurong Industrial Estate that we know of today.
>
> Today, Jurong Island has also become a symbol of national enterprise. Here, we conceived and built an integrated petrochemical industry complex out of coral reefs and a scattering of small islands. Without any oil or natural gas of our own, we have brought together on the island a collection of upstream and downstream petrochemical plants that supply one another, create synergies for each other, and make viable the whole complex ecology of different operations and products, where a single plant could not survive.

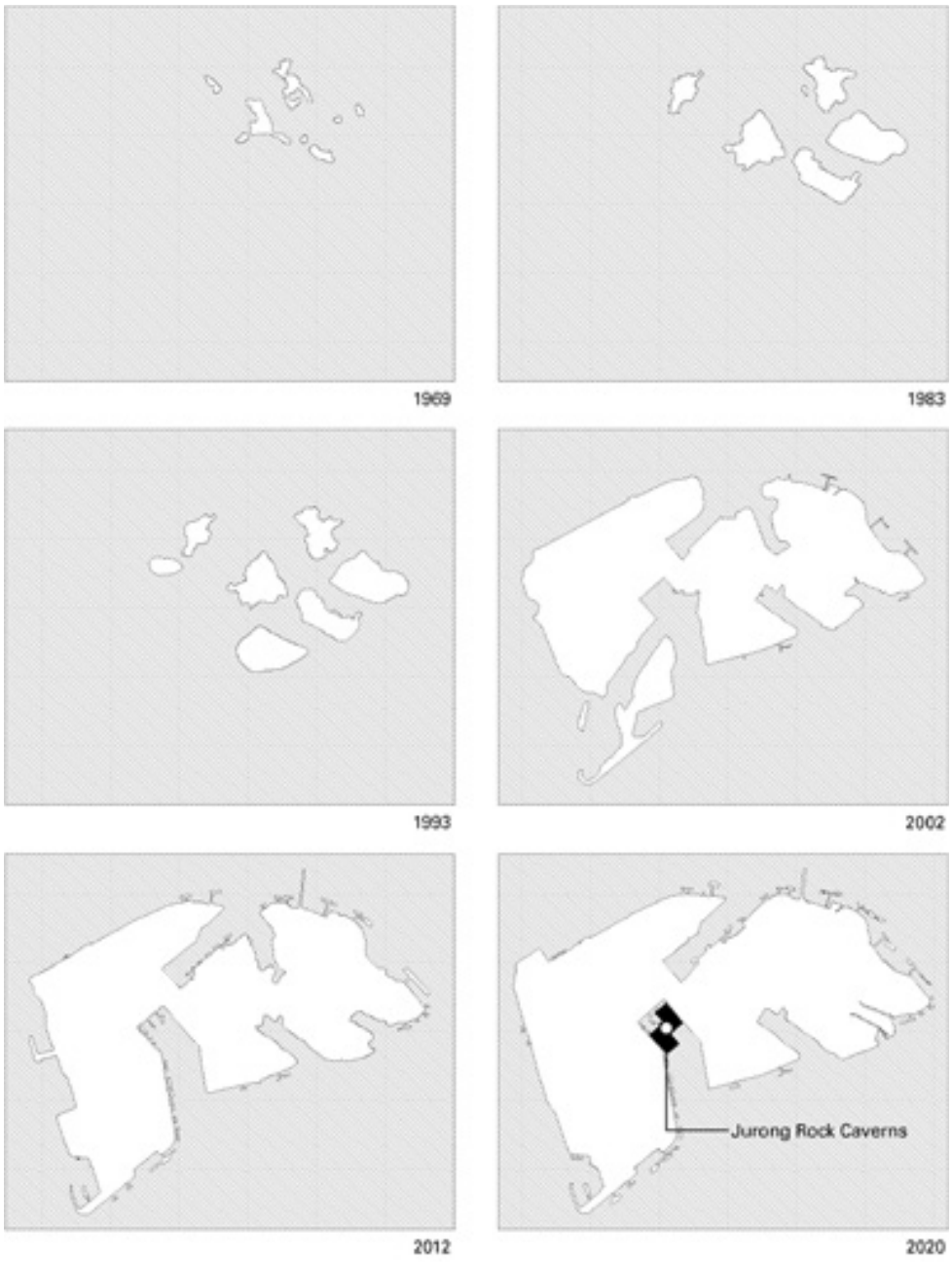

Figure 2.2. Reclamation of Jurong Island. (Map by Andrew Toland and Daniel Rooke.)

In this presentation, "national entrepreneurship" is the alchemy that transformed the natural ecology of swamps, "barren rock," coral reefs, and seawater into a much more valuable "ecology" of oil. But this achievement is not just a story of sectoral integration and infrastructural efficiencies. A more fundamental ecology also had to be engineered—an ecology that brought the bedrock under the sea and Singapore's human capital into a closer relationship.

Forming Jurong and the Jurong Formation: Engineering the Nonhuman and Human Frontier

If the Jurong swamps offered a tabula rasa for industry and manufacturing, and the "barren" islands that were demolished, amalgamated, and absorbed allowed the formation of the artificial petrochemical paradise of Jurong Island, the ground beneath Jurong Island and its surrounding waters presented an even blanker slate—it did not fit into any preexisting landscape discourse. It offered the prospect of the creation of land entirely without nature. Here in particular, Rosalind Williams's (2008, 4) reading of the cultural space of the underground becomes acutely relevant:

> The underworld setting . . . takes to an extreme the displacement of the natural environment by a technological one. It hypothesizes human life in a manufactured world.
>
> Or, in this case, non-human life in a completely fabricated, technological, and infrastructural world.

The caverns were excavated more than a hundred meters below ground in the Jurong Formation, a sedimentary geology of sandstone, siltstone, mudstone, shale, tuff, and conglomerate rocks formed from the late Triassic Period to the early Jurassic (between one and two hundred million years ago) and extensively folded and faulted by tectonic forces. The Jurong Formation is composed of the western third of the island of Singapore and adjoining undersea areas.

The first feasibility studies for the construction of underground rock caverns in Singapore were undertaken in the early 1990s, with a view to developing such spaces to house a variety of programs "ranging from industrial to recreational, such as hydrocarbon storage, warehouse and logistics, data centre, energy production, incineration plant, factory and workshop, sewage and water treatment, water storage and storm water retention, sport complex, library and learning complex, R&D laboratory, transport station and depot" (Lui, Zhao, and Zhou 2013, 8).

Underground space research has become its own distinct branch of science, engineering, and urban planning in Singapore. Nanyang Technological University has a Centre for Underground Space. Singapore's Urban Redevelopment Authority is developing a masterplan for underground spaces (URA, n.d.). As part of this process, it is creating a three-dimensional map of underground spaces and infrastructure in Singapore.

This turn to the underground is unsurprising, given that land-use planning in Singapore is a brutal calculus. In the 2013 Land Use Plan, the Ministry of

National Development predicted that Singapore's land-use requirements in 2030 would be 76,600 hectares. At the time, Singapore had 71,400 hectares, a shortfall of 5,200 hectares (Singapore Ministry of National Development 2013). There are two strategies for making up the shortfall: continued reclamation, and intensifying the use of existing land. In these circumstances, underground cavern development is seen as freeing up more land for renewed development above the surface.

Singapore's geotechnical engineers have developed highly efficient methodologies for rapidly making feasibility assessments. The quality of subsurface rock masses in terms of their suitability for rock cavern development is rated according to a valuation that assesses a potential site for various jointing properties in the rock mass, water pressure, and leakage. These factors makes it possible to immediately estimate the cost of cavern extraction and structural support (Zhao et al. 1999).

The basic construction of the Jurong Rock Caverns involves five-meter-long rock bolts that act as support systems, with the excavated interior lined with eighty millimeters of sprayed concrete, also known as shotcrete (Winn, Ng, and Wong 2017, 1045). This system defines the statics of the structure, but just as significant is the parallel infrastructure of water-curtain pipes that runs adjacent to the storage caverns and constantly injects water vertically and horizontally into the surrounding rock. The hydraulic potential of water in the surrounding rock mass is all that keeps the product in the caverns (Winn, Ng, and Wong 2017, 1041).

The process of constructing storage tanks underground was 30 percent more expensive than equivalent aboveground construction, as the proponents of the project were quick to note, but the higher added value of facilities constructed on the freed-up land above was more than enough to compensate for this. The rhetorical exhortation for Singapore to keep climbing up the economic value chain, and to read this both symbolically and materially, seems irresistible to the representatives of the Singaporean state. In his speech marking their opening, Lee (2014) made explicit that the symbolic dimensions of the Jurong Rock Caverns were as relevant as the material ones: "More broadly, the JRC demonstrates that we must constantly think out of the box, be bold in tackling our challenges, be tenacious in execution in order to create new space for ourselves whether it is physical space, whether it is space which is metaphorical, thinking space, international space, and development space. It is not just that the sky is the limit, but there are also fewer limits than we think to the depths to which we can go because we are limited only by our own imagination!"

These possibilities are also framed as opening up further space, both literal and conceptual, for continued spatial and urban planning transformations of Singapore: "JTC is exploring building an underground science city, an underground

warehousing and logistics facility, potential underground caverns near the CleanTech Park. Not every project investigated will turn out to be feasible or commercially viable, but we will explore many. And our plans, some will come true, and they will demonstrate the exciting possibilities which we can realize" (Lee 2014).

Here, the Jurong Rock Caverns are invoked as a model for other spatial transformations that may unlock the next phase of Singapore's urban and economic development. This Singaporean underground imaginary has also been taken as inspiration for other regional speculations about the possibilities of underground space. In Hong Kong, in particular, multiple proposals are being studied for burying infrastructure and services in rock caverns underground, based on the Singaporean model (Wallace and Ng 2016).

The formations created by Jurong Island and the Jurong Rock Caverns do not just assemble oil, capital, and space into a single artificial landscape (or, perhaps, an antilandscape, in the case of the underground caverns): they also work biopolitically to reorganize bodies and labor, and quite consciously so. The speeches given to commemorate various phases in Jurong Island's development provide insights into the ways in which Singapore's developmental state constructs its subjects. The state uses a strategy of intensification—not just of land, sea, and the underground, but also of human subjects: "Today, on Jurong Island, nine out of ten workers are technically trained. Half of them have tertiary education. The value added per worker is very high. At over [SGD] 650,000 [about USD 400,000], it is more than eight times the national manufacturing average. These workers must constantly upgrade their capability to keep up with developments in the chemical industry" (Goh 2000).

The drive to create multiplier effects applies not just to the intensity of land use (releasing the surface of Jurong Island from use as storage for more value-added activities), but also to the use to which human capital can be applied. There is a direct parallel between the engineering of the ground and underground, and the desire to create more value-added workers. This is in keeping with Singapore's broader goals, as expressed by the government's Economic Strategies Committee, which include the wholesale drive to increase value added per worker across every sector of the economy (Singapore Ministry of Finance 2010). The workers of Jurong Island are double geological agents: Their capacity to move up the value chain is predicated on their capacity to exploit the underlying geology of the Jurong formation and free up more surface land for higher-value activities. At the same time, their capacity to add value to themselves, as economic actors, depends on their ability to manipulate another geological source material (the oil being shipped from distant geological strata), to which they then apply the most technically advanced and

lucrative transformations in hydrocarbon chemistry. Geologies both near and far are altered by the intricacies of the global petrochemical economy.

Conclusion: Down to a Lifeless Ocean and a Sunless Sea

The history of Singapore is the history of an island and then a city, as well as of a society sitting astride international maritime trade routes. For the past several centuries, these routes have been shaped by European colonial and then Western-dominated international projects that have been central to the development of modern Singapore. Along with the international flows of materials and power, cultural imaginaries of landscapes and peoples circulated and were appropriated, misappropriated, and incorporated into new cultural formations.

One such expression of the British colonial imaginary of landscapes of the East is found in Samuel Taylor Coleridge's Romantic Orientalist fantasy "Kubla Khan," a poetic reverie imagining the summer palace of the fabled emperor, famously written under the influence of opium.[9] Coleridge's fantasy, however, had roots in historical geopolitical events. Nahoko Miyamoto Alvey (2009) shows how the poem's landscape descriptions can be traced to the travelogues recording the 1793 British mission to Emperor Qianlong, led by Lord Macartney.[10] Macartney was charged with negotiating a loosening of the restrictive Canton System to permit freer trade by the British, as well as showcasing the marvels of English science and technology. He came away largely empty-handed, but his diplomatic efforts were soon replaced by Britain's opium-driven strategy to reverse its astronomical trade deficits with China—a strategy that ultimately paved the way for the colonization of Singapore, a strategic node in British imperial trade networks in Asia.

Coleridge's "Kubla Khan" is thus not just a drug-fueled Orientalist imagining of the grandeurs of Eastern "despotism." It is also a kind of map of the ways in which British imperialism would seek to capture the riches of the East, while simultaneously constructing its cultural relationship to its colonial subjects. Contemporary Singaporean cultural identity continues to involve a layering of precolonial, colonial, and postcolonial readings of human-landscape relations (Koh 1984), a fact made evident in the ways in which Singapore's officials continue to code the cultural and discursive dimensions of the territory's large-scale infrastructure projects.

Opium was also deeply implicated in the development of colonial Singapore's trade economy: calculations of Singapore's exports to China in the second half of the nineteenth century frequently list opium as the leading commodity traded (J. Lim 2012). It has become common to refer to modern capitalism's and the global

economy's addiction to oil. Like opium in the eighteenth and nineteenth centuries, oil shapes complex assemblies, including geopolitical formations, economic and financial circulations, territories of production, and everyday lives. In "Kubla Khan," Coleridge imagined the fabled ruler's efforts to construct an earthly paradise. But instead of the life- and immortality-giving river of Eden, the sacred River Alph flows into an underground world, with its "lifeless ocean" and its "sunless sea" (Coleridge 1987, 88–89). These images of the Romantic sublime have taken on a new resonance in the Anthropocene, with predictions of mass extinctions of maritime life or atmospheric haze over Southeast Asia from Indonesian forest fires.

Singapore's Jurong Rock Caverns are more than just an example of geotechnically engineered infrastructure. The histories of international trade and its related technical infrastructures; of the expansion and reconfiguration of cities and landscapes; of cultural readings of the productive, environmental, and aesthetic value (or absence of value) of territories both above and below the earth's surface; of the manipulations of human subjects and subjectivities—these are all chains of interlocking and unfathomable complexity that shape our contemporary carbon-based existence. Scholars are increasingly trying to trace small parts of such associations, which often seem strange or discontinuous to us at first. That something as mundane as Singapore's decision to build a large underground storage facility for liquid hydrocarbons might also begin to unlock narratives about diverse trajectories of people, ideas, and things should no longer come as a great surprise. On this more associative plane, the caverns are far from lifeless. Although they might literally contain the chemical remnants of marine life that died eons ago, they are also endlessly lively spaces that carry the compounds of economic processes, national discourse, landscape values, technical knowledge, artistic imaginaries, and much else besides.

Notes

1. Singapore ranks eleventh in the world in the United Nations Human Development Index (UNDP n.d.).

2. In a speech marking the opening of the Jurong Island Road Link, Lee Hsien Loong (2000, 2), then the deputy prime minister of Singapore, observed: "But the world does not stand still. Our approach to create the industry complex has borne fruit, and given us a precious lead. . . . Others will emulate what we have done, and learn from our mistakes. So we must continue to build on what we have done, and strive to climb higher still."

3. A 1989 book on the Singapore petroleum industry was titled *Houston of Asia* (Doshi 1989).

4. The shifting alliances between Srivijayan leaders and the Malay Orang Laut ("sea people") created circumstances that have alternately been described as duties or piracy, depending on whether the Orang Laut were operating within or outside the auspices of the Srivijayan Empire (Abshire 2011, 13–25).

5. See Chua, Low, and Gouw-Iwata 2003; Singapore Ministry of National Development 2013; Lui, Zhao, and Zhou 2013.

6. Oriental shells were fashionable in late Regency and early Victorian interior decoration. This curious history has had an outsized legacy in the language of the global oil industry, leading M. Samuel and Company, Limited to adopt the name Shell when it spun off its oil business in 1897 (Shell Global, n.d.). The *Murex*, named for a tropical sea snail, was the first oil tanker to sail through the Suez Canal in 1892. Samuel had had it built to the Suez Canal Company's precise specifications to ensure that it would be permitted to travel through the canal while maximizing its load (Elliott, Alan R. 2008. "Marcus Samuel's Oil Excursion." *Investor's Business Daily*. 23 April 2008). The first shipment of kerosene received by the Singapore depot in 1892 was delivered by the *Murex* (*Singapore Free Press and Mercantile Advertiser* 1892).

7. The depot was actually built by Syme and Company, a Singapore trading house that M. Samuel and Company, Limited appointed as its local agent (Moey 1991, 27–28).

8. See Tay et al. 2018.

9. Coleridge writes in his preface of taking "two grains . . . to check a dysentry [*sic*]," rather than admitting to the opium addiction with which he periodically struggled (quoted in Hayter 1968, 28).

10. Alvey's study is an extension of the new historicist analyses of the poem by Leask (1998) and Kitson (2007, 143–213).

References

Abshire, Jean E. 2011. *The History of Singapore*. Santa Barbara, CA: Greenwood Press.

Alvey, Nahoko Miyamoto. 2009. "'Kubla Khan' and Orientalism: The Roads to and from Xanadu." In *Grasmere 2010: Selected Papers from the Wordsworth Summer Conference*, edited by Richard Gravil, 77–100. Penrith, UK: Humanities-Ebooks.

Barr, Michael D. 2007. "Lee Kuan Yew and the 'Asian Values' Debate." *Asian Studies Review* 24 (3): 309–334.

Bobbette, Adam, and Amy Donovan, eds. 2019. *Political Geology: Active Stratigraphies and the Making of Life*. Cham, Switzerland: Palgrave Macmillan.

Campbell, William. 1971. "Where 100,000 Will Live and Play on Reclaimed East Coast." *Straits Times*, August 8. http://eresources.nlb.gov.sg/newspapers/Digitised/Article/straitstimes19710808.2.147.14.

Chua, Sek Chuan, Jeffrey K. Y. Low, and Lisa Gouw-Iwata. 2003. *Singapore Waters: Unveiling Our Seas*. Singapore: Nature Society of Singapore Marine Conservation Group.

Clark, Nigel, and Kathryn Yusoff. 2017. "Geosocial Formations and the Anthropocene." *Theory, Culture & Society* 34 (2–3): 3–23.

Clarke, David J. 2006. "Shipping, Technological Change." In *History of World Trade since 1450*, edited by John J. McCusker, 673–675. Farmington Hills, MI: Thomson Gale.

Coates, Donald R. 1984. "Urban Geomorphology." In *Applied Geology*, edited by Donald R. Coates, 601–605. New York: Springer.

Coleridge, Samuel Taylor. 1987. *Coleridge: Poems and Prose*. Harmondsworth, UK: Penguin.

Comaroff, Joshua. 2017. "On the Materialities of Air." *City* 21 (5): 607–613.

Dobbs, Stephen. 2003. *The Singapore River: A Social History, 1819–2002*. Singapore: NUS Press.

Doshi, Tilak. 1989. *Houston of Asia: The Singapore Petroleum Industry*. Singapore: Institute of Southeast Asian Studies.

Goh Chok Tong. 2000. "Speech by Prime Minister Goh Chok Tong at the Official Opening of Jurong Island on Saturday, 14 October 2000, at 7.00 PM." Singapore Government media release. http://www.nas.gov.sg/archivesonline/data/pdfdoc/2000101403/gct20001014f.pdf.

Graf, Arndt, and Chua Beng Huat, eds. 2008. *Port Cities in Asia and Europe*. Abingdon, UK: Routledge.

Gupta, Avijit. 1987. "Urban Geomorphology in the Humid Tropics: The Singapore Case." In *Proceedings of the First Conference of International Geomorphology*. Edited by Vince Gardiner, 303–317. Chichester, UK: John Wiley.

Hayter, Alethea. 1968. *Opium and the Romantic Imagination*. Berkeley: University of California Press.

Hein, Carola. 2018. "Oil Spaces: The Global Petroleumscape in the Rotterdam/The Hague Area." *Journal of Urban History* 44 (5): 887–929.

Hill Samuel. N.d. "History of Hill Samuel." Accessed October 26, 2018. https://web.archive.org/web/20060112195935/http://www.lloydstsb-offshore.com/Products+-+Services/Hill+Samuel/Why+Hill+Samuel/History+of+Hill+Samuel/.

ITA. N.d. "Singapore—Oil and Gas" in "Singapore Country Commercial Guide." International Trade Administration, US Department of Commerce. Accessed November 4, 2018. https://www.export.gov/apex/article2?id=Singapore-Oil-and-Gas.

Kitson, Peter. 2007. *Romantic Literature, Race, and Colonial Encounter*. London: Macmillan.

Koh Tai Ann. 1984. "Intertextual Selves: Fiction-Makers in Two 'Singapore' Novels." In *Tropic Crucible: Self and Theory in Language and Literature*, edited by Ranjit Chatterjee and Colin Nicholson, 163–192. Singapore: University Press, National University of Singapore.

Leask, Nigel. 1998. "The Road to Xanadu Revisited." *Romanticism* 4 (1): 1–21.Lee, Hsien Loong. 2000. "Speech by Deputy Prime Minister Lee Hsien Loong at the Official Opening of Jurong Island Road Link on Thursday, 10 February 2000 at 10.00 AM." Singapore Government press release, February 10. http://www.nas.gov.sg/archivesonline/data/pdfdoc/2000021002/lhl20000210a.pdf.

Lee, Hsien Loong. 2014. "Transcript of Prime Minister Lee Hsien Loong's Speech at the Official Opening of the Jurong Rock Caverns on 2 September 2014." Prime Minister's Office, Singapore, September 2. https://www.pmo.gov.sg/newsroom/transcript-prime-minister-lee-hsien-loongs-speech-official-opening-jurong-rock-caverns.

Lim, Hng Kiang. 2007. "The First Underground Rock Cavern Storage Facility for the Oil and Chemicals Industry in Southeast Asia. Speech by Mr Lim Hng Kiang, Minister for Trade and Industry, at the Groundbreaking Ceremony of the Jurong Rock Cavern, 8 February 2007." National Archives of Singapore, February 8. https://www.mti.gov.sg/Newsroom/Speeches/2007/02/Minister-Lim-Hng-Kiang-at-the-Ground-breaking-Ceremony-of-the-Jurong-Rock-Cavern.

Lim, Jason. 2012. "Chinese Merchants in Singapore and the China Trade, 1819–1959." *Chinese Southern Diaspora Studies* 5: 79–115.

Lui, Pao Chuen, Zhao Jian, and Zhou Yingxin. 2013. "Creation of Space in Rock Caverns in Singapore—Past, Present and Future." In *Advances in Underground Space Development*, edited by Zhou Wingxin, Cai Jungang, and Raymond Sterling, 3–10. Singapore: Research Publishing.

Moey, Nicky. 1991. *The Shell Endeavour: First 100 Years in Singapore*. Singapore: Times Editions.

MPAS. N.d. "Bunkering." Maritime and Port Authority of Singapore. Accessed November 3, 2018. https://www.mpa.gov.sg/web/portal/home/port-of-singapore/services/bunkering.

Murfett, Malcolm H., John Miksic, and Brian Farell. 2011. *Between Two Oceans: A Military History of Singapore from 1275 to 1971*. Singapore: Marshall Cavendish International.

Shell Global. N.d. "Company History." Accessed November 2, 2018. https://www.shell.com/about-us/our-history/our-beginnings.html.

Singapore Free Press and Mercantile Advertiser. 1892. "The Arrival of the 'Murex.'" September 16. http://eresources.nlb.gov.sg/newspapers/Digitised/Article/singfreepressb18920916-1.2.9.

Singapore Ministry of Finance. 2010. *Report of the Economic Strategies Committee*. February 1. https://www.mti.gov.sg/-/media/MTI/Resources/Publications/Report-of-the-Economic-Strategies-Committee/Full-ESC-Report---Ministry-of-Finance.pdf.

Singapore Ministry of National Development. 2013. *A High Quality Living Environment for All Singaporeans: Land Use Plan to Support Singapore's Future Population*. https://www.mti.gov.sg/-/media/MTI/Resources/Publications/Report-of-the-Economic-Strategies-Committee/Full-ESC-Report---Ministry-of-Finance.pdf.

Parliament of Singapore. 1968. "Reclamation (Pulau Ayer Chawan)." Parliamentary Debates, Singapore, Official Report, First Session of the Second Parliament, Part II of First Session, Volume 28. Motions, E.W. Barker, Minister for Law and National Development. 3 December 1968. https://sprs.parl.gov.sg/search/report?sittingdate=03-12-1968.

Parliament of Singapore. 1971a. "Reclamation (Pulau Ayer Merlimau)." Parliamentary Debates, Singapore, Official Report, Second Parliament, Second Session, Volume 31. Motions, E.W. Barker, Minister for Law and National Development. October 19. https://sprs.parl.gov.sg/search/report?sittingdate=19-10-1971.

Parliament of Singapore. 1971b. "Reclamation (Pulau Pesek)." Parliamentary Debates, Singapore, Official Report, Second Parliament, Second Session, Volume 31. Motions, E.W. Barker, Minister for Law and National Development. December 2, 1971. https://sprs.parl.gov.sg/search/report?sittingdate=02-12-1971.

Straits Times. 2014. "Five Things to Know about the Jurong Rock Caverns." September 2. https://www.straitstimes.com/singapore/five-things-to-know-about-the-jurong-rock-caverns.

Tan Wooi Leong. 2017. "Jurong Island: What It Takes to Achieve a World-Class Petrochemicals Hub." Surbana Jurong, April 25. https://surbanajurong.com/resources/perspectives/jurong-island-takes-achieve-world-class-petrochemicals-hub/.

Tay, Jessica Y. L., Shermaine K. M. Wong, L. M. Chou, and Peter A. Todd. 2018. "Land Reclamation and the Consequent Loss of Marine Habitats around the Ayer Islands, Singapore." *Nature in Singapore* 11: 1–5.

UNDP. N.d. "Singapore: Human Development Indicators." United Nations Development Programme. Accessed May 14, 2020. http://hdr.undp.org/en/countries/profiles/SGP.

URA. N.d. "Underground Space." Urban Redevelopment Authority. Accessed May 14, 2020. https://www.ura.gov.sg/Corporate/Get-Involved/Plan-Our-Future-SG/Innovative-Urban-Solutions/Underground-space.

Usher, Mark. 2018. "Conduct of Conduits: Engineering, Desire and Government through the Enclosure and Exposure of Urban Water." *International Journal of Urban and Regional Research* 42 (2): 315–333.

Wallace, M. I., and K. C. Ng. 2016. "Development and Application of Underground Space Use in Hong Kong." *Tunnelling and Underground Space Technology* 55 (2016): 257–279.

Wilkinson, Barry. 1988. "Social Engineering in Singapore." *Journal of Contemporary Asia* 18 (2): 165–188.

Williams, Rosalind. 2008. *Notes on the Underground: An Essay on Technology, Society, and the Imagination*. Cambridge, MA: MIT Press.

Winn, Kar, Melvin Ng, and Louis Ngai Yuen Wong. 2017. "Stability Analysis of Underground Storage Cavern Excavation in Singapore." *Procedia Engineering* 191: 1040–1047.

Yusoff, Kathryn. 2013. "Geologic Life: Prehistory, Climate, Futures in the Anthropocene." *Environment and Planning D: Society and Space* 31 (5): 779–795.

Zhao, J., Q. Liu, K. W. Lee, V. Choa, and C. I. The. 1999. "Underground Cavern Development in the Jurong Sedimentary Rock Formation." *Tunnelling and Underground Space Technology* 14 (4): 449–459.