2 "A MAN OF MANY PARTS": CONSULTING ENGINEERS AND THE ENGINEERING OF MASS MINING CAPITALISM

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By the turn of the twentieth century, a new and distinctive regime had reshaped global finance, technologies, and ecologies: mass mining. Standing at the center of the technological and financial organization of these vast industrial enterprises was the consulting engineer. But who exactly was the consulting engineer? What did consulting entail? And why did this class of engineer rise to social and financial importance in the regime of mass mining? Contemporary clients and professionals were not sure. "We are accustomed to hear the phrase 'consulting engineer,'" noted one treatise. "In what particular branch of the profession he holds himself out for consultation does not always appear," it continued, "Nor is it necessary that he shall have any particular experience in the art of consulting or advising in consultation. Any man can assume this imposing title."[1] This was only partially true. Consulting was not entirely new, but as this chapter demonstrates, under mass mining, consultants reinvented the role as a new model of professional technical, managerial, and financial intermediary, part engineer-in-chief, part executive officer, part corporate capitalist.

Engineering consulting was an evolving set of advisory practices on the technical, financial, and executive challenges facing mining enterprise. As the engineering profession expanded and was transformed from a craft to a profession in the final third of the nineteenth century, consulting flourished across all its major branches. Scientific consulting emerged on both sides of the Atlantic early in the nineteenth century as a lucrative and, in the United States, the "dominant," expression of scientific entrepreneurship.[2] Historians

of science and engineering have used the term to capture the diversity of career paths open to enterprising men of practical science, including government surveying, professional expert witnessing, academic research, public lecturing, or consulting.[3] To obtain consulting positions, an entrepreneurial engineer marketed their two most important assets: their expertise and their reputation. Unlike those engaged in pure science, mining consultants did not always feel the need to abstain from commercial gain.[4] Recognition of expertise and reputation and, with it, social capital were often measured by financial reward for the consulting engineer. The close relationship between capitalism and consulting thus began early. "It was a professional practice pointing toward the union of science and capitalism," Paul Lucier has surmised.[5]

That union was completed under the regime of mass mining. The commodification of engineering expertise took on new forms under its rule, a process in which consulting engineers themselves participated. As one leading consultant wrote in 1908, they had become "the advance agent of capital."[6] By the turn of the twentieth century, mass nonselective mining took hold on mineral fields worldwide as engineers responded to increasingly complex geologies and leaner ores.[7] By removing greater quantities of unmarketable ores from the deposit and then subjecting them to intensive milling and chemical extraction processes, the mining of low-grade ores became more productive and more profitable than selective mining techniques. But increased scales of working required unprecedented scales of capital. For the financiers who invested in mass mining enterprises (or who found that this was the only way to make their investment payable), employing mining consultants was a costly but shrewd investment in human capital and an important nonmonetary asset. The consultant offered their clients organizational knowledge, managerial skill, experience, and, through their address books, access to even larger pools of human capital. Hiring consultants might unlock long-term profit, but in the short term, it also legitimized a culture of financial risk with commodified consulting expertise at its heart.

To examine these processes, this chapter turns to South African mass mining at the turn of the twentieth century. Transforming the Rand was the work of globally mobile engineers, who traveled a well-worn path to colonial enterprise through London. Center of a vast empire of financial services, colonial contracting, and knowledge industries that encompassed the world, London became the global hub of mining consulting. In the imperial capital, financiers and mining consultants collaborated in exploiting and developing

South African gold mines, both financially and materially. At the heart of this chapter are the consulting careers of a cadre of elite, internationally mobile consulting engineers—John Hays Hammond, Herbert Hoover, and Hennen Jennings—and the border-spanning networks they oversaw. These men were self-assured experts, highly experienced, unashamedly self-promotional, fiercely independent, and unapologetically capitalist. All had storied careers in the histories of late nineteenth-century gold mining and reinvented the practice, organization, and professional ethics of consulting. But while they are each well known to historians, few accounts examine their consulting practice—even though their published and private accounts tell us a great deal about their work. And they worked hard. That work meant continual movement between the industrialized ridges of the Transvaal to the offices of investors and multinational corporations in the City of London, connecting networks of technical experts to the confidence of mass mining capitalists. This chapter follows them in that work. The art of consulting lay in their ability to read the landscape, visualize the subterranean layout of the mine, and organize a commercially viable system to exploit it, as told in the first section. Increasingly, these technical arts complemented consultants' evolving role as knowledge brokers in an intangible financial marketplace, the subject of the second section.[8] Consultants engineered the machine of mass mining capitalism in the City of London as they articulated plans to investors, solicited corporate capital to bring mines into production, mobilized networks of human capital to support their work, waged public information campaigns in the technical and financial press, and dealt in insider knowledge.

Consulting blurred the distinctions between advisory and executive functions, as well as the ideal of expertise as a public good and its commodification for the pursuit of private profit.[9] As a result, reflected one observer, consultants were often "caught between the devil of self-interest and the deep sea of loyalty to employers."[10] Histories of engineers have long recognized their "double location as both objects and representatives of corporate power."[11] As we shall see in the final section, however, consultants themselves often argued there was no meaningful demarcation to be made between these boundaries. "The engineer above all things desires permanency and profitableness in mining operations. The capitalist desires the same," surmised one correspondent to the *Mining and Scientific Press*.[12] Although contested, the cultures of risk and consulting legitimized one another. It wasn't simply that the mining consultant united the separate entities of science and capitalism

then but that they coproduced the knowledge economy and culture of risk at the heart of mass mining capitalism.

THE MINING CONSULTANT

South African mass mining birthed new economies of scale that prized efficiency but involved huge financial risk. Consulting practice changed as a direct result of this new capitalist organization. Finance and geology combined to effect this transformation. After two prospectors, George Walker and George Harrison, stumbled upon gold-bearing outcrops on Langlaagte farm in 1886, miners rushed to the Transvaal and soon found that the outcrops were just the tip of the iceberg. South African gold stretched 60 miles along an almost unbroken arc from Randfontein in the west to Modderfontein in the East. What the first prospectors did not know, but which the US geologist Ferdinand Becker later confirmed, was that the reef dipped diagonally southward underground, extending the deposit to as deep as 4,000 feet in narrow, fractured seams of "banket," a conglomerate of rocks and minerals in which gold was embedded in low but remarkably consistent amounts.

The central problem facing mining companies and engineers was not where to find the gold or how to remove it from the ground but how to profitably separate the gold from the banket once it was on the surface. Fortuitously, cyanidation, introduced to the Rand in 1890, increased recovery rates from low-grade ores to as high as 90 percent and, in turn, fundamentally changed the economics and organization of deep-level mining. To create the technological and administrative machinery required for mass mining, the preferred corporate strategy among the Randlords was to form holding companies or groups (the two largest of which were Consolidated Goldfields and Eckstein & Co.) that owned, partially or in whole, subsidiaries to spread the risk of deep-level mining. Doing so enabled the group to supply a centralized set of financial, administrative, and technical services at lower costs to subsidiary members—and insulated mining finance houses from the capital shocks of unproductive properties and collapsing share prices. By the close of the nineteenth century, fewer than ten groups controlled 124 companies, and together, they accounted for more than one-quarter of the world's gold output. Group owners were, for the most part, financiers who lacked the specialist knowledge to develop prospects into producing mines and instead bought the services of consultants.

Reimagining mining on this scale required considerable engineering expertise and managerial logic, the qualities most in demand of consultants. "The special knowledge required by these men has to be almost encyclopaedic in its range," wrote British mine expert James H. Curle.[13] Before production began, consultants strategized ore extraction and tailings disposal; oversaw shaft sinking, the stoping of underground levels, the creation of dams and reservoirs from water rights, and the transportation of ore below ground; and, to speed the ore through production at maximum efficiency, erected sorting belts, stamp batteries, tube mills (for fine crushing), water coolers, cyanidation whorls, tailings wheels, engine houses, and winding gear above ground. Once operations began, often between five and seven years later, the consultant organized management hierarchies and the recruitment of skilled and unskilled laborers, as well as consulted with the mine managers, metallurgists, engineers, and machinists in each department on the mine's operations. "Their business," reflected one *Engineering* editorial, "is generally to scheme out plans for carrying out works; to draw up the specifications in which these plans are, or ought to be, described; to superintend the work as it goes on; and, in general, to formulate what they or their employers want to be done, and then to see that it is properly done."[14]

It is worth pausing to consider the scale of these "schemes." Take, for example, Simmer and Jack Proprietary (S&J), part of the Consolidated Goldfields group (see figure 2.1). By far the Rand's largest mining company, S&J embraced 1,206 claims after a series of amalgamations of deep-level companies orchestrated by their newly hired consulting engineer, John Hays Hammond. To operate the S&J's 100-stamp mill in 1895 required a battery manager, senior amalgamator, six amalgamators, two juniors, two men to run the hoisting equipment, two general hands, two fitters, and a carpenter—in addition to Black labor.[15] Under Hammond's guiding hand and the management of Pope Yeatman and his superintendent Victor Clement (all three Californians), S&J was transformed into a huge industrial enterprise whose claims stretched a mile along the Reef and employed 450 white and 3,000 to 4,000 African migrant laborers.[16] By 1899, a battery of 280 stamps (managed by George Osler Smart), each weighing 1,200 pounds and capable of crushing 400,000 tons of ore annually from 10 shafts, three of which extended to 2,500 feet, showed a profit of almost £30,000 monthly.[17] Once milled, 600 tons of tailings were processed daily through the mine's cyanidation works, "the largest of their kind in the world," comprising five vats, each 42 feet

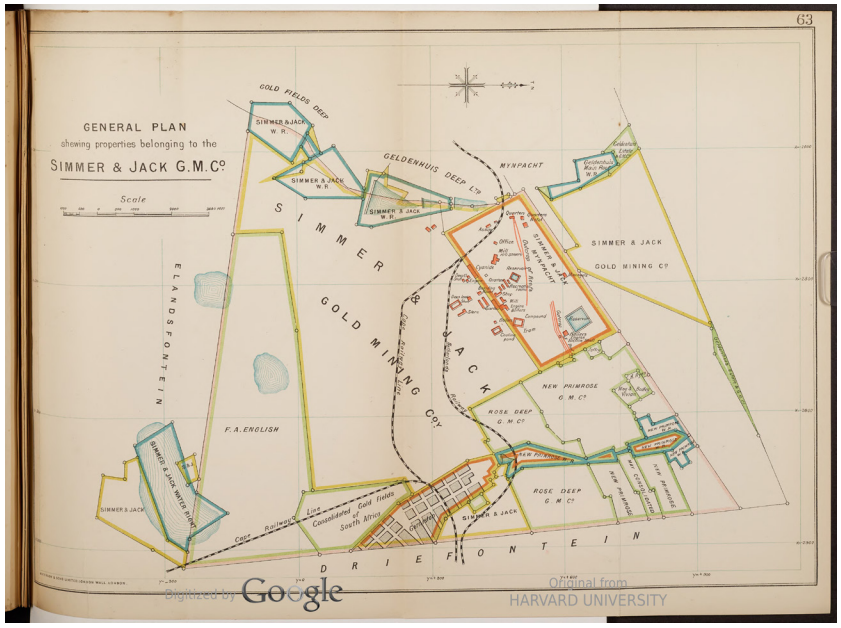

FIGURE 2.1
Simmer & Jack Gold Mining Co., circa 1895. This map shows the S&J before the installation of its 280-stamp mill. The compound for African laborers can be seen near the boilers and cooling ponds, with the accommodation for white foremen and managers some distance away near the outcrops. *Source*: Charles Sydney Goldman and Joseph Kitchin, *South African Mines: Their Position, Results, & Developments: Together with an Account of Diamond, Land, Finance, and Kindred Concerns*, 3 vols. (London: Effingham Wilson & Co., 1895), 63.

wide and 14 feet high, that took between 10 and 11 hours to fill.[18] Established on the site in 1898 was the General Electric Power Company, a subsidiary of Consolidated Goldfields, to supply current to the industrial complexes of S&J, Knight's Deep, Simmer and Jack East, South Geldenhuis, and South Rose Deep mines and to the towns of Germiston and Georgetown.[19] The Central South African Railways weaved through the property, delivering timber, coal, and frozen meat to feed this voracious industrial metabolism.

This was a colossal enterprise, replicated across the Rand. With twenty-nine companies operating 2,456 steam-driven stamps in 1898, it was little wonder that the ridge was veiled in a "greyish-brown haze" peaked with "Alpine summits" of tan-colored "heaped detritus" from cyanide processing and rang

to the percussive, never-ceasing "murmur" of stamps that "sounded like the voice of the sea."[20] After a visit to the Langlaate Deep mine, one South African marveled at the winding engines "with their huge, bright steel crankshafts and connecting rods and massive flywheels," remembering that he "afterwards had nightmares involving me and that awe-inspiring machinery."[21]

Within these multiplex organizations, consultants functioned as specializing generalists, men with expert knowledge of mine engineering but with a broad understanding of interrelated specialties. As Hennen Jennings, chief consulting engineer for the Corner House Group (H. Eckstein & Co.), advised, "The mining engineer must have some sound general knowledge of all other branches of engineering inasmuch as in the equipment and running of great mines and metallurgical plants he must make use of the training of engineers in almost all the other branches" and "at least appreciate the foundations of their specialties."[22] For Herbert Hoover, and not without a touch of self-glorification, the mining engineer required "a wide knowledge of certain branches of civil, mechanical, electrical, and chemical engineering, geology, economics, the humanities, and what not; and in addition to all this, engineering sense, executive ability, business experience, and financial insight."[23] This was a formidable skill set. As mine corporations grew through diversification, purchasing ancillary enterprises like dynamite factories, electrical companies, coal mines, brickworks, meat processing, equipment manufacturing, and railroads as subsidiaries, the executive work of consultants only increased, and they became more than mere mining engineers but engineers of technical systems.[24]

Practicing consultants agreed that under mass mining, their role had taken on more executive functions. "To be successful he has to possess a skill and a versatility required in few other professions," wrote Hugh Frederick Marriott in his 1925 work *Money and Mines*.[25] Marriott's reflections were shaped by more than two decades working on the Transvaal, where he arrived in 1891 as assistant consulting engineer to Hennen Jennings at Eckstein & Co., the Rand's largest gold producer before becoming his successor in 1905. In a chapter devoted to the topic, Marriott ruminated at length on the consultant's role and its relationship to the new forms of industrial and capitalist organization of the Rand. "To define the exact duties of a consulting engineer is difficult," he reflected, but "in the type of organization, favored by the modern group system, controlling a number of separate mines belonging to different sets of owners, the consulting engineer exercises executive,

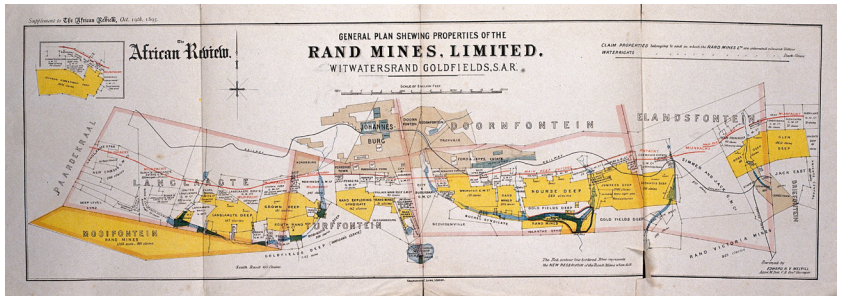

FIGURE 2.2
General plan of Rand Mines Ltd. Chromolithograph after Edward H. V. Melvill, 1895, illustrating the extent of mining company properties and the critical role of mining consultants who provided centralized technical services to the firm's subsidiaries that ran both outcrop and deep-level mines, the sheer extent of which can be seen above. At the time the map was made, Rand Mines had just one mine in production (the Geldenhuis Deep), but by 1898, this had risen to nine. *Source*: Wellcome Collection, https://wellcomecollection.org/works/ngr7jjwk/items.

as well as consultative, functions." He was the "chief technical authority" and formed "the link between the administration and the operating staffs at the mines."[26] As Marriott's mentor, Hennen Jennings, put it, "In these days of impersonal corporation ownership, the closest and most intelligent link between capital and labour is that of the engineer."[27] The consultant was the lynchpin of the mass mining groups. "Under the group system," wrote Marriott, "the consulting engineer has a special value, in that he has the opportunity of knowing what is being done at the different mines, and is therefore able to put the managers in touch with each other on common problems to point out how difficulties affecting one mine have been solved in another."[28]

Professional identity was never based on technical proficiency alone, however. For consultants, credentials were established by spending time in different roles within the multinational mining enterprise—from the mineshaft to the management office—and across different mineral fields. As a matter of course, the consultant was male and white.[29] The professional identity of the mining consultant amalgamated masculine notions of technical mastery, expert autonomy, and imperial notions of civilization and progress. "Essentially the mining engineer is a pioneer," mused Hammond, "Alone he makes his way through the difficult conditions imposed by the promoter or capitalist who employs him, and success or failure hangs on his sole judgement."[30]

Engineering narratives were replete with the claim that expertise was embodied in autonomous, mobile, white manhood.[31] Mine engineers were not exceptional in this regard, but their peripatetic careers gave them a prominent place in the cultural romance of the pioneering engineer.[32] "The consulting engineer must be prepared at a moment's notice to go to any part of the world," wrote one typical account, "whether it be the tropics or the Arctic Circle it is all the same" to the mining engineer, the account continued, making him "truly a man of many parts."[33] Global mobility was thus both real and idealized. In the iconography of the male technical expert, mobility was a surrogate for white male authority, but the genuine mobility of consultant engineers also equipped them with two of their greatest assets—hard-won knowledge of mineral fields across the globe and their access to a great store of human capital in the form of social and professional networks they created en route.

Global mass mining depended on this hypermobility, as did the culture of engineering expertise and professional practice that was itself redrawn around the new technical system of mass mining. Mechanisms of organization and diffusion contributed to the creation of strong professional networks among leading mining engineers. Technical schools were one component of the international spread of expertise and a form of cultural capital accumulated by elite engineers to publicly demonstrate their professional and social standing. As chapter 1 in this volume illustrates, the number of technical schools and students grew rapidly from 1870 in the United States and Europe and enjoyed international student enrollments, with many new graduates then joining professional associations to augment their technical credentials. The membership rolls of professional organizations therefore also grew across the world (see table 2.1). Concerning mining, the American Institute of Mining Engineers (AIME), founded in 1871, and London's Institute of Mining and Metallurgy (IMM), founded in 1892, were the most prestigious of these national societies. By 1905, AIME's membership had reached more than 3,600, representing ferrous and nonferrous mine engineers in addition to chemists and geologists.[34] In contrast, the IMM's membership stood at 1,799 in 1909, rising to 2,000 four years later—in both cases, a small proportion of the number of practicing engineers but evidence of the growing culture of professionalism.[35]

Professional societies—local and international—were modeled closely after one another and sustained the global flow of experts and expertise through shared memberships, reciprocal honorary memberships, and swapping of

Table 2.1
Institutes of mining, 1855–1898.

1855	Australian Miners' Scientific Association, Sandhurst, Victoria
1859	AMSA becomes the Bendigo Miners' Association
1860	Ballarat Mining Institute
1871	American Institute of Mining Engineers (AIME)
1887	Mining Society of Nova Scotia
	Engineering Institute of Canada
	Witwatersrand Chamber of Mines
1889	Institution of Mining Engineers, London
1890	Engineering Institute of Canada, Toronto Branch
1891	Ontario Bureau of Mines
1892	Institution of Mining and Metallurgy, London (IMM)
	Association of Mine Managers, South Africa
	South African Association of Engineers and Architects
1893	Australasian Institute of Mining and Metallurgy
1894	Chemical and Metallurgical Society of South Africa
1897	American Mining Congress
1898	Canadian Institute of Mining and Metallurgy

Source: Compiled by the author.

publications, a process that was a strategy of professionalization and exclusion.[36] Local professional networks were integral to the coproduction of mining expertise, ensuring that knowledge created on the frontier of extraction was ensconced in metropolitan professional settings. In South Africa, the Witwatersrand Chamber of Mines (1889), the South African Association of Engineers (1891), the Association of Mine Managers (1892), the Chemical and Metallurgical Society of South Africa (1894), and the South African School of Mines and Technology, founded in Kimberley in 1896, were all important venues in the generation and diffusion of expert knowledge of the geology, extraction, and refining of gold.[37]

Engineers further participated in the global culture of expertise by attending international conferences, contributing to the technical press, and writing autobiographies. All these activities burnished professional reputation, cultivating the markers of manhood and prestige necessary for engineers to distinguish themselves in the competitive entrepreneurial world of consulting and often as public intellectuals.[38] A great deal of the ideas shared in these venues also pertained to the financing of gold mines. Indeed, engineers insisted that they possessed "character" and were "trustworthy" and

"honorable" individuals—key idioms of capitalist cultures of risk in the late nineteenth century.[39] Technical acumen and good business sense meant little if not supported by moral and masculine vigor. Mining consultants therefore spent a great deal of intellectual energy establishing the boundaries of professional practice and the ethics of their relationship to mining capitalists. In some instances, as we shall see, the culture of expertise curated by consultants was one that normalized close connections between specialist knowledge and the high-risk financing of mass mining.

GLOBAL NETWORKS OF MASS MINING

As the South African landscape was dismantled, a new landscape of mass mining capitalism was erected in the City of London. Engineering consultancy thrived here in its "golden age" between 1890 and 1914.[40] In that period, some 8,408 mining and exploration companies were registered in the UK with a combined capitalization of roughly £1,045 million (of which £250 million was actually issued).[41] From an annual average of £8 million in the 1880s, investment in mining surged to around the £20 million mark for much of the 1890s, before dropping back to around £10–15 million per annum between 1902 and 1914.[42] Less stringently regulated than its competitors in Paris and Berlin, the London Stock Exchange (LSE) offered ready marketability for leading mines, competitive lending markets, and a rapid system of international arbitrage (especially Paris).[43] London was also the world's leading bullion market, equipped with high-quality refining facilities, and through the Bank of England maintained the remarkable stability of the gold-backed pound. Even though much of this investment was never put into gold production, as early as 1898, British-owned companies produced 60 percent of the world's annual output of gold and created a mining investment market that produced new forms of corporate organization to finance and manage the global mineral industry.[44] Mining consultants were central to the global knowledge economy sustaining this extraordinary boom.

While mass mining operations may have been truly global in scope, it depended upon a tight-knit, at times remarkably local, world. Among the foggy, gas-lit streets of the Inner City around the Bank of England and LSE, the cultures of capital and consulting were interwoven. Here mining investors, consultant engineers, and the specialist mining press were headquartered cheek-by-jowl with the offices of mining finance houses, company

promoters, and stockbrokers—scrupulous and not. Just as imperial civil engineers established themselves as the "Great George Street Clique" close to Westminster and the government offices that could secure them lucrative contracts, global mining consultants gravitated toward the City.[45] Here they took advantage of a supporting web of financial services, including merchant bankers, insurers, credit reporters, and accountants, and accessed and influenced the flows of market information that converged there. Finch Lane was home to the editorial offices of the *Mining Journal*, founded in 1835 by the London stockbroker Henry English, whose specialist reports complemented the general investing advice of the financial press. For those dealing in copper, life revolved around the London Metals Exchange, established in 1882, just a stone's throw away. A walk northward along Old Broad Street from the LSE was London Wall, home to some of the city's largest investment banks, where they jostled with the offices of mining syndicates and consultants, the editorial offices of T. A. Rickard's *Mining Magazine*, and, from 1892, the headquarters of the Institute for Mining and Metallurgy. Walking south from the LSE, one reached St. Swithin's Lane, the epicenter of gold rush finance: the Rothschilds. For the international mines they invested in, Rothschilds acted as financial advisers, metal brokers, gold refiners, insurance agents, shipping brokers, and bankers. Here was surely the most lucrative gold field in the world.

Mining capitalism required a steady flow of reliable information into the city. Consultants produced that information in the form of technical reports and assays. Some consultants acted as independent generalists, such as the firms Hill & Stewart, James Brothers, Williams & Co., and Pellew-Harvey & Co., all based on London Wall or nearby on Old Broad Street, as did "celebrity" engineers like Hoover (after leaving Bewick Moreing in 1909) and Hammond, who established offices on London Wall and Old Jewry, respectively (seen in figure 2.3). Most consultants developed specialist mineral expertise, and their practices could be quite small, consisting of an office and perhaps one or two senior engineers and a few apprentices. Others were regional specialists and were sizable operations. This was especially so of well-known consulting firms, which took on mine management in addition to surveying such as John Taylor and Sons for southern Spain and India; Bewick Moreing & Company in Western Australia; Tarbutt, Janson and Son in West Africa; Sir Robert Williams & Co. in the Central African Copperbelt; and Wernher Beit & Company in Southern Africa. The sheer scale of the work involved for these firms was often staggering. By 1897, for example, Bewick Moreing was

FIGURE 2.3
Location of mining company offices in the City of London. *Source*: Israel G. Solares and Edward Beatty, Blueprint for Modernity Engineering Database, accessed through https://github.com/solaresig/Blueprint-for-Modernity or engineeringhistoryproject.org.

consulting engineer to sixty-four Western Australian gold mining companies registered in London and, by 1904, produced 37 percent of the state's gold and employed almost 20 percent of its goldminers.[46] Mining consultants were thus one part of a great flow of expertise into London that made the city "the centre of the mining world."[47]

Metropolitan spaces were integral to mining's global reach. In New York, mining consultants were part of the city's expanding economic elite, drawn

to its dense networks of business contacts, technical experts, and financial elites clustered around Wall Street and the New York Stock Exchange (NYSE) and Consolidated Stock Exchange of New York.[48] New York was the financial epicenter of the "American World of Copper," connecting the city's capitalists to the frontiers of wealth in Montana, Utah, and the Southwest.[49] Phelps Dodge, the American Smelting and Refining Company, and the "Father of the Porphyries" Daniel Jackling's Utah Copper Company and Ray Consolidated Copper Company all had headquarters in Manhattan. As in London, an undergrowth of financial services thrived in the city to support the activities of these firms. Specialist dealers in mining stocks such as Graham & Horton and Waller & Hirshfeld, assayers, credit rating agencies, wire services, and the technical press established offices on Broadway, Pine Street, and others close to the Consolidated building on the corner of Exchange Place and Broadway.[50] The Ingersoll Rock Drill Company could be found at Park Place, neighboring the offices of the *Engineering and Mining Journal*, while the Chicago-based specialist in mine machinery, Fraser & Chalmers, took offices on Fulton Street. Consultants marketed their expertise here too, many acting on behalf of subsidiaries owned by the international groups located in London or for US mining corporations. On his return to New York in December 1899, for example, John Hays Hammond took offices in the Mills Building, on the corner of Broad Street and Exchange Place, from where he orchestrated the mining empires of the Mills and Guggenheim families in Mexico and the interests of London's Venture Corporation in the United States.[51] Capital could not be any closer since the L-shaped Mills building wrapped around the offices of J. P. Morgan, who would later team up with the Guggenheims to develop copper mines in Kennecott, Alaska.

A network of mining cities stretched across the globe. Some acted as gateways for financial capital. Dubbed "the hub of the mining world" by one of the city's leading capitalists, San Francisco was home to bespoke mining markets with savvy investors, a leading technical press, and the headquarters of extractive empires that stretched across the American West and Pacific World.[52] British banks established branch houses and agencies in the city to invest in western mining, and between 1860 and 1914, an estimated 584 joint-stock companies were registered in London to exploit western mines.[53] "London is a lake of money," reflected the *Mining and Scientific Press* in September 1895, "bank full, and running over."[54] In turn, San Francisco's hinterland was subordinated to an urban extractive empire overseen by local

capitalists.[55] Regional mining stock exchanges across the American West, such as in Denver, and in British settler wests, such as Johannesburg and Melbourne, Montreal and Vancouver, did a brisk business.[56] These regional exchanges were far from insignificant in the global context. Although nowhere could match Imperial London for the sheer concentration of human and financial capital, these urban bridgeheads were part of an international network of engineering consultancy services, each with their own wells of human capital, that connected bourses in Philadelphia, Boston, Paris, Berlin, and Amsterdam to major ports and inland mineral cities like Butte (MT), Deadwood (ND), Virginia City (NV), and Bisbee (AZ) in the United States, Cananea (Mexico), Nova Lima (Brazil), and Broken Hill and Kalgoorlie in Australia, to name just a handful.

London, though, was the frontier of extraction for mining finance. By 1895, the South African and Westralian markets dominated the daily rhythms of the LSE, not only on the bourse but also on "the jungle" or informal Kerb Market of Throgmorton Street. Share prices rocketed as these markets boomed, their "Circean revels" proving "irresistible" to speculators.[57] By 1899, the par value invested in the Rand mining industry amounted to £25 million, and by 1914, it had reached £125 million as the Rand produced 40 percent of the world's gold.[58] This was a boom in company promotion. To take advantage of the investing public's appetite for mining shares, the number of joint-stock mining finance houses, often called exploration companies, rocketed. In 1895, at the height of the South African and Westralian booms, 40 percent of the 961 newly created mining companies were created for the purposes of exploration and company promotion.[59] With the phenomenal growth of company promotion came new investment practices that were wide open to fraud and disinformation. Many of these firms were little more than speculative endeavors overseen by charismatic financiers. But some exploration companies systematized the search for and development of new mines, providing a steady supply of new prospects for promoters. This was carried out to great effect by the Rothschilds-backed Exploration Company, a joint-stock venture founded in 1885 by the American consulting engineers Hamilton Smith and Edmund de Crano, that directed the Rothschilds toward valuable mining properties worldwide. Smith and de Crano identified the properties through careful research that enabled them to "pick the eyes out" of mining markets and enrich the inside few with "promotion plunder."[60] The company's adroit combination of social connection,

financial invention, and engineering expertise can be seen in one attempt by Hammond to procure finance for a Mexican mine when he told its prospective operator, Charles D. Lane, that after making a social call to Smith and de Crano, they were

> very favourably disposed to entertain your . . . proposition especially when I told them what I know of your standing etc. but they have stipulated that you obtain a larger option on the property, so as to enable them to send their expert, upon whose report they will float the property. While having perfect confidence in you, they say that in going to the public, they must have a complete engineers report, and that engineer must be one of their selection. I told them that I would arrange to have [Frederick W.] Bradley make a report which would greatly enhance the value of the property when presented to the public.[61]

Consultants were therefore prominent among the "new breed of intermediaries" bringing mines to the market.[62] Their chief marketable commodity was expertise. As one mining investment manual advised, "Professional advice can now easily be obtained. There are many experienced mining engineers now resident in London, whose services can be obtained as consulting engineers to boards of directors . . . and who can supply the technical knowledge unnecessary in the ordinary director."[63] An engineer's report was essential to any new company prospectus, legitimizing high levels of financial risk with technical expertise. But their advice came at a cost. At the Exploration Company, Smith and DeCrano each took home salaries of £5,000 a year and 1.5 percent of all the business conducted by the company, as did Joseph Harry Lukach, who joined as a consultant in 1896.[64] Hammond was rumored to be taking home a salary of $75,000 at Consolidated Gold Fields. Jennings, a protégé of Smith's, was equally well compensated. Mining financiers also made regular use of so-called founder's shares and vendor's interests, which granted exclusive rights to a specified part of a company's profits before ordinary shareholders received dividends. The remainder of the shares, usually a small proportion, were then offered to the public at prices well above par. Once the capital had been raised, company mongers then filleted the assets for themselves, leaving the investing public with the "shrivelled carcass."[65]

But what exactly were financiers investing in? In short: human capital. Hammond, Jennings, Hoover, Smith, and others called on deep reserves of professional contacts thanks to their global careers. In their executive role, consultants recruited skilled experts to oversee the development of deep-level mines. Shortly after his appointment to Consolidated Gold Fields, Hammond enriched his trusted inner circle with plumb positions. "Advise you strongly

to come here prospects are undoubtedly good," Hammond wrote Thomas Leggett, an engineer of great repute who had experience managing mines in the western United States, Mexico, Honduras, and Colombia, in a typical missive, adding, "Will pay you £3,500 . . . expect to do better later."[66] Hammond also secured the services of Pope Yeatman, George Washington Starr, Victor Clement, Ernest Abram Wiltsee, Harry Howard Webb (Hammond's eventual successor), Thomas and William Wallace Mein, Robert Mayo Catlin, and Richard A. Parker, who collectively had experience of working mines in California, Nevada, Mexico, Alaska, and the famed El Callao mine in Venezuela.[67] "I get the expert engineers who are really worth their salt," Hammond bragged.[68] Jennings brought with him trusted colleagues from El Callao to Eckstein & Co. Likewise, the Exploration Company was "instrumental" to the spread of American engineering talent overseas.[69] Consultants thus brokered the great movement of expertise between mining regions in the Global South. "In no other part of the world are collected so many engineers and chemists of the first rank, constantly engaged upon the problem of decreasing the working costs and increasing the percentage of extraction," reflected the British consultant-turned-financier Lionel Phillips while senior partner of Eckstein & Co.[70]

Engineers had considerable power to create markets and capitalized on the city's unrivaled opportunities for social networking. Leading consultants dined at spots favored by investors like "Maeby's" chop house and the City Athenaeum (commonly known as "Thieves Kitchen") on Throgmorton Street, keeping an ear to the ground for financial intelligence. At investors' meetings, they performed their expertise to stockholders and directors, where they cultivated financial and social capital. After returning from the Rand, Hammond spent the autumn of 1894 in London, acting as a "high pressure salesman" to "convince mining investors of the attractiveness of deep-level shares" with diagrams of the outcrop and deep-level mines and charts of his calculations of yield per claim, expenses, and profit, establishing his trustworthiness to potential investors.[71] Maintaining the public image of mining houses was a crucial part of the engineer's expert role. To do so, some consultants were regular contributors to the financial press. Herbert Hoover, for example, was a prolific pseudonymous contributor to the *Financial Times*, *EMJ*, and *Mining Magazine*, assuring readers that the new breed of engineers had introduced efficiencies into mining operations and reformed speculative excess.[72]

A consultant's report could be the difference between a bull or bear market. Hammond recalled of his time surveying the longed-for "Second Rand"

in southern Rhodesia that "it was of supreme importance to Rhodes that my report be favourable." It was not. The financial stakes were self-evident. "On my findings would hinge the investment or the non-investment of enormous sums of British capital."[73] But the information consultants provided only grew in asymmetry alongside the scale of mass mining capitalism. As a result, engineers participated in creating a knowledge economy that enriched those on the inside as it impoverished those on the outside, and it often eroded the independence of the consultant. To ensure the loyalty of engineers of repute—and so steady access to valuable stores of human capital—firms made strategic use of shares. Hamilton Smith, for example, was offered four or five shares at $150 below the market value when he was appointed chief engineer of one Corner House mine in 1893. "Smith is a very good friend of ours, and we could afford to be generous and take credit for letting him have shares," the firm's executives concluded.[74] Likewise, when Rand Mines Limited was launched in February 1893, four mining engineers were together allotted 15,000 shares in total. Invited in on the "ground floor," that is, before the initial public offering, these engineers stood to make substantial profits once the company began trading publicly. And so they did. The value of their stock rose 500 percent within a month.[75] As the firm's director Herman Eckstein explained, "In the long run it will pay better to let other people earn something as well. It will bring grist to the mill in the shape of timely information."[76] The directors of these firms invested not only in technical expertise but also in privileged access to information that placed them in "positions of absolute power" to manipulate futures markets.[77] "Everyone has heard of the system of buying information from people in more or less responsible positions in the mines, and acting on it in the market," reported the *Pall Mall Gazette* in 1904.[78] Indeed, it was entirely routinized in the relations between consultants and capitalists.

RISKY SPECULATION AND PROFESSIONAL OBLIGATION: CULTURES OF CONSULTING AND CAPITAL

What are we to make of the close relationship between engineers and the cultures of risk in mining finance? Some historians have argued that following the spectacular collapse of share markets in 1896, a process of rationalization set in as the major gold mining firms turned their attention from company-mongering to production. Favoring a steady flow of working capital to

overcome the technical challenges of mass mining, major mining finance houses attempted to distance themselves from the manias of the "circus," with the result that technical expertise supplanted speculation.[79] Consultant engineers were thus central to the management of risk. "The organisation of expert advice and information," write Turrell and van Helten, "went a long way towards reducing the risks associated with mining."[80] Indeed, tangible results accrued as the value of gold production rose from £5,180,090 in 1893 to an excess of £15 million in 1899.[81]

Managing risk was certainly the aspiration of the new institutions of mining, the technical press, and a vocal group of mining experts. To protect the public against the worst excesses of mining's culture of financial capitalism, the international technical press policed the boundaries of professional behavior and posed as the protector of the investing public. From their offices in New York, Rossiter Raymond and Richard Rothwell, editors of the *Engineering and Mining Journal* (*EMJ*), proclaimed independence from all "entangling alliances; with mining speculations and stockbrokers," declared the *EMJ* the "enemy of all fraudulent mining ventures," and vowed to expose the swindlers and confidence tricksters plaguing the mining industry who reduced mining investment to a "form of gambling in which the 'outsider' stood but little chance of winning."[82] Such regulatory impulses, argues Edward Balleisen, were part of a growing culture of fraud detection and surveillance in the United States that attacked the routinization of crony capitalism and the spread of disinformation in financial markets.[83]

Given mining's global reach, there was a transnational dimension to this surveillance. Thomas Arthur Rickard, himself one of the world's leading mining consultants, took up Raymond and Rothwell's cudgels as editor of the *EMJ* (1903–1906 and 1922–1929), as owner-editor of San Francisco's *Mining and Scientific Press* (1906–1909 and 1915–1922), and founder-editor of London's *Mining Magazine* (1909–1915). Rickard targeted both the professional dilemma of collaboration with capitalists and the financial presses' opaque relationship with speculators and promoters. "If the profession of mining-engineering has reached no higher philosophy that that of Wall Street and Throgmorton Avenue," Rickard editorialized for the *EMJ*, "it has become obtuse indeed."[84] From his desk on London Wall, Rickard waged war against the "incurably amateurish, superficial, ignorant, and pontifical" financial press and the "guileless scribblers" and "hired purveyors of misinformation . . . as competent to write on aviation or dairy farming as on

mining."[85] Rickard recommended a variety of solutions, ranging from the proper scrutiny of engineers' CVs by the investing public and a vigilant technical press to the complete abstention from promoting mines, speculating in shares, or receiving contingent fees. At threat was fragile public confidence in the hard-won expertise, independence, and professional standing of the mining engineer. "Risky speculation undermines moral and professional obligations," Rickard asserted.[86]

Such preventative strategies should be viewed as integral features of the ongoing public scrutiny of the line between illegitimate gambling and fair enterprise on both sides of the Atlantic.[87] Opportunities for deceit, information asymmetries, and fraud exist in any financial market. But they were perhaps particularly salient in late nineteenth-century mass mining markets where technological breakthroughs, innovative financial organization, eye-watering levels of capitalization, and the "fevers" and "manias" embedded in the cultural perception of mineral rushes lent themselves to high-risk speculation. By policing the boundaries of reputable professional and legitimate economic activity, these commentators attempted to exclude both reckless swindlers and charlatan engineers from the world of mining finance, and by doing so, they in turn reinforced the respectability of some forms of investment and the reputability of professional expertise.[88] Rickard was plain: the problem was not the mining profession, which was "the natural protector of those who place their money in mining ventures," but the corrupting effects of founders' shares and investments in properties one was contracted to advise on.[89] Other engineers agreed. "When a man prays to be delivered from temptation he should not invite it," reflected Henry Cleveland Perkins, a veteran of DeBeers diamond mining and the Exploration Company, on the subject of consultants owning shares in the company that employed them.[90] "There is no moral wrong in an engineer holding an interest in a property which he has examined; there is not even any moral obligation which could require an honest man to decline contingent fees, granting that he believed his judgement would not be warped by the self-interest at stake," Rickard reflected in the *MSP*. But was that possible? Rickard pleaded "deference to the prevailing Adamic weakness."[91]

Yet, using the same moral vocabulary as their critics, many corporate engineers reached the opposite conclusion: financial participation was the guarantor of professional integrity. Consultants were often explicit about their capitalist ambitions. In his address on "Professional Ethics" as president of

AIME for 1908, Hammond was plain: "a mining engineer engaged in such consulting practice should aim to become himself a capitalist, and a purchaser and developer of mining properties."[92] Fresh from a five-year contract with Guggenex working as the highest salaried employee in the United States (1903–1907), recently a nominee for the Republican vice presidency, and now a professor of mechanical engineering at Yale (1902–1909), Hammond took an expansive view of the "Mining Man" as an engineer-financier.[93] "Should he acquire business experience, he might become avowedly a promoter, in a high and worthy sense of that term," he continued, "and thus assist in driving out the unscrupulous promoters who are really parasites."[94] A year later, Hammond expanded on these views in a commencement address at the Colorado School of Mines. "There is now interposed between the mining engineer and the investors a class of men known as promoters," Hammond told the Class of '09. "Not only are the majority of men in this class incompetent and ignorant about mining matters," he continued, "but they are very often unscrupulous as well."[95] Should the "Mining Man" take the place of the promoter, "mining investments would be placed upon a more conservative basis, thereby greatly minimizing the risks of such investments."[96] This was, to borrow Richard White's term, the "morality of consequences."[97] The engineer's social function—protecting investors from the sharp practices of middlemen—justified his reward. In this way, holding and speculating in shares on properties examined was merely the side effect of sound professional practice rather than its antithesis. "In helping themselves," as White put it about the self-perception of early Gilded Age financiers, "they helped investors."[98] In fact, then, as Ian Phimister and Jeremy Mouat have forcefully demonstrated, mining engineers often merely reconfigured, rather than reduced, risk.[99]

Debate raged in the technical press. Reformers saw only hypocrisy in this combination of personal enrichment and ethical virtue. "He thinks that he speaks as a mining engineer," scoffed Rickard, "but he talks as a promoter. . . . A regrettable retrogression."[100] But Hammond was far from alone in his expansive view of the engineer as financier. Hoover leaped to Hammond's defense, reiterating his central claim that the "evils in the mining business can be more quickly remedied if the whole, or a larger portion of the personnel of the industry, forming the chain between the mine and the capitalist . . . are men of technical and practical training."[101] Seeking to cement his reputation as a responsible engineer while building a new one as a public intellectual,

Hoover posed in the *Mining Magazine* throughout 1909 as the "Professional Speculator," attempting to police the boundaries of meritorious speculation and reckless gambling, noting that there was "no common ground" between the engineer-financier and the company promoter whose "business is based on the yield from human credulity; mine upon realizing minerals into metal. He [the promoter] would succeed equally well as a 'bookie' or running a yellow journal."[102] Such a sleight of hand deflected attention from Hoover and his fellow consultant's ruthless exploitation of the information gap between themselves and the investing public.[103]

In the late nineteenth century, mass mining capitalism and modern mining consulting were coproduced. Together, consultants and capitalists achieved impressive feats, mobilizing vast resources of human and financial capital for the exploitation of the Earth's resources on an unprecedented scale. Consultants were far from being instrumental tools of mass mining capitalism's expansive reach, however; they generated, articulated, and sometimes hoarded the engineering knowledge upon which it rested. Adaptable and imaginative, precociously talented, and unashamedly capitalist, mining consultants transformed the community and work of modern engineering. The modern, engineered world system depends upon minerals in staggering quantities.[104] And so, engineers and consultants continue to be key agents in reordering world economic production around new scales of mass mining capitalism. Engineering consulting firms have boomed in that context. They are now much larger, offer a greater range of consulting services, and are more multidisciplinary, more multinational, and more collaborative.[105] They have also been key contributors to the myth that the world economy can continue to overcome the Earth's natural limits.

An Engineered World

The Role of Engineers in Global Modernity

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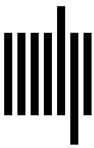

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