4

Subterranean Frontier

Tin Mining, Empire, and Environment in Southeast Asia

Chapters 1–3 have focused on the role of plant commodities in reshaping the ecosystems of the tropical world.[1] Although environmental constraints clearly influenced where certain crops were grown, for the most part their story has been one of remarkable mobility. Throughout the colonial era, a host of different cultivars were transplanted via an imperial botanical diaspora as part of a concerted attempt to modify and profit from tropical ecosystems around the globe.

The relationship between mining and imperialism was somewhat different. Unlike plant-based industries, which could be deliberately built up in areas where it was politically or economically advantageous to do so, mineral wealth was more a matter of geological chance. Granted, the accessibility of coveted ore deposits was often crucially facilitated by the application of financial might and technical capability, and was not infrequently predicated on the exertion of military power. But the deposits themselves were nonetheless embedded in certain places. The fact that they had to be extracted *in situ* meant that mining tended to shape the geography of modern empire rather than the other way around. The quest for mineral resources was one of the factors that helped transform the focus of European imperialism from the control of trade to the control of territory.

The spread of industrialization in the nineteenth century created an unprecedented demand for metals on world markets. While miners burrowed holes across the topography of industrial Europe, a growing number of prospectors fanned out around the globe in search of new deposits. In many parts of the world these entrepreneurs acted as pioneers of imperial expansion, from the goldfields of Witwatersrand to the nickel pits of New Caledonia. Although few of the earliest speculators enjoyed official backing, the strategic importance of mineral ores made home governments acutely alert to questions of supply, and generally supportive of efforts to exploit the deposits that their nationals discovered. For the European powers, the ever-increasing demand for more metal—and for more types of metal—far outstripped their own resources. The lure of mineral wealth thus furnished a powerful incentive for conquest and colonization overseas.

[1] Sections of this chapter are largely based on material first published in Corey Ross, 'The Tin Frontier: Mining, Empire and Environment in Southeast Asia, 1870s–1930s', *Environmental History*, vol. 19 (2014), 454–79.

The mining industry, though long a favourite stomping ground of labour and economic historians, has generally been something of a stepchild of modern environmental history. In the early 2000s studies that focused on its broader ecological ramifications were still conspicuously rare.[2] Fortunately, this state of relative neglect has improved over the last decade with a handful of fine studies on the environmental history of mineral extraction, chiefly focused on the North American West.[3] But for much of the rest of the world, the role of mining in transforming regional environments remains underexposed, despite the fact that it has perennially been one of the dirtiest of all industries as well as a cornerstone of empire and global trade.[4]

There is no better example than tin, which played a central role in Europe's industrial empire in Southeast Asia. Although environmental histories of Southeast Asia have long focused on the region's vast forests, extensive plantation complexes, and dynamic rice frontiers,[5] tin mining was one of its largest industries during the colonial era. Moreover, Southeast Asia's tin fields dominated world production from the late nineteenth century through most of the twentieth.[6] Like many other metals—gold, iron, copper—tin was in high demand from the mid-1800s onwards. Few minerals, however, were so vital for the industrial economy yet so reliant on supplies from tropical territories, in particular the western foothills of the Malay Peninsula and the nearby 'tin isles' of the Dutch East Indies. The search for tin not only fuelled the extension of European power in the region, it also drove a

[2] See the comments in John R. McNeill, 'Observations on the Nature and Culture of Environmental History', *History and Theory*, Theme Issue 42 (Dec. 2003), 5–43, esp. 41. An exception he noted was Duane A. Smith, *Mining America: The Industry and the Environment, 1800–1980* (Lawrence: University of Kansas Press, 1987); another exception was Kerstin Kretschmer, *Braunkohle und Umwelt. Zur Geschichte des nordwestsächsischen Kohlenreviers (1900–1945)* (Frankfurt a. M.: Peter Lang, 1998).

[3] Kathryn Morse, *The Nature of Gold: An Environmental History of the Klondike Gold Rush* (Seattle: University of Washington Press, 2003); Andrew C. Isenberg, *Mining California: An Ecological History* (New York: Hill and Wang, 2005), 23–51; Timothy J. LeCain, *Mass Destruction: The Men and Giant Mines that Wired America and Scarred the Planet* (New Brunswick, NJ: Rutgers University Press, 2009).

[4] For Europe, see the recent collection by Peter Anreiter (ed.), *Mining in European History and its Impact on Environment and Human Societies* (Innsbruck: Innsbruck University Press, 2010). Beyond Europe and North America: Matthew Evenden, 'Aluminum, Commodity Chains, and the Environmental History of the Second World War', *Environmental History*, vol. 16 (January 2011), 69–93; Carl N. McDaniel and John M. Gowdy, *Paradise for Sale: A Parable of Nature* (Berkeley: University of California Press, 2000); B. Daley and P. Griggs, 'Mining the Reefs and Cays: Coral, Guano and Rock Phosphate Extraction in the Great Barrier Reef, Australia, 1844–1940', *Environment and History*, vol. 12 (2006), 395–434; Elizabeth Dore, 'Environment and Society: Long-Term Trends in Latin American Mining', *Environment and History*, vol. 6 (2000), 1–29.

[5] This literature is vast. For a useful overview and bibliography, see Peter Boomgaard, *Southeast Asia: An Environmental History* (Oxford: ABC-Clio, 2007).

[6] There is a sizeable literature on the economic, social, and political dimensions of the industry: see esp. Wong Lin Ken, *The Malayan Tin Industry to 1914: With Special Reference to the States of Perak, Selangor, Negri Sembilan and Pahang* (Tucson: University of Arizona Press, 1965); Yip Yat Hoong, *The Development of the Tin Mining Industry of Malaya* (Kuala Lumpur: University of Malaya Press, 1969); Francis Loh Kok Wah, *Beyond the Tin Mines: Coolies, Squatters and New Villagers in the Kinta Valley, Malaysia, c.1880–1980* (Singapore: Oxford University Press, 1988); Mary F. Somers Heidhues, *Bangka Tin and Muntok Pepper: Chinese Settlement on an Indonesian Island* (Singapore: Institute of Southeast Asian Studies, 1992); Amarjit Kaur and Frits Diehl, 'Tin Miners and Tin Mining in Indonesia, 1850–1950', *Asian Studies Review*, vol. 20 no. 2 (Nov. 1996), 95–120.

far-reaching set of social and environmental changes that profoundly transformed the physical, ethnic, and cultural landscape. Although the impact was most acute at the immediate sites of extraction, the mines also radiated complex ripple effects throughout their hinterlands. Indeed, many of the connections reached far beyond Southeast Asia itself. Like the rubber, sugar, and coffee that poured out of the region's plantations, tin was part of a global commodity network that was inextricably woven into the web of industrialization and mass consumption in Europe and North America.

For all these reasons, the tin boom in colonial Southeast Asia provides a useful lens for examining the dynamic interactions between imperial power and colonized environments. It highlights the intense ecological consequences of focusing global demand for a resource onto a limited area of supply. It demonstrates the importance of re-engineering environments to suit the needs of industry and investment. Above all, it displays many of the classic characteristics of a 'commodity frontier', an advancing boundary of trade, political control, investment, and (sometimes) settlement that together reshaped environments and the ways in which people perceived and used them.[7] Like commodity frontiers in general, the tin frontier had its pioneers and latecomers, its phases of expansion and consolidation, and it tended to reward predation over prudence. Like mining frontiers more specifically, its multi-dimensional expansion—both outward across the surface landscape and downward into lower depths and grades of ore—gave it an unusually fluid character, closing and reopening in any given area as technological advances made previously unworkable deposits both physically and economically exploitable.

Yet despite these common traits, the development of Southeast Asia's tin mines also demonstrates how social, cultural, and political peculiarities shape the ecologies of resource extraction in specific times and places. If the basic economic pressures were common throughout the global mining industry, the subterranean tin frontier was also animated by contemporary ideas about race, waste, and efficiency that fundamentally structured the colonial enterprise. As this chapter will show, the story of colonial tin mining is, at base, a story about the interactions between technology, culture, and environmental change.

BREAKING NEW GROUND: THE OPENING OF THE SOUTHEAST ASIAN TIN FRONTIER

Tin is one of the oldest metals known to humankind. Used since ancient times mainly in alloy form (bronze, pewter), by the late nineteenth century it had become a crucial component of industrial civilization. Among its numerous applications,

[7] On commodity frontiers generally: Alf Hornborg, J. R. McNeill, and Joan Martinez-Alier (eds), *Rethinking Environmental History: World-System History and Global Environmental Change* (Lanham, Md: AltaMira, 2007); Jason W. Moore, 'Sugar and the Expansion of the Early Modern World-Economy: Commodity Frontiers, Ecological Transformation, and Industrialization', *Review*, vol. 23 (2000), 409–33.

tin played an essential role in several key sectors of industry, from textiles (mordants, dyes) to electrical and mechanical engineering (solder, bearing metal) to military armaments (gun metal). Most tin, however, was used for tinplating, or coating sheets of steel or iron with molten tin to prevent corrosion. And among the many uses of tinplate, the most significant by far was the humble tin can. Although tin cans were first widely used by the British and French armies during the Napoleonic wars, it was mainly from around the 1860s that they became an object of everyday life. By allowing producers to conserve rural food surpluses and transport them to the industrial cities—whose burgeoning populations could only be sustained by drawing vital supplies from ever-greater distances—the tin can played a mundane but critical role in processes of urbanization and industrialization in the metropoles of the global economy. As its use expanded, demand for tin skyrocketed. World production rose from 36,000 tons in 1874 to 124,000 tons in 1914. But since European reserves (mostly in Cornwall) had been largely exhausted by this time, the bulk of supplies came from overseas, primarily from Southeast Asia, with smaller amounts imported from Bolivia and Nigeria.[8]

Nearly all tin comes from its oxide ore, cassiterite (SnO_2), which occurs in two different types of deposits: underground lodes or veins (as in Cornwall and Bolivia), and shallower alluvial deposits (the dominant type in Southeast Asia). The main Southeast Asian deposits were formed by the weathering of the tin-bearing granite ranges that run along the western side of the Malay Peninsula towards the Riouw islands, which skirt the south-east coast of Sumatra. Large parts of this region are stanniferous to varying degrees, though alluvial cassiterite, like placer gold, tends to settle quickly due to its high specific gravity and is therefore concentrated in certain spots. The biggest concentrations formed the major tin fields of the region, most notably at Larut, the Kinta valley, and Kuala Lumpur in Malaya, and the islands of Bangka, Belitung, and Singkep in the East Indies (Fig. 4.1).[9]

Tin mining was not new to these areas in the colonial period; small amounts had been extracted for many centuries. As early as 1513 Portuguese traders brought tin from the Malay Peninsula back to Europe. By the mid-seventeenth century the trade was dominated by Dutch merchants, whose hold on markets was further strengthened by the discovery of tin deposits on Bangka in 1711. Nonetheless, only small amounts of 'Banka tin' ever made it to Europe during the eighteenth century due to the proximity of Cornish supplies.[10] All of this changed in the second half of the nineteenth century. As demand soared and inter-continental transport costs sank, European mines could no longer keep up. Quality was also an important factor, since tinplating firms strongly preferred alluvial 'East tin' over Cornish lode tin for its superior colour and higher purity, which allowed them to

[8] Ken, *Malayan Tin Industry*, 246–7; on Nigeria: Bill Freund, *Capital and Labour in the Nigerian Tin Mines* (Harlow: Longman, 1981).

[9] H. Stauffer, 'The Geology of the Netherlands Indies', in Honig and Verdoorn (eds), *Science*, 320–35; Alex L. Ter Braake, *Mining in the Netherlands East Indies* (Bulletins of the Netherlands and Netherlands Indies Council, 1944).

[10] Ken, *Malayan Tin Industry*, 3.

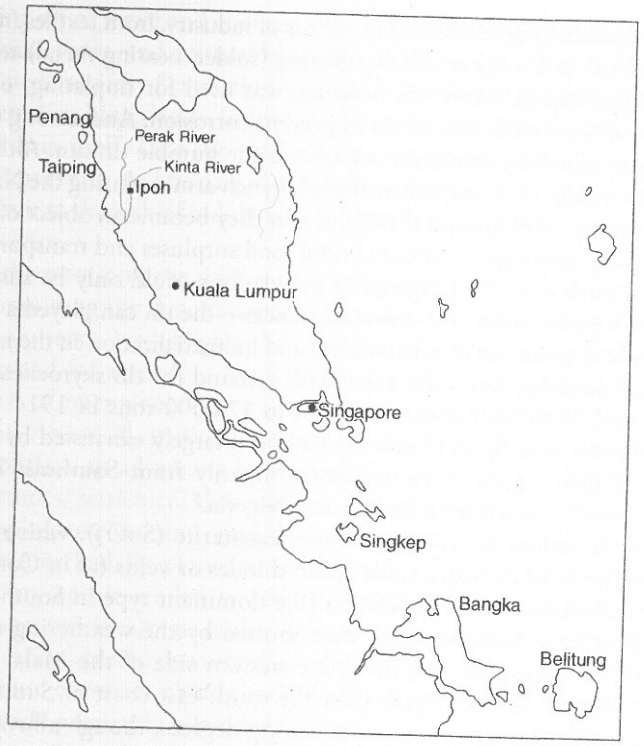

Fig. 4.1. Map covering the main tin-producing areas of colonial Southeast Asia.

achieve a thinner coating.[11] The growing scarcity of European tin deposits, along with their military significance and the lack of easy material substitutes, made Southeast Asian tin an important strategic resource. Guaranteeing a steady supply was what prompted the Dutch to rule Bangka directly from Batavia, just as the risk of disruption to the tin trade in Perak triggered the creation of the British Residency of the Federated Malay States in 1874.

Together, Bangka and Malaya marked the world's primary 'tin frontier' during the late nineteenth and early twentieth centuries. I use the term guardedly, and in full awareness of its Turnerian associations with successive waves of American pioneers creating a new civilization in the Western wilderness.[12] But leaving aside Turner's social-evolutionary logic, let alone his arguments about how it shaped the American character, the frontier concept is useful here for suggesting an interlocking set of economic, social, and cultural conditions that are either absent or less pronounced in other circumstances. As Walter Prescott Webb later formulated it, a defining characteristic of a frontier is the availability of resource 'windfalls' seemingly

[11] Ken, *Malayan Tin Industry*, 10.

[12] Clyde A. Milner II (ed.), *A New Significance: Re-Envisioning the History of the American West* (Oxford: Oxford University Press, 1996); William Cronon, George Miles, and Jay Gitlin (eds), *Under an Open Sky: Rethinking America's Western Past* (New York: Norton, 1992).

there for the taking.[13] These windfalls—land, wood, soil fertility, minerals—generally attract a transient population of pioneers and speculators with an instrumental attitude towards the land and with both the means and motivation to move on, thus allowing them to repeat the process of outward frontier expansion once the assets of any particular locality are exhausted. In turn, this ability to escape the consequences of one's actions, often underpinned by a weak state presence and an ideology of unending resources, imposes few social restraints against destructive behaviour, and even fewer obligations to cover the costs of depreciation—a tendency that is magnified wherever the frontier is sparsely populated or regarded as idle 'wilderness'. If one way of seeing a frontier is as a transitory boundary of settlement, trade, or technology, another is as a set of conditions that encourages short-term, extractive behaviour over other forms of land use.

Much of colonial Southeast Asia was a 'frontier' in both senses.[14] Outside the main centres of population such as Java or Bali, land was abundant and the state's power precarious. Well after the turn of the century, the bustling towns and mining camps of Malaya were still viewed as 'mere patches' in the vast expanse of forest 'that sweeps from one Sultanate to another, and is only limited by the sea'.[15] In such a seemingly endless wilderness it was relatively easy for commodity producers to move on once resources were depleted in any given area.

The early growth of the tin industry clearly exhibited these characteristics. On the Malayan Peninsula and Bangka, Malay pioneers had long mined tin via several methods. The simplest technique was panning in streams with a *dulang*, or large wooden dish. More common was the creation of a *lampan*, or ground-sluice, which essentially involved clearing the area above the would-be mine, digging a channel from a nearby stream to divert the water through a deposit, and then processing the pay dirt (*karang*) in the channel. As the light sediment washed into a tailrace, the heavy tin sand was retained by a series of small dams where it was periodically scooped out and concentrated in a sluice box (*palong*). Both methods were remarkably lucrative on unworked tin fields where the cassiterite particles were heavy enough not to be washed away. Neither, however, could tap the deeper ores just above the bedrock. To reach these deposits miners dug open pits (*lombongs*) several metres deep, usually upward into a hillside so they could wash the pay dirt in a channel below. All of these techniques were land-extensive in character; that is, miners worked the shallowest deposits and quickly moved on. They were, however, subject to fairly tight geographical constraints. Panning and ground-sluicing were only possible on slopes in close proximity to streams. Open *lombongs* could only reach deposits at a maximum depth of around 6 metres due to drainage problems, and were also dependent on streams for concentrating the pay dirt. The early Malay tin frontier was therefore largely

[13] Walter Prescott Webb, *The Great Frontier* (London: Secker & Warburg, 1953), esp. 180–202.

[14] Karl J. Pelzer, *Pioneer Settlement in the Asiatic Tropics: Studies in Land Utilization and Agricultural Colonization in Southeastern Asia* (New York: American Geographical Society, 1948); Freek Colombijn, 'The Ecological Sustainability of Frontier Societies in Eastern Sumatra', in Boomgaard, Colombijn, and Henley (eds), *Paper Landscapes*, 309–39.

[15] Sir George Maxwell, *In Malay Forests* (Edinburgh: Blackwood, 1907), 2.

limited to shallow deposits on the sides of foothills that benefited from both good drainage and good water availability.[16]

The arrival of Chinese *kongsis* (commercial syndicates fuelled by 'coolie' labour) marked a significant expansion of this frontier, both outward but more importantly downward. Appearing first on Bangka (from the late 1810s) and then in Malaya (from the late 1840s), their key innovation was to use the Chinese *chin-chia*, a traditional wooden bucket-chain mechanism driven by a water wheel, which could remove up to 3,000 gallons (13,650 litres) of water per hour and allowed miners to reach deposits 10 (and sometimes up to 25) metres deep. Apart from the lower depths it could reach, the Chinese technique was broadly similar to Malay open casting. After clearing all surface vegetation, retaining any hardwood for charcoal, and excavating the pit down to the water table, miners would divert a nearby stream to drive the water wheel and would pile the waste overburden around the mine-head to keep rainfall from running into the pit. As they burrowed into the hillside they raised the pay dirt manually, concentrated it in sluice boxes, and generally smelted the dried ore with charcoal fuel on site or at a nearby smelting house. Most of what went through the sluices ended up as waste tailings, which were simply washed downhill and deposited on the worked-out area below.[17]

In many respects the influx of Chinese miners represented a second wave of pioneers who tapped a deeper 'windfall' and moved on once it was depleted. On Bangka, their efforts made tin the third largest East Indies export by the middle of the nineteenth century. By 1900 there were around 14,000 miners on the island, the vast majority of them Chinese or *peranakan* (local-born Chinese speakers).[18] In Malaya, the number of Chinese miners in the Larut district rose from 3,000 to 40,000 between 1848 and 1872; in the Kinta valley it increased from 1,000 to 45,000 in less than a decade (1880–1889) before soaring to around 133,000 (out of a total population of *c.*185,000) by 1911, making Kinta not only the most populous and densely inhabited district in the Malay States but also the world's single largest tin field.[19]

But the Chinese tin frontier was also shaped by several key constraints. One was depth, for despite the effectiveness of Chinese open-cast methods, they grew increasingly unprofitable below 3 metres and became unsound at around 9 or 10 metres.[20] Water was another limiting factor, since the water-wheel-driven *chin-chias* depended on fairly benign rainfall conditions. The water wheels were only deployable near streams, were no use during droughts, and were not powerful enough to keep the mines dry in heavy rains. On Bangka in particular, the irregularity of

[16] Ken, *Malayan Tin Industry*, 43–7; Heidhues, *Bangka Tin*, 11–15.

[17] Heidhues, *Bangka Tin*, 37–48, 175–8; Hoong, *Development*, 19, 69–71; Ken, *Malayan Tin Industry*, 48–9.

[18] By 1920 the Bankatinwinning had over 21,000 employees, mostly Chinese; on Belitung, nearly the entire mining population was Chinese in 1920: Heidhues, *Bangka Tin*, 175–8.

[19] Wah, *Beyond the Tin Mines*, 9; Hoong, *Development*, 58–9; Salma Nasution Khoo and Abdur Razzaq-Lubis, *Kinta Valley: Pioneering Malaysia's Modern Development* (Perak Darul Ridzuan: Perak Academy, 2005).

[20] H. Zondervan, *Bangka en zijne bewoners* (Amsterdam: J. H. de Bussy, 1895), 111; see also Hendrik Merkus Lange, *Het eiland Banka en zijne aangelegenheden* (Gebr. Muller, 1850), 95f.

water supplies was considered the 'main hindrance of an increased tin production' in the late nineteenth century.[21] As one contemporary remarked, 'Bangka is rich in rivers but poor in water'; its many small, fast streams quickly emptied in the dry season.[22] The construction of reservoirs was a crucial prerequisite for working many sites on the island, but even the most extensive dam works could not guarantee adequate supplies.[23] As a result, rainfall was the main factor for determining the seasonal calendar of work. Whereas excavating was prioritized during the driest months from May to October, the rainy season from November to February was mainly reserved for washing. Water supplies also had a significant influence on overall output. Years of low production corresponded not only with low tin prices but also with years of low rainfall.[24] Although this problem was less extreme on the larger watersheds of the Malayan Peninsula, prolonged dry spells also caused mine stoppages there.[25] In short, Chinese open-cast techniques overcame only some of the constraints that had bounded the earlier mining frontier.

All of the methods on the tin frontier were highly destructive. They worked the most easily accessible surface deposits and quickly abandoned them, leaving denuded, pockmarked, and severely eroded hillsides in their wake. As the industry expanded in the late nineteenth century, some contemporaries became increasingly sensitive to the aesthetic and material costs that it entailed. 'Being full of large holes, and covered with an excavated soil of gravel and sand... such land is a great eyesore, and gives a bad impression of the country to the casual traveller,' noted a visitor to Malaya in 1904.[26] *Lampanning* was, after all, essentially a means of focusing the erosive potential of watercourses onto sloping ground that was already prone to soil wash. Moreover, the fact that it was capable of reaching only shallow ores exacerbated the damage by dotting the landscape with hundreds of derelict sites. Although the deeper open-cast mines produced more tin in relation to the surface area they destroyed, they nonetheless created gaping man-made canyons and thousands of tons of tailings with little if any regard for the after-effects of their activities (Fig. 4.2).

As production continued to rise, the forests near the mines were also severely affected. The valuable *Dipterocarp* species in the region were ideal for making charcoal, and consequently paid a heavy tribute to the smelting furnaces. 'There are certainly few mining operations that run in such cavalier fashion as the tin mines on Bangka,' remarked an East Indies medical officer in the 1870s. Neither the permanent dereliction of large areas, nor the 'ruthless devastation of the forest', nor any attempt to replant the affected woodlands was given serious

[21] Theodor Posewitz, *Die Zinninseln im Indischen Ozean II. Das Zinnerzvorkommen und die Zinngewinnung in Bangka* (Budapest: Franklin-Verein, 1886), 92.

[22] Zondervan, *Bangka*, 50–62, quote p. 50.

[23] Otto Mohnike, *Banka und Palembang nebst Mittheilungen über Sumatra im Allgemeinen* (Münster: Aschendorfss'chen Buchhandlung, 1874), 37–8; Posewitz, *Zinninseln*, 86–90.

[24] Posewitz, *Zinninseln*, 90–2.

[25] Mohnike, *Banka*, 37–8; Posewitz, *Zinninseln*, 86–92; Ooi Jin-Bee, 'Mining Landscapes of Kinta', *Malayan Journal of Tropical Geography*, vol. 4 (Jan. 1955), 1–58, here 19.

[26] John C. Willis, *A Report upon Agriculture in the Federated Malay States* (Kuala Lumpur: FMS Government Printing Press, 1904), 15.

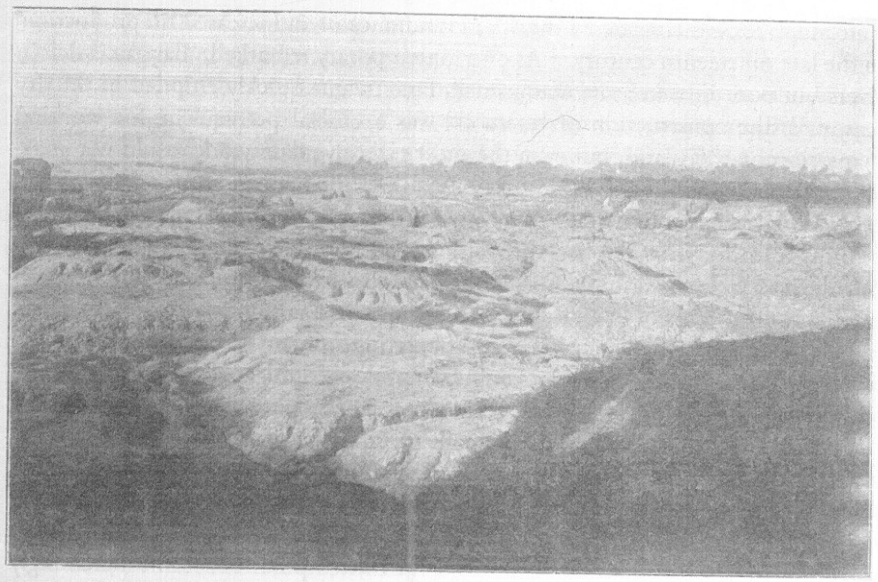

Fig. 4.2. Yong Phin open-cast mine near Taiping, Malaya, *c.*1908.

Source: Arnold Wright, H. A. Cartwright (eds), *Twentieth-Century Impressions of British Malaya: Its History, People, Commerce, Industries, and Resources* (London: Lloyds, 1908), p. 506.

consideration.[27] As a result, by the 1890s there were already reports of wood shortages and an almost complete absence of large trees in the main mining districts. Visitors to the island noted that 'little or nothing remains of the original forest' beyond 'small islands' dispersed amidst the young secondary growth.[28] Overall, Bangka lost an estimated two-thirds of its forest between the mid-nineteenth century and the 1920s, much of it to mining operations.[29]

Similar concerns soon emerged in Malaya, first around the Larut tin mines, which had severely depleted the forests within a 20- to 30-kilometre radius by the end of the 1870s. Attempts to slow the damage—for instance, by banning inefficient smelting ovens or establishing forest reserves—were of limited effect.[30] As the frontier moved to the Kinta valley in the 1880s–1890s, the same pattern of radial deforestation repeated itself. At the turn of the century it was estimated that the Malayan mines used over half a million tons of fuel and lumber per year. Around

[27] Mohnike, *Banka*, 28–9, 45.

[28] See the overview of observations in Zondervan, *Bangka*, 69–71.

[29] Karl Helbig, 'Die Insel Bangka. Beispiel des Landschafts- und Bedeutungswandels auf Grund einer geographischen "Zufallsform"', *Deutsche Geographische Blätter*, vol. 43 nos 3/4 (1940), 137–209, here 160; Heidhues, *Bangka Tin*, 98, 108; A. M. Burn-Murdoch, 'Forests of Malaya', in Wright and Cartwright (eds), *Twentieth-Century Impressions*, 329–30. Although swidden cultivation by the indigenous Orang Gunung or Orang Darat groups had long influenced vegetation on the island, it was clear that mining accounted for most of the change: Helbig, 'Bangka', 195.

[30] Zondervan, *Bangka*, 112–13; Heidhues, *Bangka Tin*, 68; Kathirithamby-Wells, *Nature*, 62–3; Ken, *Malayan Tin Industry*, 160.

5 per cent of the 213,000 Chinese 'miners' in the Federated Malay States were, in fact, engaged solely in cutting timber.[31] Ultimately, the most important reprieve for the woodlands came not through early conservation measures but rather from the construction of coal-fired smelters on Pulau Brani island near Singapore in 1890, followed by smaller works at Butterworth and Penang.[32]

Waterways were also acutely affected as mine tailings clogged streams and eventually worked their way into the major riverine arteries. By 1885 the Larut River was so badly silted that ore could no longer be brought downriver to the coast. To bypass this problem, a new rail link was built from Port Weld (Kuala Sepetang) to Taiping, but it was not long before Port Weld also began to silt up as the tailings load carried by local rivers worked its way downstream.[33] During the Kinta valley boom of the 1890s, uncontrolled tailings emissions threatened not only the riverine environment but also the growth of the industry itself, which continued to depend on the ever-shallowing waterway for transport. The Kinta Valley Railway, completed in 1896 between Ipoh and Telok Anson on the Perak River, was explicitly built to obviate the need for navigating what was increasingly written off as a doomed river. As the 1896 Perak Annual Report unsentimentally put it, 'the competition of the Kinta River is still being felt, but should decrease as the higher part of the river becomes silted up by the operations of the miners. By special arrangement, the railway has secured the entire carriage of tin and tin-ore.'[34]

But despite all the environmental damage caused by the mines, the chief concerns for the colonial authorities were economic. Tin was a crucial source of government revenue for the Federated Malay States, Batavia, and the Palembang sultanate, and the basic problem they faced was in some ways similar to that of the wild rubber industry: namely, the growing disparity between the industrial scale of demand and primitive methods of extraction. Bangka, noted one contemporary, 'is for Holland like a hen that still lays golden eggs but which sacrifices a bit of itself with every egg, so that one can foresee a time when there is nothing left but a dead skeleton. It is therefore an imperative duty to ensure that this moment is delayed as long as possible through the most systematic, thrifty, and gentle method of exploiting the still available ores.'[35] Once it became clear that the major tin fields of the region had all been discovered (if not yet worked), the spectre of decline could only be banished by expanding the tin frontier in several directions: into deeper strata, into poorly watered areas, and above all into lower grades of ore that could not return a profit via current methods. In short, the exploration frontier had to be replaced by a frontier of technological innovation. And technology, as the 'measure of men', was to the colonial mind very much an attribute of race and culture.[36]

[31] Burn-Murdoch, 'Forests of Malaya', 329–30; Kathirithamby-Wells, *Nature*, 61–2.

[32] K. G. Tregonning, *Straits Tin: A Brief Account of the First Seventy-Five Years of The Straits Trading Company, Limited. 1887–1962* (Singapore: Straits Times Press, 1962), 17–25.

[33] Tregonning, *Straits Tin*, 19–20.

[34] W. H. Treacher, Resident of Perak, *Perak Annual Report* (1896), 28, quoted in Jin-Bee, 'Mining Landscapes', 22–3.

[35] Mohnike, *Banka*, 48.

[36] Adas, *Machines*.

THE INDUSTRIAL FRONTIER: MODERNIZATION, DEGRADATION, AND REMEDIATION

Calls for 'modernizing' Bangka's tin industry could already be heard in the 1850s, roughly concurrent with the start of mining operations on nearby Belitung. By the 1870s they began to mushroom amidst concerns about future production.[37] European officials were outspokenly critical of the fact that Chinese miners 'could start mines anywhere that seemed suitable to them and then quickly abandon them entirely at their own discretion'. As production rose, such practices were not only deemed 'highly disadvantageous for the ground conditions of the island' but also damaging for the industry over the long term.[38] In 1883 the first steam pumps were brought to Bangka in order to bring deeper deposits into reach, but they only became more widespread after the turn of the century.[39] In Malaya the shift towards mechanized production occurred somewhat later, above all in the wake of a new Mining Code in 1895, which was deliberately designed to encourage European investment by granting secure tenure and distributing mineral concessions in large tracts suitable only for sizeable enterprises. The aim was to make profits where older methods could not. Contemporaries estimated that *lampanning* was viable on only 2–3 per cent of a given plot. Even Chinese open-cast techniques recovered only half the available ore. Through technological innovation, so it was argued, miners could widen and deepen the tin frontier by tapping low-grade deposits and even by reopening worked-out wastelands.[40]

The problem with this line of argument was that most early attempts to modernize the tin industry were lessons in what *not* to do. Although the mines on Bangka (owned by the East Indies government) and the famous Billiton Maatschappij on Belitung (forerunner to the multinational BHP-Billiton) proved that European firms could make handsome profits, their actual operations relied almost entirely on Chinese labourers and their existing manual methods.[41] By contrast, the first wave of European miners who flocked to Malaya in the 1870s–1880s generally imported mechanized techniques from elsewhere, and nearly all were failures.[42] Rather naively, most of these entrepreneurs assumed that highly capitalized systems (with teams of surveyors, engineers, steam equipment, etc.) were inherently superior to labour-intensive methods. But as the British Resident of Perak remarked in 1893, 'after possibly a series of great hardships to the staff and disasters to the company, it is found that the tin raised is infinitesimal in value when compared with the rate of expenditure.... The company is wound up and the State gets a bad name with investors, and the only people who really enjoy

[37] Heidhues, *Bangka Tin*, 54, 65–6; M. F. S. Heidhues, 'Company Island: A Note on the History of Belitung', *Indonesia*, vol. 51 (Apr. 1991), 1–20.
[38] Quotes from Mohnike, *Banka*, 29. [39] Zondervan, *Bangka*, 111.
[40] Heidhues, *Bangka Tin*, 54, 65–6; Zondervan, *Bangka*, 111; C. G. Warnford-Lock, *Mining in Malaya for Gold and Tin* (London: Crowther & Goodman, 1907), 179; Ken, *Malayan Tin Industry*, 54–8; Hoong, *Development*, 87–8.
[41] On Belitung, 92% of production was still dug by hand in 1908/9: *Gedenkboek Billiton 1852–1927* (The Hague: Nijhoff, 1927), 198.
[42] Ken, *Malayan Tin Industry*, 35–9, 46–8.

themselves are the neighbouring Chinese miners who buy the mine and plant for an old song and make several large fortunes out of working on their own ridiculous and primitive methods.'[43]

It is an intriguing remark, at once denigrating non-European techniques while conceding their commercial effectiveness. Many colonial officials found it consternating, even disconcerting, that European firms should find it so difficult to prevail over their Chinese competitors. But if this subversion of presumed civilizational hierarchies (on which more below) was one cause for concern, the main worry was that the prevailing methods of tin mining would inevitably render themselves obsolete by depleting the rich, shallow deposits within their reach. Even some Chinese operators had meanwhile reached the conclusion that 'relying upon the small workers, the yield must dwindle, for the easily treated deposits are nearing exhaustion'. Many agreed that the further expansion of the tin frontier 'depends largely upon outside capitalists and investors, to whom we look for the money to bring the deeper deposits to a producing stage with suitable mechanical processes'.[44]

But in order to attract investment it was necessary to render both the physical and commercial environment more predictable. Creating a more stable basis for investment soon became the central thrust of colonial mining policy. From the 1890s onwards the attempt to modernize the industry revolved around three main elements: new laws to facilitate concessions for large firms, the re-alienation of concessions that were left unworked, and greater control over water resources.[45] The first two measures were in effect a form of commercial discrimination against small Chinese outfits, and were followed up by ordinances against opium use, gambling, and the so-called 'truck system' (in which small operators agreed to sell ore to a creditor at a fixed price and paid their contracted labourers after the sale, often in the form of food and opium already consumed on credit).[46] The third measure sought to lure investors by precluding private monopolies of water supply and thereby making the business of resource extraction more certain.[47] But despite all of these interventions it remained difficult to attract investment, not least because it remained all but impossible to compete with Chinese *kongsis* on labour costs given their dominance of 'coolie' recruitment networks.[48] This left few options for European firms hoping to break into the industry. Ultimately, their inability to adopt capital-intensive methods due to the lack of investment, or labour-intensive methods due to the obstacles of recruitment, prompted them—much as their counterparts in the American West—to implement resource-intensive methods instead.[49]

[43] Frank A. Swettenham, *About Perak* (Singapore: Straits Times Press, 1893), 34.
[44] Ralph Stokes, *Malay Tin-Fields: Mining Position Broadly Reviewed* (Singapore: Straits Times Press, 1906), 36, quoting Liong Fe (owner of the large open-cast Tambun Mine).
[45] *Report and Proceedings of the Mining Conference Held at Ipoh, Perak, Federated Malay States, September 23rd to October 6th, 1901* (Taiping: Perak Government Printing Office, 1902).
[46] On the 'truck system', see Wah, *Beyond the Tin Mines*, 16–18.
[47] See Frank A. Swettenham, *British Malaya: An Account of the Origins and Progress of British Influence in Malaya* (London: Allen & Unwin, 1907), 235: 'It is impossible to over-estimate the value of this apparently simple but probably unique regulation.'
[48] Hoong, *Development*, 69–77. [49] See Isenberg, *Mining*, 51.

The solution was hydraulic mining, a technique that targeted low-grade deposits in which the Chinese and Malay competition was uninterested. The basic method is simple. Water is collected in a reservoir at altitude and piped to the mine face where high-pressure monitors wash entire hillsides down sluices, sometimes with the aid of water- or steam-powered gravel pumps to elevate the wash-dirt onto raised chutes. Though ancient in conception, it had been perfected in the gold rushes of California and Victoria during the 1850s–1860s.[50] Despite being banned in California in 1884 due to the excessive damage it caused to local river systems, hydraulic mining was first introduced near Ipoh in 1892 and spread more widely around the turn of the century. Its crucial advantage was minimal labour input per ton of earth moved. To take one example, at the pioneering Gopeng Mine just south-east of Ipoh, water was diverted from a nearby river along a 4-km watercourse and 8 km of pipe to a 2-inch (*c.*5 cm) monitor nozzle. Ten to twelve Chinese labourers broke up the mine face with the water-jet and washed the pay dirt into a nearby ditch, where some forty Malay and Tamil women panned for ore while ten more workers washed the accumulated tin sand in sluice boxes.[51] The basic technique was similar on Bangka and Belitung. Huge monitors capable of removing 50 cubic metres of earth per hour washed entire hillsides into tailraces where suction dredges (*spuitbaggers*) pumped the slurry onto raised chutes.[52] This combination of hydraulic cutting and gravel pumping made earthmoving far cheaper than ever before, costing only 13 cents per cubic yard (*c.*1.25 tons, or 0.77 cubic metres) compared to at least 61 cents by traditional open-cast techniques. Human hands could not compete. By 1916/17 hydraulicking accounted for around half of all earth moved in Belitung's mines (*c.*1.25 million cubic metres in total). In Malaya the proportion of miners in hand-dug pits fell from three-quarters in 1911–15 to only one-third by 1921–5.[53]

Hydraulicking and gravel pumping thus drove a twofold expansion of the tin frontier, first into areas located further from watercourses, and secondly into lower grades of ore. In the process, the very definition of a 'deposit' became as much a question of technological application as geological serendipity. Whereas hand-dug pits in the 1890s required a minimum of 3 lb of ore per cubic yard (*c.*1.8 kg per m^3) in order to be profitable, hydraulic mines worked deposits only one-sixth as rich, especially as prices gradually rose after 1900.[54] By 1908, it was generally agreed that 'the day when the Federated Malay States might be regarded as the happy hunting-ground for the small miner seems to have passed, and the future of the tin mining industry in the States will depend upon the economical development on a large scale of low-grade propositions'.[55]

[50] For a comparative account of these industries: David Goodman, *Gold Seeking: Victoria and California in the 1850s* (Stanford, Calif.: Stanford University Press, 1994).

[51] L. Wray, 'Some Account of the Tin Mines and the Mining Industries of Perak', *Perak Museum Notes*, vol. 2 part 2 (1898), 83–4.

[52] J. C. Mollema, *De Ontwikkeling van het Eiland Billiton en van de Billiton-Maatschappij* (The Hague: Martinus Nijhoff, 1918), 85–9.

[53] Figures from Mollema, *Ontwikkeling*, 89; Hoong, *Development*, 131, 384.

[54] Hoong, *Development*, 133.

[55] Wright and Cartwright (eds), *Twentieth-Century Impressions*, 510.

The advent of hydraulic mining thus carried considerable social costs for small operators, and its ecological costs were similarly steep. In many ways it represented what Tim LeCain has called a 'mass destruction' technique, whereby miners worked ever-lower grades of ore by shifting ever-greater burdens onto the environment.[56] As was also the case with the copper mines LeCain has studied, the key characteristic of this system was not the reduction of labour costs per se (which it also achieved), but rather a dramatic increase in throughput by means of a highly indiscriminate method of resource collection that chewed up and spat out much more than what it targeted. Contemporaries noticed the shift: 'the whole mass of the hill, rich and poor, hard and soft, is served alike; all is removed and passed through sluice boxes.'[57] As lower-grade deposits came into production, the ratio of ore to tailings shifted accordingly. For every kilogram of tin produced, five to six times more waste soil was washed away.

And where did all these tailings go? They ended up in vast 'dead zones' and ultimately in the rivers, just as in California.[58] Although local waterways had long suffered from *lampanning* and open-cast effluents, the advent of hydraulic mining greatly exacerbated the problem. As the discharge of tailings rose, especially in Perak, streams that had been 'clear as crystal' in the 1870s turned into muddy, meandering watercourses 'the colour and consistency of tomato soup'.[59] Numerous river beds were raised by several feet, some by several metres, increasing the frequency of floods and covering downstream agricultural land with sterile tailings. Among the worst affected was the Sungei Raia, a tributary of the Kinta River. Despite repeated attempts to dredge its channel and stabilize its banks, the continued deposition of sand and silt on the river plain gradually transformed a large rubber estate into a marsh of lagoons and swamp grass.[60] Large sections of the Kinta River itself (the 'River of Silt') were likewise severely affected. Whereas in 1895 it averaged between 12 and 15 feet deep (3.7–4.6 metres), by the mid-1920s the river at normal flow 'was so shallow that a matchbox could scarcely float down it', and by the 1930s the stretch near the mouths of the Sanglop and Teja Rivers presented 'as woeful a picture as any of endless swamp'.[61]

One of the most worrying upshots for colonial authorities was the increasing frequency and severity of flooding in the urban centres, especially after the 'great flood' of 1926, which inundated much of Ipoh (jokingly nicknamed the 'Malayan Venice' in the mid-1920s) and Kuala Lumpur, and which triggered major canalization and flood retention works.[62] There were even cases of mine tailings killing off

[56] LeCain, *Mass Destruction*, esp. 7–11.

[57] Warnford-Lock, *Mining*, 133.

[58] Isenberg, *Mining*, 30–47.

[59] Swettenham, *British Malaya*, 117; *Report by the Right Honourable W. G. A. Ormsby Gore*, 157.

[60] *Annual Report of the Drainage and Irrigation Department of the Malay States and the Straits Settlements for the Year 1937*, 86–7; Jin-Bee, 'Mining Landscapes', 35, 37.

[61] Quotes from *Annual Report of the Drainage and Irrigation Department of the Malay States and the Straits Settlements for the Year 1938*, 80; Ho Tak Ming, *Ipoh: When Tin was King* (Ipoh: Perak Academy, 2009), 461, 472.

[62] *Report of the Commission Appointed to Inquire into and Report upon Certain Matters Regarding the Rivers in the Federated Malay States* (Kuala Lumpur: Government Printing Office, 1928); Ming, *Ipoh*, 466–72.

entire settlements. Balun Bidai, a village of 2,000 paddy farmers near the mouth of the Tumboh River, gradually became a swamp in the 1900s as the river silted up. In Pahang state, the town of Bentong was threatened by mines that loaded the gorges above the Bentong River with up to 9 metres of silt and that gradually spread tailings across the entire valley below.[63] Even more dramatic was the fate of Kuala Kubu, a market town that was eventually relocated after being buried under 5 metres of tailings washed down the Selangor River from mining operations in the Peretak Hills.[64] There is also evidence that tailings damaged shad fisheries along the west coast of Malaya. Amidst declining catches around 1920, one official repeatedly 'picked up these fish by hand in a dying condition apparently choked by silt in their attempt to ascend the rivers'.[65]

Simply put, the costs of mining were passed on to others downstream. And what made the siltation problem so intractable was the difficulty of repairing the damage once it was done. Many of the worked-out sites—devoid of all topsoil and vegetation, often nothing more than exposed rock and regolith—were virtually impossible to stabilize and continued to erode at a rapid pace. On Bangka, the hundreds of washing sluices left vast flats of sterile sand where vegetation could scarcely take hold even after decades.[66] In Malaya, it was estimated in 1939 that the mines were still annually depositing 16 million tons of silt into the rivers of Perak and Selangor, much of it from abandoned sites.[67] Even after watersheds were stabilized, the silt still took decades to clear from the rivers. As a 1928 report on Malaya's rivers noted, 'today the country is faced with the problem of dealing by curative measures with a disorder, which in the nature of things is peculiarly amenable to preventive measures, and which, had adequate preventive measures been taken in the past, need never have attained very serious proportions'.[68]

By the time a new Malayan Drainage and Irrigation Department was founded in 1932 it could do little more than remedial work: dredging, channelling, and straightening watercourses into classic 'organic machines' that bore little resemblance to their previous riverine ecosystems.[69] Huge flood relief works were built for the Kinta River at Ipoh, which effectively turned a sizeable stretch of the waterway into a drainage canal. At the former site of Kuala Kubu, engineers retrained the Selangor River into a 5-km long, 30-metre wide channel that emptied into the original river bed below the abandoned old town. And while dredges on the most stricken sections of the Kinta and Larut Rivers slowly cleared the main channels,

[63] *Annual Report of the Drainage and Irrigation Department of the Malay States and the Straits Settlements for the Year 1937* (Kuala Lumpur: FMS, 1938), 94.

[64] Federated Malay States, *Report on the Administration of the Mines Department and on the Mining Industry*: 1914, 1920; *Annual Report of the Drainage and Irrigation Department of the Malay States and the Straits Settlements for the Year 1938*, 83; Jin-Bee, 'Mining Landscapes', 37.

[65] John G. Butcher, 'The Marine Animals of Southeast Asia: Towards a Demographic History, 1850–2000', in Peter Boomgaard, David Henley, and Manon Osseweijer (eds), *Muddied Waters: Historical and Contemporary Perspectives on Management of Forests and Fisheries in Island Southeast Asia* (Leiden: KITLV, 2005), 63–96, here 75.

[66] Helbig, 'Bangka', 195. [67] Fermor, *Report*, 154.

[68] *Report of the Commission* (1928), 7–8.

[69] *Annual Report of the Drainage and Irrigation Department*, 1932, 1937, 1938; Richard White, *The Organic Machine: The Re-Making of the Columbia River* (New York: Hill & Wang, 1995).

a Sisyphean two-year dredging effort on the Sungei Raia only managed to lower the riverbed by less than 30 cm.[70]

These degraded mining landscapes were situated at one end of a long chain linking the kitchens and factories of the industrialized world to the forests of Southeast Asia. For many years their remote location and their indispensability for colonial coffers allowed miners to work them with scant regard for the damage they caused. On Bangka and Belitung, the quasi-official status of the industry essentially gave it a free hand. In Malaya, where early attempts to retain effluents led to 'serious friction between the Mines Department and the miners', the creation of a Tailings Commission in 1904 ultimately resulted in weak self-regulation and a lack of enforcement.[71] 'As a consequence', the Chamber of Mines later complained, 'the situation regarding the silting of rivers and water-courses which was acute in 1904 had become critical in 1914'.[72] All the same, during the First World War even these lax controls were loosened to maintain production.[73]

Yet over time, the dire effects on the region's rivers placed a new set of constraints on the industry. One limit came in the form of tighter regulation. By the 1920s and 1930s colonial governments were far more aware of such problems than they had been a generation earlier. In part this reflected the more general spread of conservationist thinking among officials, who increasingly understood their task to include both the 'development' and 'stewardship' of colonial resources. In part it also reflected hard economic interests, especially the growing power of the rubber lobby, which supported stricter mine pollution controls. In Malaya, a 1922 Control of Silt Enactment—by far the oldest such provision in the British Empire—was soon followed by a ban on hillside mining above the 250-foot contour.[74] In 1928, two years after the 'great flood' in Ipoh and Kuala Lumpur, a further enactment required explicit permission to dispose of all overburden and tailings on any given site.[75] A more fundamental constraint was the growing scarcity of exploitable deposits. By the mid-1920s engineers agreed that the hydraulic frontier had closed. There were few suitable areas left for building new reservoirs to feed the monitors, and miners had already cut down most of the workable hill sites in any event.[76] But while the soils and streams of the foothills were showing clear signs of exhaustion, world consumption of tin—and the prices it fetched—continued to

[70] *Annual Report of the Drainage and Irrigation Department*, 1937, 86–8.

[71] *Report on the Administration of the Mines Department and on the Mining Industry for the Year 1904*, 7.

[72] *Report of the Commission* (1928), 13–14.

[73] Imperial Mineral Resources Bureau, *The Mineral Industry of the British Empire and Foreign Countries: War Period. Tin (1913–1919)* (London: HMSO, 1922), 53; Fermor, *Report*, 165; see also 'Report of the Commission appointed to enquire into various matters affecting the tin mining industry in the FMS', in *Proceedings of the Federal Council of the FMS, 1919*, c63–c71.

[74] Sir Harold A. Tempany, *The Practice of Soil Conservation in the British Colonial Empire* (Harpenden: Commonwealth Bureau of Soil Science, 1949), 74; Jin-Bee, 'Mining Landscapes', 35–6; H. G. Harris and E. S. Willbourn, *Mining in Malaya* (London: Malayan Information Agency, 1940), 46.

[75] *Report of the Commission* (1928), 13–17.

[76] L. G. Attenborough, 'Tin Mining in Malaya', in *Empire Mining and Metallurgical Congress, Proceedings: Part II. Mining* (London: Congress, 1925), 490–514.

rise, surpassing pre-war levels by 1920 before peaking at 193,000 tons by the end of the decade.[77]

Everything pointed towards a new frontier in the lowlands, especially in swampy areas like the lower Kinta valley or Bangka's estuaries, which were known to possess tin but were unworkable via existing mining techniques. The solution, once again, was technological innovation: namely the introduction of the bucket dredge. Having already chewed up river bottoms from the Antipodes to California, the first dredges arrived in Malaya just before the First World War and systematically began eating their way across the river valleys of Perak and Bangka during the 1920s. By 1930, the hundred or so dredges operating in Malaya accounted for 30 per cent of its tin output, rising to over half by 1940.[78] They essentially combined three operations in one. A chain of buckets excavated and lifted the pay dirt, a series of jigs separated the ore from the waste, and the tailings were finally deposited at the rear, often into bunded paddocks on previously worked land.

Fuelled by copious amounts of inanimate energy, the tin dredges devoured vast swathes of low-lying alluvial land in search of the tiny (and ever-decreasing) fraction of resource that they valued. Even the early 300-horsepower dredges could lift and treat up to around 75,000 cubic metres per month, equivalent to the output of around 2,000 labourers. In the mid-1920s new models the size of apartment blocks could process up to 230,000 cubic metres per month to depths of over 30 metres. Their low operating costs—similar to the cheapest hydraulic mines—meant that ore grades as meagre as 0.4 kg per cubic metre were profitable. Like hydraulicking and gravel pumping, dredges thus extended the tin frontier in two senses. They not only opened up whole new landscapes for exploitation; they also allowed miners to work lower ore grades including even long-abandoned tailings dumps (e.g. at Larut).[79]

By utilizing a different set of land and energy resources, tin dredging opened the 'final frontier' on the wet valley floors. In addition, the different waste footprint of dredging operations took some of the pressure off erosion-prone foothills and damaged rivers. Although it would be exaggerated to claim that this was as important as economic and political considerations for inducing colonial governments to promote dredging over other methods, mitigating environmental damage did play a part, especially as the rubber industry expanded in Malaya. Dredging was, by and large, less detrimental to local hydrology. Contemporaries estimated that no more than 5 per cent of the excavated ground escaped in the form of fine slimes. Furthermore, it was centred on swampy terrain unsuited to agricultural production, and in some areas it could even ease existing drainage problems caused by mining and siltation upstream.[80]

But as is often the case, the solution for one set of problems brought new ones. Although some historians have suggested that dredging markedly reduced the

[77] *Minerals Yearbook 1932–3* (Washington, DC: Government Printing Office, 1933), 295.
[78] Hoong, *Development*, 126, 400. [79] Hoong, *Development*, 133.
[80] *Report of the Commission* (1928), 139; Fermor, *Report*, 156–7; Jin-Bee, 'Mining Landscapes', 43.

ecological costs of tin mining in the region,[81] it is more accurate to say that it displaced them from the hillsides and rivers to the lowlands and coasts. For one thing, the sites themselves were demolished in the process, which mixed the ground from approximately 7 to 45 metres deep and thereby spoiled the topsoil with large amounts of infertile subsoil. Moreover, even when the finer slimes (which contained nearly all the organic matter) and coarser material were separated, the latter was often deposited on top of the former, leaving the surface effectively dead. As the dredges worked their way across valley floors, they left behind a landscape of sterile sand hummocks and miniature dunes that contemporaries regarded as 'permanently damaged'.[82] They also extended the mining footprint from terrestrial to marine environments. Bangka and Belitung soon became the world's largest offshore tin producers as dredges tore up the former alluvial river bottoms that had been inundated by rising ocean levels after the last Ice Age. Although we have no records of the damage it caused, given the indiscriminate nature of this method there can be little doubt that it devastated large areas of the sea beds around the islands, above all in the productive shallows less than 50 metres deep. Along the coasts, too, dredges slowly excavated whole new waterways that changed river and tidal flows as they chewed their way inland (Fig. 4.3).[83]

Despite repeated calls for the mandatory deposition of slimes on top of sterile sands and for stockpiling topsoil in preparation for subsequent redistribution, the failure to enact such preventive measures meant that the restoration of former mining lands, much like the repair of damaged rivers, was limited and remedial.[84] In Malaya, where rapid population growth and the expansion of rubber planting intensified the pressure for land, the Agricultural Department conducted rice growing trials on dredged sites in the 1930s, and later experimented with a variety of green dressings—especially woody shrubs of the *Mimosa* and *Crotalaria* genera—as a means of kick-starting plant succession (by contrast, former opencast or hydraulic sites were generally deemed irretrievable).[85] But despite some successes, the lack of binding regulation meant that worked-out sites were usually left infertile and derelict.[86] Once the tin frontier had encompassed a particular

[81] e.g. Headrick, *Tentacles*, 267; Ken, *Malayan Tin Industry*, 202; Donald H. McLaughlin, 'Man's Selective Attack on Ores and Minerals', in William L. Thomas (ed.), *Man's Role in Changing the Face of the Earth* (Chicago: University of Chicago Press, 1956), 851–61, here 859.
[82] Fermor, *Report*, 150; Helbig, 'Bangka', 194. Malaria was also a problem given the creation of a landscape of small artificial ponds: Mary Somers Heidhues, 'Poor Little Rich Islands: Metals in Bangka-Belitung and West Kalimantan', in Greg Bankoff and Peter Boomgaard (eds), *A History of Natural Resources in Asia: The Wealth of Nature* (Basingstoke: Palgrave, 2007), 61–79, here 71.
[83] William Robertson, *Tin: Its Production and Marketing* (London: Croom Helm, 1982), 17–18, 59, 174; Helbig, 'Bangka', 194–5.
[84] Fermor, *Report*, 157–8.
[85] F. Birkinshaw, 'Reclaiming Old Mining Land for Agriculture', *Malayan Agricultural Journal*, vol. 19 (1931), 470–6; B. A. Mitchell, 'Malayan Tin Tailings: Prospects of Rehabilitation', *Malayan Forester*, vol. 20 (1957), 181–6; see also H. N. Ridley, 'Reclaiming Abandoned Mining Lands', *Agricultural Bulletin of the Straits and Federated Malay States*, Second Series, no. 2 (1903), 63–4.
[86] *Report by Sir Frank Stockdale*, 62–3; V. M. Palaniappan, 'Ecology of Tin Tailings Areas: Plant Communities and their Succession', *Journal of Applied Ecology*, vol. 11 no. 1 (Apr. 1974), 133–50; L. H. Ang and W. M. Ho, 'Afforestation of Tin Tailings in Malaysia', Forest Research Institute Malaysia, 2002: <http://www.tucson.ars.ag.gov/isco/isco12/VolumeIII/AfforestationofTinTailings.pdf>.

Fig. 4.3. Bucket dredge on a low-lying tin-field, east of Manggar, Belitung, 1937. By permission of the Nationaal Museum van Wereldculturen, coll. no. 10007195.

site, it rarely reverted to anything resembling its former character, and in many cases the damage was too severe even to merit the label of an anthropogenic 'second nature'.[87]

Dredging was, then, another form of 'mass destruction'.[88] Like hydraulicking and gravel pumping, it expanded the tin frontier primarily at the expense of the biophysical environment. But just as with these earlier innovations, it was crucial for meeting the rising demand for tin. World production peaked in 1929 (193,000 tons) and once again between 1937 and 1941 (211,000–42,000 tons), principally thanks to output from Southeast Asia.[89] Although wartime disruption made tin one of the scarcest of the vital war materials, it remained a crucial element in numerous manufacturing processes ranging from chemicals to armaments.[90] By the Second World War dredging already accounted for around half of tin production in Southeast Asia, and after the war it became the mainstay of the industry.

[87] The term comes from William Cronon, *Nature's Metropolis: Chicago and the Great West* (New York: Norton, 1991).

[88] LeCain, *Mass Destruction*.

[89] *Minerals Yearbook 1932–3*, 295; *Minerals Yearbook 1941* (Washington, DC: Government Printing Office, 1943), 720. On inter-war production agreements: Hoong, *Development*, 189–263.

[90] John B. DeMille, *Strategic Minerals: A Summary of Uses, World Output, Stockpiles, Procurement* (New York: McGraw-Hill, 1947), 483.

As real energy costs fell and electrolytic techniques for thinner plating pushed tin prices downward, dredges enabled miners to process ever more minuscule percentages of ore through the ever-greater substitution of inanimate power for human energy.

RACE, WASTE, AND EFFICIENCY IN THE TIN FIELDS

The history of tin offers a particularly vivid illustration of the link between 'mass destruction' and mass consumption in the modern world. One of the basic fundaments of modern consumerism is an unprecedented ability to escape local resource limits by drawing on distant raw materials. For the industrial societies of Europe and North America, the growth of the global tin economy helped expand their ecological footprint in two ways. Directly, of course, the metal itself constituted an important material subsidy from halfway around the world, underpinning a range of vital industries and ending up in countless consumer goods. But indirectly too, it facilitated a multitude of other subsidy flows linking the industrial metropoles to their increasingly far-flung areas of supply. As one of the principal means for conserving and transporting the perishable goods that they required, the tin can quite literally fed the rise of modern consumer societies. By the late 1950s, world production of canned food reached 18 million tons. In 1962, the United States alone produced over 48 billion cans, which corresponded to around 257 per person annually.[91] Though few consumers knew it, their well-stocked cupboards were closely tied to the man-made badlands and silted rivers of Southeast Asia.

Tin was therefore a doubly important element in the globalization of consumption and imperial networks of extraction. The connections between the households of the industrial world and the subsoils of Southeast Asia typified the expanding resource frontiers and the thickening web of commodity chains during this period. This is why the tin frontier showed so many social and environmental parallels to extractive frontiers elsewhere in the world.

But if the common themes are clear enough, it is the variations that enable us to situate particular goods and industries more firmly within their historical contexts, and therefore to understand more clearly how they related to wider processes of social, cultural, and environmental change. For the specific case of tin, one such variation had to do with the nature of industrial-era mining, and in particular with the role of technological innovation as a key driver of mineral frontiers. By the early twentieth century, the mining industry at large relied progressively less on the discovery of new reserves and ever more on the ability to tap known but previously inaccessible or unprofitable deposits. In Southeast Asia as elsewhere, the progressive depletion of the richest deposits prompted miners to work declining ore grades

[91] Ernest S. Hedges, *Tin in Social and Economic History* (London: Arnold, 1964), 151–8; Simon Naylor, 'Spacing the Can: Empire, Modernity, and the Globalisation of Food', *Environment and Planning A*, vol. 32 (2000), 1625–39.

through greater mechanization and economies of scale.[92] Admittedly, a mineral 'reserve' is always a moving target, ever shifting in accordance with prices and methods of extraction. By this time, however, most mines had ceased to be treasure troves stumbled across by prospectors, and instead had become essentially anthropogenic sites, products of a particular constellation of closely interrelated factors: technological innovations that made mines profitable at current prices, a political system that privileged large enterprises and allowed many of the costs to be passed to the environment, and a culture broadly willing to countenance these costs in the name of 'progress'. In this sense, the mining industry epitomized frontiers of technology and investment.

Other variations were rooted mainly in socio-cultural phenomena, an understanding of which helps reduce the risk of economic tunnel vision that can sometimes plague commodity analyses.[93] The tin frontier was, like any other space, not merely a physical stage for human activity but was itself constituted by ideas and experiences, by 'mental geographies'.[94] Just as the rhetoric of 'idle lands' and profligate aborigines animated the colonization of the American West or Australian interior, perceptions of the 'waste' or 'inefficient plunder' of resources in Europe's tropical colonies both promoted and served to legitimize European dominance.[95] Viewed in this light, efforts to mechanize the tin industry reflected more than just commercial imperatives and the lure of profit (though, to be sure, there was no shortage of European-owned firms eager to work the tin sands of the region). They also mirrored the colonial ideology of the right, even duty, of Europeans to spread their mastery of nature to benighted parts of the world. Wedded to this outlook was a quasi-moral objection against permitting a resource to lie idle if it could serve human purposes. According to the sociologist Benjamin Kidd, it was imperative to avoid 'the inexpediency of allowing a great extent of territory in the richest region of the globe—that comprised within the tropics—to remain undeveloped'.[96] This same distinction between what might be called 'resource globalism' and 'resource primitivism' was equally manifest in a 1939 Malayan mining report, which asserted that anyone in control of ore deposits was 'under an onus to permit the exploitation of that mineral'.[97] As elsewhere in the tropical world, imposing industrial technology in Southeast Asia's tin fields was both a sign of European power and a means of exerting it.

Exploring these relationships between technology, culture, and power has been one of the foremost preoccupations of colonial and post-colonial historiography

[92] Robertson, *Tin*, 39–43.

[93] Steven Topik, 'Historicizing Commodity Chains: Five Hundred Years of the Global Coffee Commodity Chain', in Jennifer Bair (ed.), *Frontiers of Commodity Chain Research* (Palo Alto, Calif.: Stanford University Press, 2009), 37–62.

[94] Paul Carter, *The Road to Botany Bay: An Essay in Spatial History* (London: Faber, 1987).

[95] Settler complaints about the use of buffalo by Native Americans are strikingly similar to European criticisms of mining in Southeast Asia: Krech, *Ecological Indian*, 133–45.

[96] Benjamin Kidd, *Social Evolution* (London: Macmillan, 1894), 316.

[97] Fermor, *Report*, 20; on resource 'globalism' and 'primitivism', see Megan Black, 'Interior's Exterior: The State, Mining Companies, and Resource Ideologies in the Point Four Program', *Diplomatic History*, vol. 40 (2016), 81–110.

in recent years. A central leitmotif has been the concept of 'technopolitics', which has influenced work on topics ranging from colonial medicine to agricultural development. Among the many merits of this conceptual approach is its emphasis on the inextricable links—often obscured by an ideology of scientific autonomy—between control over the material and social world. As Timothy Mitchell has formulated it, technopolitics is 'a particular form of manufacturing, a certain way of organizing the amalgam of the human and nonhuman, things and ideas, so that the human, the intellectual, the realm of intentions and ideas seems to come first and to control and organize the nonhuman'.[98] Since the 1990s a vast literature has shown how the application of supposedly apolitical expertise, usually in the name of 'modernization' or 'development', carries fundamental political and social implications, even if scholars disagree on the extent of its quiet hegemonic power.[99]

Seen through this lens, the modernization of Southeast Asia's tin industry was one of many examples where the application of technical expertise, and assertions of its necessity and universal validity, served to underpin imperial power. But perhaps more than most cases, it illustrates the ways in which such expertise, far from merely parading in an 'apolitical' guise, was also overtly politicized, whether in the form of incessant complaints about superficial 'Asian' production methods or the celebration of Western miners as saviours of the industry. At one level, such evidence confirms the well-established argument that nineteenth- and early twentieth-century imperialism was animated by ideologies that measured human societies by their technical achievements.[100] But to take this argument a step further, the evolution of the tin industry also suggests that it was not just 'machines' and technical rationality per se that were regarded as the 'measure of men', but more generally the degree to which human communities were able to control the physical environment and extract wealth from it.

What was ultimately being judged in evaluations of different mining processes was not so much their level of mechanization as their level of 'efficiency'. We can get a broad sense of what this concept meant from Kidd's 1898 treatise on *The Control of the Tropics*, which declared that 'the last thing our civilisation is likely to permanently tolerate is the wasting of the resources of the richest regions of the earth through the lack of the elementary qualities of social efficiency in the races possessing them'.[101] Efficiency, in this scenario, denoted not only a superior organizational and technical aptitude but also a deeper knowledge of the natural world that permitted an appreciation of the full bounty it offered for human design—provided that design be good enough.

Such ideas were deeply engrained in the imperial project, and what made them so compelling was that they linked colonial authority not only with technological prowess but also with contemporary notions of race and environment. In the particular context of Southeast Asia's tin fields, Malays were seen to lack both of

[98] Mitchell, *Rule of Experts*, 42–3.

[99] Seminal works besides Mitchell include: Ferguson, *Anti-Politics Machine*; Bruno Latour, *We Have Never Been Modern*, trans. Catherine Porter (Cambridge, Mass.: Harvard University Press, 1993); Escobar, *Encountering Development*; Cooper and Packard (eds), *International Development*.

[100] Adas, *Machines*.

[101] Kidd, *Control of the Tropics*, 96–7.

the above elements of 'efficiency'. Regarded by colonial observers as 'an indolent, contented, thriftless, unambitious, polite and peaceful race', they supposedly possessed neither the urge nor the know-how to capitalize fully on the assets that lay under their feet.[102] By comparison, Chinese miners were seen to have the former trait but not the latter: though industrious and commercially astute, their technical capabilities confined them to rich, shallow deposits.[103] Only the colonizers purportedly had both the motivation and ability to maximize the extraction of available resources, and this tendency to associate race and technology was magnified by the close structural correspondence between the ethnic ownership of a mine and the techniques it deployed. By the turn of the century colonial administrations made no bones about deliberately promoting Western mining enterprise, though it was unclear whether the various mining codes, prohibitions on the 'truck system', and increasing size of concessionary plots merely amounted to or were specifically intended as a form of racial discrimination.[104]

These ideological hierarchies of efficiency and waste clearly framed contemporary perceptions of Southeast Asia's tin fields. As we have seen above, in certain ways they also helped to promote the specific policy of modernization via Western mining techniques, particularly as European entrepreneurs turned to hydraulicking and gravel pumping in order to break into the hitherto Chinese-dominated industry. When European hydraulic miners faced the prospect of tighter environmental regulations, they repeatedly cited the 'thoroughness' and 'economy' of these methods in order to counter what they saw as 'a persistent prejudice against monitor workings on the assumption that they cause immense damage'.[105] The real damage, they contended, resulted from Asian methods that did not exhaust the ground before moving elsewhere. As one hydraulic mine manager boasted in 1905, 'the most striking feature of mining affairs at present is the losing of ground by the wasteful Chinese miner, who has practically picked the eyes out of the country, and the advance of the White miner, who is making excellent profits out of ground the Chinese could not touch'.[106] The fact that Chinese miners were not slow to adopt the hydraulic monitor and gravel pump did little to undermine these racialized claims to superiority, and if anything was taken as confirmation of Europe's technological trailblazing and the benefits it brought to subject peoples. Indeed, many of the same assumptions framed the subsequent advent of dredging, which was celebrated for performing a kind of racial role reversal in the working of low-grade ores. 'It had always been the case in alluvial working, whether in California or Australia, that the patient Chinaman could come after the hasty European and obtain a living from what the European had left,' noted one engineer in the mid-1920s. The fact that 'dredging now took place in considerable part upon areas already worked and left by the Chinaman' provided 'a comfort more grateful than cocoa, and a stimulation greater than that of wine'.[107]

[102] *Notes on Perak, With a Sketch of its Vegetable, Animal and Mineral Products* (London: William Clowes, 1886), 10.
[103] Zondervan, *Bangka*, 111.
[104] Hoong, *Development*, 151.
[105] *Report and Proceedings of the Mining Conference Held at Ipoh*, 19.
[106] Stokes, *Malay Tin-Fields*, 36.
[107] *Empire Mining and Metallurgical Congress*, 523–4.

These examples illustrate an important point: despite the vast amounts of waste material they produced, hydraulicking and dredging were not considered wasteful. On the contrary, they represented the pinnacle of 'efficiency' by coaxing profits from even marginal grades of ore. What counted as profligate in the economic culture of colonialism was not the systematic destruction of entire hills, rivers, and valley floors for low-grade ore, but rather the inability to make meagre deposits pay—to allow them to run 'largely to waste under the management of races of low social efficiency'.[108] If waste therefore denoted a failure to convert a potential resource into cash, then efficiency represented a maximization of output regardless of the collateral effects. A survey of the Malayan industry summed up the matter as follows: 'efficiency of mining really means the degree of completeness attained by the miner in recovering the mineral from the ground that has been leased to him'.[109] The only thing that truly counted was profitability in relation to current world prices, including transport, fuel, and all other costs. The 'mass destruction' technologies that European firms introduced in the region worked because the costs were shifted to the environment, which did not have a column on the balance sheet.

Obvious though it may seem, it is worth emphasizing that these definitions of waste and efficiency were markedly different from—even diametrically opposed to—those that have informed more recent critiques of pioneer profligacy and 'frontier economics'. The core issue at the time was not whether natural resources were used sparingly but whether they were exploited thoroughly. This meant that, ironically, the 'waste' of untouched ore in the ground represented a greater transgression than laying waste to an entire mountain or watershed in the pursuit of low-grade ore. And what permitted the maximal extraction of the targeted resource was of course the active utilization of other natural resources—above all fossil fuels and hydrological power—that could be harnessed to this endeavour. Tapping nature's energy flows to capitalize fully on the other gifts of nature thus gave this particular brand of efficiency a double environmental dimension, though neither entered its cost calculation.

As some contemporaries noted, this narrow method of accounting was hardly unique to tin mining, or even mining at large, but increasingly characterized economic thinking in general during this period.[110] 'We have lived so long in what we have regarded as an expanding world, that we reject in our contemporary theories of economics and of population the realities which contradict such views,' remarked Carl Sauer in 1938. 'Economics unfortunately has become restricted increasingly to money economics, instead of embracing the study of *Wirtschaften*, and largely has missed this ominous fact.'[111] John Maynard Keynes likewise criticized the obsession with 'the financial results' for turning the entire conduct of life 'into a sort of parody of an accountant's nightmare.... We destroy the beauty of the countryside because

[108] Kidd, *Social Evolution*, 316.
[109] Fermor, *Report*, 115.
[110] LeCain, *Mass Destruction*, 212–16.
[111] Carl Sauer, 'Destructive Exploitation in Modern Colonial Expansion', in *Comptes rendus du Congrès International de Géographie Amsterdam 1938*, vol. 2, IIIc (Leiden: Brill, 1938), 494–9, here 494.

the unappropriated splendors of nature have no economic value. We are capable of shutting off the sun and the stars because they do not pay a dividend.'[112]

The expansion of the tin frontier in Southeast Asia clearly exemplified central elements of this broader economic culture. It also reflected distinctively imperialist ideas about race, technology, and efficiency that served to justify colonial power. If the main drivers of change were economic and material pressures common across much of the global mining industry—above all declining ore percentages and a corresponding need for economies of scale—the attitudes and values that framed these processes nonetheless provided an important ideological support. The colonial claim of bringing Europe's mastery of nature to the 'underused' resources of the tropical world not only abetted the entry of mechanized Western firms into the industry, it also condoned, even encouraged, the deployment of techniques more wasteful, by other criteria, than what they replaced.

The imperial tin frontier left a broad and enduring imprint on the lands it touched. During the late nineteenth and early twentieth centuries it played a central role in the construction of modern infrastructure across large parts of the region, from railways and roads to dams and waterworks. The hunger for goods, services, and energy to fuel the mining industry spurred a range of supporting activities, from logging and smelting to electrification—including Malaya's first hydroelectric plant, a 27-megawatt installation on the Perak River, which was the biggest civil engineering project in all of Southeast Asia in the late 1920s. As a leading source of export revenue for Malaysia and Indonesia, the tin mines also underwrote the rise of new secondary industries and served as an engine of economic growth long after independence. The social, economic, and ecological consequences of colonial tin production reached far beyond the mines themselves, and they lasted long after decolonization.

The most acute effects were felt in the tin fields and their nearby surroundings, especially those located downstream. From the 1860s onward the relentless quest for cassiterite denuded foothills, eroded soils, clogged rivers, and finally churned terrain across the wet lowlands. On the islands of Bangka and Belitung, it was noted by 1940 that 'not a single landscape has remained unchanged by the tin economy'. No other part of the Indonesian archipelago had witnessed such radical change, 'neither the coal finds on Sumatra, Borneo and Pulau, asphalt on Buton, . . . not even petroleum on Sumatra, Java, Borneo and Tarakan have caused the same degree of equilibrium disruption through transformation of the landscape'.[113] Even in the twenty-first century the islands still serve as symbols of resource imperialism and industrial-scale devastation in the tropics.[114]

In Malaysia too, the eerie moonscapes fringing the Kinta and Klang valleys still bear witness to the destruction caused by the tin mines. Many of these sites remain

[112] John Maynard Keynes, 'National Self-Sufficiency', *The Yale Review*, vol. 22 no. 4 (June 1933), 755–69.

[113] Quotes from Helbig, 'Bangka', 192–3, 204.

[114] See e.g. the Friends of the Earth campaign to mitigate the effects of tin mining on Bangka: <http://www.foe.co.uk/sites/default/files/downloads/tin_mining.pdf> (accessed July 2016).

completely devoid of vegetation and continue to afflict nearby rivers. Studies in the 1990s still confirmed rapid erosion rates from abandoned mining lands. Sediment loads on tributaries of the Klang River increased almost fivefold as they ran through former mining sites, whose sediment yields were over eighteen times higher than disturbed forest catchments.[115] Even at the start of the twenty-first century it was estimated that only 9.7 per cent of ex-mining land had been reclaimed, and most of this area was earmarked for housing and industry rather than agriculture or forestry.[116] Although the handful of underground lode mines on the Malay Peninsula left fewer surface traces than the alluvial tin fields, they too bequeathed a troublesome inheritance. Tailings wastes from the British-run Sungei Lembing mine in Pahang—for many decades the world's largest and longest underground tin mine, comprising 322 kilometres of tunnels—still contaminate surrounding waterways with arsenic, lead, and acid drainage some forty years after operations were wound down.[117]

But the colonial tin boom left other legacies as well, for it also spurred a range of efforts—effluent regulations, forest reservation, river conservancy, agricultural reclamation—to limit or reverse the damage it caused. In part these initiatives were motivated by mounting conservationist concern about 'the cost of a scarred countryside'.[118] To some extent they also emerged within the mining industry itself, at least insofar as the danger of resource depletion and externally imposed pollution regulations threatened profits and production. Together, these partly overlapping, partly conflicting impulses gave rise to a body of environmental legislation that long outlived colonial rule, especially with regard to river protection. Over the long term the resulting legal provisions significantly reduced tailings discharge from mining operations, which once again showed that many of the worst environmental consequences of tin mining could have been avoided in the first place through tighter regulation. But as beneficial as such conservationist measures were, they were still vastly outweighed by the desire to exploit Southeast Asia's mineral resources. Profits generally came before prudence, and for the most part conservationist regulation could only make substantial headway once the costs of environmental degradation threatened the prospects for the industry itself or the interests of other powerful groups downstream, not least the plantation lobby.

Ultimately, the wealth generated by the tin industry, and the convenience it offered food shoppers in the industrial world, were an exercise in spatial and temporal displacement. Like so many industries of the nineteenth and twentieth centuries,

[115] G. Balamurugan, 'Tin Mining and Sediment Supply in Peninsular Malaysia with Special Reference to the Kelang River Basin', *The Environmentalist*, vol. 11 no. 4 (1991), 281–91; C. P. Lee and E. B. Yeap, 'Reclamation after Tin Mining in Malaysia', in Ming H. Wong and Anthony D. Bradshaw (eds), *The Restoration and Management of Derelict Land: Modern Approaches* (Singapore: World Scientific Publishing, 2002), 211–22.

[116] Ang and Ho, 'Afforestation of Tin Tailings in Malaysia'.

[117] Fares Yahya Alshaebi, 'Risk Assessment at Abandoned Tin Mine In Sungai Lembing, Pahang, Malaysia', *The Electronic Journal of Geotechnical Engineering*, vol. 14 (2009), bundle E:9, 2–3.

[118] 'Rationing the Ever-hungry Dredges', *Straits Times*, 15 Nov. 1937, cited in Kathirithamby-Wells, *Nature*, 154.

it not only depleted nature's capital by exploiting a subsidy from afar, it also spread the costs far into the future. A whole host of factors encouraged this process of transposition. One was the 'distancing' effect of long commodity chains, which insulates end-users from the consequences of extraction and makes the costs largely invisible. Consumers at the end of the chain had little if any inkling of where the tin in their cans originated, let alone what was sacrificed in the process. Another factor was the semi-transient character of the mining population itself, most of them Chinese or Europeans who were there to make money and then leave, and who tended to treat the land as a disposable resource. Still another reason was the importance of mining for the regional economy. In Malaysia and Indonesia alike, the problems of erosion, river pollution, and deforestation were broadly regarded as the acceptable costs of revenue generation for the state, of profits for investors, and of jobs and income creation (at least until the opening of low-cost Brazilian mines sent world tin prices tumbling in the mid-1980s).[119] From this perspective, the transformation of vast swathes of rainforest into anthropogenic badlands was not just the product of short-sighted plunder, but was rather quite systematic and deliberate. It was all part of the modern urge to make nature more legible and to regularize the flow of resources and profits that it generated.

The story of the colonial tin industry thus displayed many attributes that were common to resource frontiers in other times and places. In the beginning, the availability of a lucrative windfall attracted successive groups of entrepreneurs who serially depleted the most easily accessible resources. Before long, production could only be sustained through greater investment and new technologies of extraction: in Webb's terminology the 'secondary windfalls' of the frontier.[120] As the boom continued—driven, as so often, by an alliance of private and government interests keen to collect the resource rent of the territories they controlled—it radically transformed the landscape. Eventually the despoliation of what had previously been regarded as pristine wilderness prompted a significant conservationist response, though it nearly always lagged far behind the pace of exploitation. In all of these respects the story of Southeast Asian tin shows remarkable parallels to processes of environmental change on other resource frontiers.

Yet as this chapter has shown, the particular constellation of social, political, and technological factors that shaped the tin industry also gave it a distinctive dynamic. Compared to the growth of Southeast Asia's cash-crop industries—such as pepper, gambier, and eventually rubber—the mining frontier was peculiarly mutable and provisional. Long after the region's mineral wealth had been explored and surveyed, the frontier of production continued to advance in a series of steps as new technologies opened up ever-deeper deposits, ever-lower grades of ore, and whole new types of terrain to commercial exploitation. Of course, all resource frontiers are moulded by the technologies that enable human extraction, but the deployment of new techniques and new sources of energy loomed larger for the tin industry

[119] See esp. Khoo and Razzaq-Lubis, *Kinta Valley*.
[120] Webb, *Great Frontier*, 182–91.

than for the leading agricultural commodities of the region, even those, such as sugar and rubber, which were objects of extensive research.[121]

Such frontiers of technology were critical to the growth of mineral production in many parts of the world, but they possessed a special symbolic importance in colonial settings. Throughout much of the tropical world, technological innovation was more than just a means of extracting resources from colonized territory (though it certainly was this). It also served to reinforce the racial and cultural hierarchies that furnished the very scaffolding of the colonial project. In territories where large-scale European settlement was never on the agenda, the assertion of superior knowledge and technical ability was the chief justification for the European presence. And in an ideological context in which a people's level of 'civilization' and 'social evolution' was largely defined by its mastery of the biophysical environment, there was every incentive to view the methods of 'less advanced races' as wasteful and improvident, just as there was every reason to contrast them with the supposed efficiency of privileged European technologies that were, at least by some measures, even more profligate and indiscriminate in their collateral effects.

The expansion of the subterranean tin frontier thus highlights the fundamental interaction of the cultural and the material, of ideas and economics, in processes of environmental change. If the technical evolution of the colonial tin industry was driven primarily by commercial expediency, the broader ecology of the tin frontier was also shaped by an asserted cultural and racial superiority that powered and legitimized the colonial enterprise.

[121] For research on rubber, see Chapter 3. On sugar: Wim Van der Schoor, 'Pure Science and Colonial Agriculture: The Case of the Private Java Sugar Experimental Stations (1885–1940)', in: Chatelin and Bonneuil (eds), *Nature*, 13–20; Headrick, *Tentacles*, 237–48.