The Contributions of American Mining Engineers and Technologies to the Witwatersrand Gold Mining Industry, 1890-1910

By Elaine Katz

In January 1903, in the aftermath of the Anglo-Boer War (1899-1902), Joseph Chamberlain, British secretary of state for the colonies, visited South Africa "to enquire on the spot into the conditions of the country."[1] This mission, of course, included a tour of the industrial engine of the whole country, the Witwatersrand goldfields. These were situated in the Transvaal, the former South African (Boer) Republic under President Paul Kruger, since the end of the war a British colony under the governorship of Lord Milner, high commissioner of South Africa.

As soon as Chamberlain announced his travel plans, the influential Transvaal Chamber of Mines, the authoritative "voice" of the mine owners, invited a number of consulting engineers to form a committee and to compile an economic statement on the "present position" of the industry.[2] The fifteen-man committee consisted of a chairman and a secretary, a delegate from each of the ten mining financial houses or groups of companies, plus another three delegates who represented the six-odd "independent," unaffiliated mines.[3]

The team produced a massive report, which included exhaustive statistics on many historical aspects of the industry, such as yields, working costs, wages, etc., plus estimates for the future.[4] What is significant about this committee, for the purposes of this paper, is that ten of these fifteen leading mining engineers were Americans. Of the remaining five, three were British, one Australian, and one South African.[5]

The committee's findings were impressive. They showed that in 1899 the Witwatersrand was the world's top gold producer, a position it had already attained in 1895. The region produced 7,331,446 tons of ore yielding 2,491,593 ounces of gold, with an estimated value of approximately \$52 million (£10,583,616), representing roughly 24 percent of the world's estimated gold production.

As important, many of the committee's predictions for the industry were realised, as its American chairman, Hennen Jennings, confirmed.[6] By 1914, the gold production figures for 1899 had more than tripled. The Witwatersrand, still the world's top gold producer, produced 25,701,954 tons of ore yielding 8,033,570 ounces of gold, with an estimated value of \$170,622,170 (roughly £34,124,434). This was approximately 40 percent of the world's total production and double that of the United States, the runner up.[7]

The preponderance of ten American consulting mining engineers on this fifteen-man committee in 1902 was probably the same as that of the previous Republican era, from 1893 onwards, when there were far more than sixty American mining engineers at any one time in the Witwatersrand district.[8] Such numerical strength was not confined to mining engineers.[9] Many other salaried staff members were also Americans. These included superintending engineers, electrical engineers, mechanical engineers, superintending managers, mine managers, battery superintendents, mill foremen, assayers, and so forth.[10]

In 1895 San Francisco's *Mining and Scientific Press* reported that an ex-foreman of the Empire

Mine at Grass Valley was the fortieth "from that section to have accepted flattering offers made by owners and superintendents of the South African gold mines."[11] And a month later the same journalist probably correctly calculated that the Witwatersrand gold mines had "so far given employment to over a thousand skilled California mining men at annual salaries ranging from \$2,500 to \$60,000 [roughly £500 to £12,000]."[12] By contrast the approximately six thousand white wage-earners (mineworkers) on the Rand, although a cosmopolitan body with a sprinkling of Americans, were roughly 85 percent British, with Cornishmen constituting approximately 58 per cent of British nationals.[13]

During this era the term "mining engineer" was loosely applied and, following Spence, I use it to denote those who, having made a career of mining, perceived themselves as mining engineers, as did their peers, irrespective of whether or not they had received specific formal training in this field. They therefore included: those who had trained at college or university, regardless of whether they had graduated; those who, previous to pursuing a mining career, had qualified in another branch of engineering or another science; those who, in the British tradition, had served and completed an apprenticeship with the addition of formal course work; and, lastly, those who had "worked their way up" and had been "disciplined in the hard school of experience."[14]

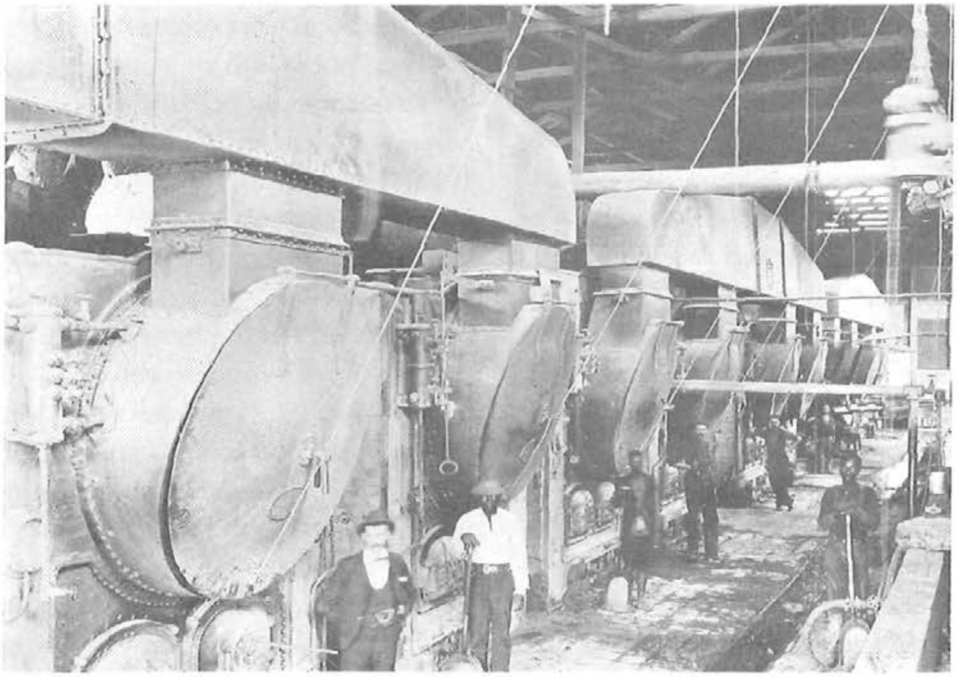
Hamilton Smith, Captain Thomas Mein, and Henry Cleveland Perkins, all Americans, fell into the last category. Not only did they contribute substantially to the development of the infant Witwatersrand gold mining industry, they also achieved universal recognition for their mining feats elsewhere, often in similarly remote areas.[15]

Finally, it should be noted that all of the engineers who worked on the Witwatersrand mines were males, as were most other categories of workers: from 1896 Transvaal Republican laws (and the subsequent Transvaal mining regulations) forbade the underground employment of any "female person of any age."[16]

The "pre-eminence" of the American mining engineers was well known to, and unreservedly acknowledged by, their contemporaries.[17] In 1915 Hennen Jennings, the American consulting mining engineer for the Corner House, by far the largest of South Africa's mining finance houses (known as groups), asserted in his ever even-handed and modest way: "Any impression that the American technical men did it *all* must be set aside. . . . It would be quite impossible, impolitic, and presumptuous to attempt in any way to adjudicate individual praise to the engineers, managers, and technical men cited." By this he meant the relatively large contingent of English mining men, at least thirty strong, who, like himself, had been "early on the spot" in the late 1890s, and the tiny group of "engineers of other nationalities," of whom half a dozen had been "notable."[18]

It was not long before the distinction of the pioneering American engineers faded into obscurity. As early as 1908, M. H. Coombe, a New Zealand pioneer mine manager, contended that the progress of the Witwatersrand owed nothing to knowledge from other mining centres. All the same he had to be reminded that the Rand "had borrowed the highest talent that was available."[19] But after another thirty years, by a gradual but steady process of etiolation, the role of American mining engineers has been almost totally eliminated from histories dealing with the Witwatersrand gold mining industry, except for those in popular books.[20]

The same trend is evident in academic studies from the 1940s onwards. Although a plethora of South African studies concerned with the nature of imperialism, race, and class emerged in the 1960s, they were not concerned, to any significant degree, with mining and technology *per se*.[21] Even in social and labour studies of the industry, which also proliferated from the 1960s to the 1980s, American mining engineers went unnoticed, perhaps because their national iden-



Boiler House, Nourse Deep.
(Courtesy of Museum Africa, Johannesburg.)

tity was considered to be irrelevant to the themes under analysis. Given the predominantly British ethos of Johannesburg and its environs, it is also possible that researchers assumed the same to be so of most mining engineers.[22]

Other books and studies, a few by South Africans, most by Americans, have been devoted exclusively to examining and comparing links between South Africa and America and analysing their importance.[23] Some of these works, therefore, as a small part of their larger purpose, do tackle the role of American mining engineers in South Africa, but it is this subject which has, on the whole, received the shoddiest treatment.[24]

In many instances the authors seem to have hunted down any American mining engineer who could be identified by name, and to have assigned to him an often-unwarranted worth. More importantly, errors made in 1938 have been constantly recycled. It is not just the repetition of the initial mistake that is distracting; it is the embellishment that has accompanied the re-runs.

This is what happened, for instance, with Ethelbert George Woodford, the first Transvaal state mining engineer, appointed in 1887.[25] First we learn that he "evolved" the efficient mining laws "which have changed little with the passing of the years."[26] Next we are told that important though this work was, "his greatest significance was in being the forerunner—he led and pointed the way" for those American mining engineers who played an even greater part.[27] Lastly, we have an indictment: "Woodford, the chief engineer for the Transvaal [R]epublic, drafted the Witwatersrand's first safety code, a somewhat ironical distinction in light of the industry's appalling mortality rates."[28]

Woodward was indeed the first state mining engineer, his appointment to that position being the only element that is true in all of these versions. He so lacked practical mining experience that his "resignation" before completing his contract was greeted with relief by the Witwatersrand mining community.[29] He played no part in framing the Transvaal's first mining regulations—enacted in 1893 to govern health and safety in the mines—as this was done by his successor, Joseph Adolf Klimke.[30] Woodford's role, if any, with regard to the Gold Law (presumably the legislation to which the original writer was referring), which defined ownership of mineral rights, could only have been indirect and minimal.[31] Finally, the Gold Law was amended and significantly revised more than twenty times between 1871 and 1914 alone.[32]

There are other defects to these studies. Apart from presenting potted catalogues of individual technical exploits listed without context or sense of periodisation,[33] poor research has led writers to overstate the achievements of some engineers or to confer inappropriate honours upon others. Thus James Storey Curtis is exaggeratedly labelled the "father of scientific gold-mining in South Africa" because he worked out the angle of the dip of the reef.[34]

The tendency towards magnification is particularly true of accounts of John Hays Hammond, a major accomplice in the secret plan to overthrow the Kruger government with his crony and employer, Cecil John Rhodes, joint managing director of Consolidated Gold Fields, chairman of De Beers, and prime minister of the Cape Colony. The failed Jameson Raid of December 1895 to January 1896, an escapade with all of the ingredients of a soap opera—a botched plot in cahoots with the rich and famous against alleged injustices, a brush with a death sentence and subsequent reprieve—served to catapult Hammond to world-wide celebrity status.[35]

All this, however, should not be conflated with Hammond's achievements and influence as a mining engineer on the Rand. Nor do his adventures demand that social scientists believe the claims to professional singularity stated in his autobiography, including his being the "first" to advocate deep-level mining on the Rand, an assertion which most historians have decisively controverted.[36] But this self-important man seems to have as much capacity today, as in the past, to seduce his audiences.

With the outbreak of the Anglo-Boer War, American mining engineers did not suddenly pack their bags and leave, never to return, as is often contended or implied.[37] Such a fiction probably derives from the coincidental departure of a handful of the most prominent and colourful ones when there was political unrest in 1895 and 1896, at the time of the Jameson Raid and shortly before, or when the threat of war began to loom in 1898.

All these men were indeed highly paid and left with nest-eggs, if not fortunes. But their departure should not be construed as the beginning of a flight of the Americans from the Witwatersrand which the outbreak of war finalised. Nor was their leaving the signal that American influence was on the wane. Those who left for good were replaced by other American mining engineers, a number of whom later served on Hennen Jennings' committee.[38] And American mining engineers continued to occupy as many important jobs after the war as they had before. In fact, their periods of service in the postwar period sometimes exceeded their prior ones.[39]

A noticeable reduction in their numbers could be seen in 1914.[40] It is from this date that it can be said that the "American" period among the Witwatersrand mining engineers had closed. The attrition of American "pre-eminence" in all likelihood began about 1910, with the creation of the Union of South Africa. This event coincided with the "winding up" of Wernher, Beit, and Company (Wernher-Beit), the private mining finance company, upon the retirement of its senior partner and the transfer of control of its gold mines to Central Mining and Investment Corporation, Ltd.[41]

Central's policy, which other mining houses adopted, was not to replace American mining engineers who returned home "with fresh importations" of foreign experts, as this was "wasteful."[42] Kubicek dates the process earlier, to 1906, and suggests that "spendthrift American engineers were replaced with more cost-conscious British experts."[43] That may well have been true, but it was not the stated intention of the Corner House, which controlled Central and offered a different explanation. As Lionel Phillips, senior partner of Eckstein's (another piece of the Corner House empire) stated in 1909:

> I want to avoid introducing new blood from home in the shape of managers, if we can possibly do so, because if we can only make all the subordinates feel that there is a chance of their rising to the very top upon merits, we shall get much better results than if there is a general feeling that outsiders are imported for the purpose. I am convinced that we have heaps of the right material here.[44]

The "right material" by this time included a handful of South African-trained mining engineers, the first graduates of the newly established Transvaal Technical Institute in Johannesburg, an institution the like of which Hennen Jennings had keenly championed.[45]

The high profile of American mining engineers on the Witwatersrand diminished after 1902, in the wake of the Anglo-Boer War. This, despite continued American dominance of senior mining positions and many technical feats that could compare with those in the past. With the standardization of the industry, management became increasingly homogenised, a state of affairs which diminished the financial scope for American mining engineers.

The changes were spelled out by Hennen Jennings in an interview in 1915. When asked whether the relative uniformity of the ore and the big scale of operations on the Witwatersrand militated against an engineer's usefulness, he replied that "the Rand has been a very limited school of late years for giving initiative in the investigation of new properties. Current methods in the Transvaal have been standardized by the great similarity of the problems to be solved at the various mines."[46]

In short, the Rand had become a practical school for "experience in handling men and material on a large scale," and innovation lost ground to convention and conformity. There was room for efficient technicians and administrators, but not for entrepreneurs, adventurers, and individualists with the "daring" of a Hamilton Smith or the "spirits" and "boyishness" of a Charles Butters.[47]

All of this is clearly illustrated by the tube-mill controversy in 1906. There were good grounds for acknowledging that the Australian mining engineer George A. Denny, with help from his brother Harry, had introduced the cylindrical-tube mill to the Rand in 1904.[48] On the basis of its successful trials in West Australia, the Denny brothers installed a tube mill at the George Goch Mine, and used it to fine-grind the ore.[49] This facilitated the cyanide treatment of pulp by the all-slime Diehl process, obviating the necessity for separate treatment of the sand and slimes, then conventional practice on the Witwatersrand.

The South African Association of Engineers, however, refused on a spurious technicality by majority vote to acknowledge that the Dennys had founded tube milling and the all-sliming method on the Witwatersrand.[50] The truth was that neither George Denny, nor Albu's, the financial mining group for which he worked, conformed to the new board-room approach to mining. Their innovative approach— apparently at odds with the establishment, the larger mining groups—provoked the following remarks from a metallurgist during the discussion of Denny's paper:

> We all appreciate Messrs. Denny's [*sic*] efforts here, and we think that in return they at least might have given us credit

> for conscientious work, even if it were not carried out on their own lines. We are not all in a position to carry out brilliant and daring innovations like those at the Meyer and Charlton, and because we consider our duty to our employers to lie in surely, if slowly, developing means to secure higher returns from capital invested other than those outlined in the paper, is surely no reason for our being dubbed "ultra-conservative metallurgists."[51]

This reproach from metallurgist Sydney Herbert Pearce is surprising. He was on the ground floor with the cyanide process, as one of J. S. MacArthur's English assistants at the Salisbury Mine trials in 1890, and thereafter a keen experimenter.[52]

Pearce's comments illustrate another significant point: after the Anglo-Boer War mining engineers—with metallurgists such as Pearce alongside, but subordinate to them—worked under greater compulsion than before to attain profits and so satisfy shareholders. Although American mining engineers continued to maintain an important presence on the Rand, development and working capital were no longer as freely forthcoming for their plans as when they first arrived.[53]

If we are to understand the specific contributions of American mining engineers to the development of the Witwatersrand gold mining industry, it is to the nature of the deposits and to the infant industry that we must now turn. The Witwatersrand gold deposits consisted of a stratified series of parallel conglomerate beds, known as ledges in America but called reefs in South Africa.[54]

These reefs—the Main Reef Series being the most important during most of the period under review—tilted upwards towards the surface where they protruded as outcrops. The quartz conglomerate, known in South Africa as banket because of its resemblance to a Dutch sweetmeat, was distinguished at the surface by white pebbles ranging in size from a pea to an egg, and it was in the cement that bound the pebbles to the quartz that the finely-divided gold was embedded.

The parallel outcrops, the strike, extended from west to east in a reasonably straight line for as much as forty miles (and later was found to extend far further).[55] What was unique about the reefs was their persistence and payability at depth. From the surface they dipped southwards, in some places very steeply, but at a depth of approximately fifteen hundred feet they flattened, and then continued their inclined descent gradually at an average angle of only one degree per one hundred feet.[56] Although the ore grades averaged far lower than ores simultaneously being mined in the U.S. and Australia, the reliability of the reefs made the Witwatersrand deposits "unique in the history of gold mining."[57]

The mines later established on the dip of the reefs and south of it were classified as first, second, and third row deep-level mines according to their distance from the outcrops to the north. Thus the first row of deep-level mines, extending for about twelve miles on the central portion of the strike, were situated about a thousand feet south of the outcrops, while the second and third row of deep-level mines were far further south: four to five thousand feet, and six to seven thousand feet south of the outcrops.[58] Consequently mining generally took place at deeper levels in each succeeding row.

The early years of mining on the Rand need not detain us. Suffice it to say that at the end of 1889, when Hennen Jennings, one of the first American mining engineers, arrived on the Witwatersrand, this was the situation: The speculative market had collapsed and a three-year slump lasting from 1889 to 1892 had arrived. The capital requirements for mining low-grade banket, however abundant, were too high for the survival of most of the infant mines in the hands of joint stock companies; only those with access to substantial capital could continue working.[59]

Even these companies had problems. The relatively rich surface ores had been exhausted, and production now entailed mining in the pyritic zone at 60 to 150 feet in depth, with concomitant increased costs exacerbated by the want of a suitable method for treating pyritic ore. This was one of the reasons for Hennen Jennings' engagement as consultant to Eckstein's via the recommendation of Hamilton Smith. Smith was the partner of fellow American Edmund de Crano in the London Exploration Company, an enterprise in which the English branch of the Rothschild banking house had a substantial interest.[60]

Momentous events then occurred in which American mining engineers were involved. In 1890, J. S. MacArthur arrived at the Salisbury Mine for the trials of the cyanide process with pyritic ore. The success of the MacArthur-Forrest cyanide process in releasing gold convinced Jennings that it was as efficacious on a commercial scale as claimed.[61] In 1891, the borehole which J. S. Curtis directed south of the outcrop intercepted the reef at 581 feet, enabling him to calculate the angle of the dip.[62] This was reassurance for those who had secretly bought properties south of the outcrop on the gamble that the reefs were persistent and payable at depth. Finally, in 1892, Hamilton Smith, ahead of proof,[63] boldly estimated the gold values of the eleven-mile central portion of the reef as being £350 million ($1.75 billion).[64] Smith's report spurred the successful launch of Rand Mines, Ltd., the first holding company for deep level mines.[65]

These details have not been provided for any antiquarian purpose, but for their telling suggestiveness, which has great relevance for this topic. In this formative period and persisting until the close of the nineteenth century, the mining environment on the Rand was conducive to entrepreneurial endeavour, a characteristic common to mining directors and mining engineers. The American mining engineers were bold, even adventurous, as their pursuit of the deep-level mines illustrates. They were also flexible. When Eckstein's, and Hennen Jennings, set out to find an expert chlorinator, their expressed wish was that he should be "a man capable of not only applying a certain method, but [able] to modify same to suit differing circumstances."[66]

Charles Butters was just such a man. He was sufficiently adaptable to admit that at least on the Witwatersrand, cyanidation, not chlorination, did the required job. The same was true of Jennings and Thomas Mein, general manager of the Robinson, who operated a cyanide plant under joint management at the Robinson. They were not welded to conservative practices, a trait often exhibited by fellow members of their profession, particularly the British,[67] but were innovative; they tried out many other gold extraction processes too. Thus endless experimentation, which was a feature of the Rand at this time, preceded their final commitment to cyanidation, which occurred only after the process had been improved and the plant had been modified.

All this would not have been possible without the financial support of their employers, whose business instincts were consonant with those of their managerial staff. What perhaps encouraged the development of this entrepreneurial spirit among the American engineers, and what often distinguished them from their British and continental peers, was the prior experience of some as accountants and secretaries—a launching pad for subsequent wider-ranging careers.[68]

The fact that many American mining engineers had earlier worked together, especially at the El Callao Gold Mine in Venezuela, instilled in them not only a camaraderie conducive to the progress of their assignments, but also a shared knowledge and experience on which they could draw for solving present problems. The confidence and assertiveness of some, often generalised as American national traits,[69] enabled them, as it did Hennen Jennings, to establish good relations with non-American staff members who, likewise, committed themselves to accomplishing projects in the interests of their company.[70] Why else did the British-born members of the original cyanide plant team continue to work for many years on the Robinson even though under a new management, one dominated by Americans?

On a wider scale, the Rand, even at this early stage in the industry's development, provided an environment conducive to managerial cooperation. Not only did company directorships overlap, but groups willingly established joint undertakings with one another. With regard to gold recovery techniques, Eckstein's issued an open invitation to the other companies "to show them what we do" on the Robinson Mine.[71] When one mining group introduced machinery that proved effective, it shared the knowledge, providing encouragement for the same course of action by others.[72]

So it was, too, with the employment of American mining engineers. While Barnato Brothers was the first to follow the lead of the Corner House, it was not long before Consolidated Gold Fields, S. Neumann and Company, and the German firm A. Goertz acted similarly.[73] Even the maverick house, the Robinson Gold Mining Company, finally succumbed to American mining engineering guidance in 1898.[74]

As with the Corner House, the chief American mining engineer, often recruited through the London Exploration Company, tended to bring with him a squad of engineers who were loyal to him rather than to the mining group that employed them. When John Hays Hammond moved from Barnato's to Consolidated Gold Fields, his entire band of hand-picked men followed him.[75] The practice was not unique to the Rand. Traditionally, in mining camps all over the world, miners tended to follow mine managers when managers changed jobs.[76]

The cooperative climate was partly due to the nature of the industry. The price of gold, for which there was an unlimited demand, was fixed by the Bank of London at 84s. (roughly $20) [77] per fine ounce. Thus there was little competition between the mining houses except for the recruitment of African labour.[78] And the fact that industry was cost sensitive—that it had to bear all increases in costs without the possibility of passing them on to consumers because the gold price was fixed—meant that it was in the interest of all the mining houses to share effective cost-reducing practices. What was good for one mining company, it was rightly reckoned, was good for the entire industry.[79]

Thus at the group level or in the Chamber of Mines there was much exchange of information on technical and other related matters, and contentious issues were freely debated. This also occurred informally and on an individual basis, and was especially apparent at meetings of the various professional and technical societies. Such discussions served to keep members in touch with technical expertise elsewhere in the world, as their numerous articles and papers attest.

Despite the marked interest in and knowledge of world-wide technological developments, and despite the wide field that the industry offered for inventive talent, little emerged locally. This was confirmed by an engineer in 1903, who complained that while local inventors had done a great deal to improve "details," and engineers had done much to effect "economies of labour and material" through the reorganisation and rearrangement of plants, no improvements of a "revolutionary nature" had emerged. This he attributed in general terms to financial and practical restraints, and to the engineer's lack of time.[80] By this he probably meant that workshops, with few exceptions, were company-owned and literally housed on the mines. This was in contrast to mining centres elsewhere in the world, where the maintenance, construction and repair of mine machinery was usually subcontracted to private enterprises.[81]

But what he did not explain was that secondary industry was conspicuously absent in South Africa in general, and in the Transvaal in particular, a phenomenon that persisted well beyond 1914.[82] Secondary industry in South Africa was, therefore, a derivative of the mining industry. During the period under review, there was no significant secondary industry that could complement and invigorate the mining industry.

Nonetheless, there arose on the Witwatersrand an industry of great magnitude which could borrow foreign innovations and adapt them to its own unique needs. This would not have been feasible without the commercial success of the cyanide process. It was the coincidence of the advent of cyanidation, together with the validation of the existence of persistent, abundant, and payable gold at depth, that led to the industrialisation of the mines.

A number of other essential elements were also conducive to the industry's take-off in 1892. Apart from coal deposits in the vicinity of the mines which provided a cheap source of power, railway links, established in 1892 between the coastal ports and the mines, reduced the transport costs of plant and machinery and ensured the regular arrival of other supplies.[83] Europe's timely new technologies, as Kubicek suggests, were important: Nobel's blasting gelatine; hard steel alloys that enhanced the performance of mills; stamps, now produced on a large scale; and the transformation to electricity as a source of power.[84] Substantial capital was also at hand from Britain, and putatively to a lesser extent from France and Germany.[85] And an adequate, skilled, foreign labour force of European stock, mostly from Britain, was easily attracted to the Rand, at least in the 1890s, because of the inducement of relatively high wages. Finally, and very important, was the availability of an enormous African migrant labour force that was unskilled and "cheap" at unit cost; the wage was sufficient for the support of only a single man in his rural homestead.[86]

Two preliminary tasks were necessary to production: the reconstruction of the outcrop mines on scientific lines; and the speedy development of the deep-level mines on the first and second rows (the first and second row deeps).[87] At the same time, the mining engineers equipped the surface of the mines so that the mills could begin crushing in tandem with first production. Such preparation was required to implement the economies of scale vital for profitable mining of low-grade ore, the essential problem for the American mining engineers. What constrained their use of technology was the fact that, right from the start, the industry was both capital- and labour-intensive.

Surface procedures, which were more mechanised than those used below ground, worked so well that they became standardised by 1899.[88] The excavated rock came from the mines in skips and was delivered into hoppers at the headgear. It then passed over grizzlies—gratings of parallel iron bars with spaces between them—which separated the fine rock from the coarse. At the same time the rock was wetted to make ore identification easier during the next stage. Having passed through the grizzlies, the fines passed directly into bins, while the coarse rock underwent additional processing before it passed back into the same bins for further handling.

The first process was sorting, a method probably first developed in America, and initially crudely practised underground on the Witwatersrand. In 1892, British mining engineer J. H. Johns introduced, at a cost of £3,000 ($15,000), the first experimental surface sorting plant.[89] The procedure was cost saving, as it eliminated waste rock—an estimated 20 per cent of the total excavated—from the milling process.[90]

Yet it was clearly both capital and labour intensive. Alongside the sorting table—a revolving counter (usually made in Britain) or a conveyor belt (usually made in the U.S.)—stood Africans. Under the supervision of a white workman, they picked out the barren lumps of rock and threw them into holes, where other Africans shovelled them into trucks which trammed the waste to dumps. The African sorters had no difficulty identifying the white-pebbled pay-ore, particularly since it had already been hosed down.[91]

The coarse pay rock was next subjected to preliminary wet crushing effected mostly by ordinary reciprocating crushers of the British Blake type, but sometimes by gyratory ones of the American Gates kind.[92] Having been reduced to fines, the crushed pay-rock dropped into the ore bins with the rest of the fines. It was then trammed (trucked), either manually by Africans or by locomotives, to the battery bins, from where it was automatically fed into the mortar boxes for wet stamping. After this, the pulp was subjected to amalgamation with mercury over copper plates, and the residual slimes and sand were then treated by the cyanide process.

The setup for cyanidation was elabourate, and included large vats, precipitating tanks, and huge powered tailing wheels. J. S. MacArthur was mostly responsible for the development of this equipment. Butters' innovation in 1891 of the bottom-discharge doors for the vats, the first of its kind in South Africa, was a minor foreign borrowing.[93]

A more important innovation in 1893 was the Butters-Mein distributor, a hydraulic cone filter used to get the right proportion of sand and slimes. But many cyanide men considered intermediate filling, the method in which it was used, too expensive. They preferred direct continuous treatment, a process during which Africans continuously agitated the pulp in the vats with paddles, thereby, its advocates claimed, performing a similar function more cost effectively.[94] As with other extraction methods, ore treatment processes combined capital- and

Headgear and Waste Dump, Crown Deep. The timbers in the foreground are for stope support underground. (Courtesy of Museum Africa, Johannesburg.)

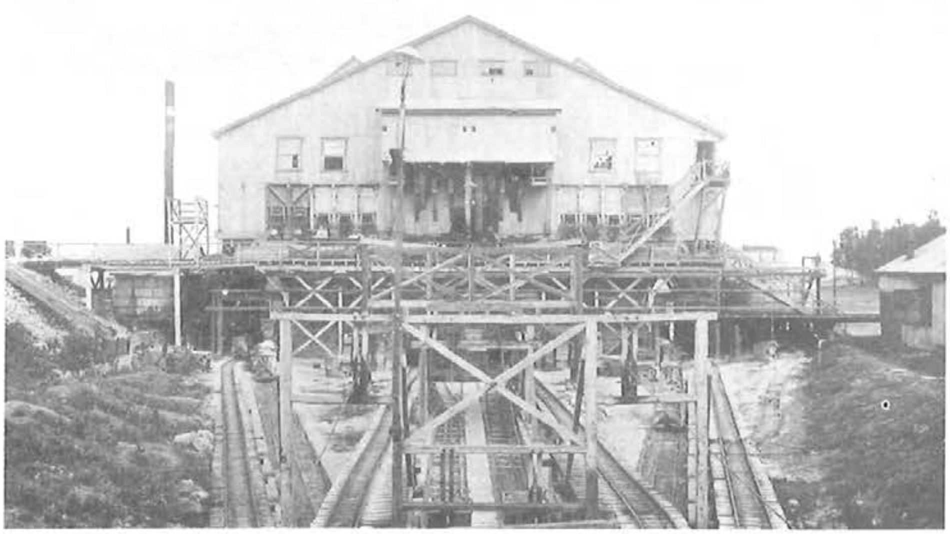
labour-intensive procedures.

Surface working costs were still high in 1899, but management reckoned that they had been virtually pared to the minimum. This minimum was attained after 1904 by the use of the West Australian tube mill, and the accompanying all-slimes method of treatment. Visiting mining engineers were impressed by the "process of milling made almost automatic," but did not believe that this elabourate and costly surface setup showed any minor, let alone major, innovative features.[95]

Ross E. Browne, an American efficiency expert commissioned by the Corner House in 1904, while agreeing that the Rand engineers had enabled low working costs, nevertheless thought the "general" equipment "unnecessarily expensive."[96] By the late 1890s, the number of machines on the surface had an estimated value of £6,355,037 (approximately $31,775,185).[97] Almost a thousand boilers generated steam for as many steam engines for winding and pumping and operating air compressors for driving drills and other labour-saving machines. On a smaller scale, more than two hundred dynamos provided the current for electric lighting, pumping, and hoisting.

No expense was spared in providing stamps. In 1892 most of the stamps, in five- or ten-stamp batteries, had a capacity of 3.21 tons per day. By 1895, before the first of the deeps started producing, the forty-four reconstructed outcrop mines had between them over three thousand stamps—more than in the whole of California—in fifty-to sixty-stamp batteries, with an average stamping capacity of 4.72 tons per day—an average greater than those in California.[98] And by 1899, on the eve of the Anglo-Boer War, the seventy-eight producing mines, which now included twelve first level deeps, crushed approximately twenty-eight thousand tons of ore per day.[99]

This huge volume of tonnage was produced by a disciplined and regimented underground workforce.[100] Eighty per cent of the African workforce was deployed underground in the ratio of one white to twelve blacks, while the surface ratio was one to four. The total underground workforce comprised approximately eighty-three thousand workers, of whom seventy-eight thousand were Africans. Labour costs, which comprised approximately 50 per cent of total working costs, were therefore considerably higher for underground work than for surface work, where fewer men, both black and white, were employed.



Crusher Station, Jumpers Deep. (Courtesy of Museum Africa, Johannesburg.)

Despite the prodigious tonnage produced for the mills, there was nothing unique about the design of the Witwatersrand mines to facilitate this. The American mining engineers resorted to using a geometric layout that was the standard and universal design for metal mines. So, too, were the techniques they used for development and production.[101]

What was unique to the Rand, although precedents existed elsewhere, was its labour practices. Highly-paid, professional white miners, drawn from overseas, were made supervisors over low-paid, unskilled African workers labouring in gangs of twenty to thirty or in smaller groups, depending on the nature of the task. This system resulted in professional miners being dispossessed of their all-around versatility, the criterion for their status as skilled workmen.

What was different about this form of job fragmentation on the Rand was that it did not occur, initially at any rate, through the use of labour-saving machines. Instead, it happened through the deployment of large numbers of African manual labourers, disparagingly referred to as "muscular machines." Job fragmentation through mechanisation occurred several years later, when the use of machine drills became more general. Every attempt by management thereafter to increase the number of rock drills under the aegis of the white supervisors provoked strikes, not least because of the dust hazard and its potential for causing silicosis.[102]

American mining engineers had no difficulty in adapting to these labour arrangements. Many, particularly those who had worked at the El Callao Gold Mine in Venezuela, had experience of similar work patterns, though on a far smaller scale.[103] American mining engineers estimated the unskilled labour requirements for mines as being fifteen Africans per mill stamp. When the supply did not meet this enormous demand, they resorted to labour-saving devices. This was the reason, or so it was claimed, that surface operations were more mechanised than underground workings.[104]

Accomplishments with shaft sinking brought great credit to the American mining engineers, especially with regard to speed. Important as this was for the outcrop mines, it was even more so for the deeps. With a deep-level mine, production could only start after the shafts had been completed. Thus any return on capital might take as much as three to four years.

From 1895, many mining engineers achieved record speeds for shaft sinking, but the teams organised under the experienced John Hays Hammond outdid them all. He tripled the average monthly shaft-sinking speed—some claim from 70 to 250 feet—so setting new standards of efficiency.[105] The importance of speed is not in the records achieved, but what the speed itself accomplished: a rapid beginning of production. Yet many of these olympian speeds, including those of Hammond, were attained by methods using hand labour and not machines.[106]

Important, for the same reason, was speed in driving through barren rock to expose the ore at the face, and the winzing of vertical passages to connect the drives. Not only did the readiness of these openings facilitate the start of production, they also exposed ore reserves for exploitation. Witwatersrand mines, many of which were over-stamped, required speedy development. This facilitated rapid production, which helped to offset the high capital and maintenance costs incurred by the introduction of so much machinery.

Management rightly claimed that the use of rock drills in stoping was more expensive than supervised hand-drilling;[107] The rock drills then available were simply too slow, cumbersome, and unwieldy to be cost effective in the narrow reefs that predominated on the Rand.[108] In times of unskilled labour shortages, rock drills were used. But when the supply of unskilled labour met the demand, hand-drilling again became the norm, as happened when indentured Chinese labourers were employed after the Anglo-Boer War.

The growing importance of rock drills in stoping is shown by the increased numbers in use. Between 1895 and 1899, the number of rock drills doubled from one thousand to two thousand, and this latter figure remained more or less constant until 1906, for it was only then that the industry regained its pre-war production levels. With the repatriation of the Chinese, starting in 1907, and with the mines then having more than eight thousand stamps to feed, the industry, with state support, made even more concerted efforts than before to encourage the invention of a small stoping drill.[109] As a Corner House director confidently told a mining engineer after Stephens made extensive tests of the Holman drill in Cornwall: "24 drills with 150 natives are doing the work of about 500 natives."[110]

Although the favoured British model did not come up to expectations, two important competitions were held and prizes awarded. The Gordon Drill, invented locally by an American engineer in private practice, won the 1908 competition. But it was considered unsatisfactory, as was the case with the winner of the second competition in 1910.[111] Nevertheless, Ingersoll-Rand, the giant US rock-drill manufacturing company which had contributed most of the entries to the 1908 competition, bought the world-wide patent rights to the Gordon, thus extending even further its dominance in these appliances on the South African market.[112]

What was really wanted was a hollow-steel percussive drill of the Leyner type, the more so because it had an automatic water feed to comply with anti-dust regulations. The principle of this drill, with its hammer action, had been affirmed many years earlier, but it had been rejected then because of the poor quality of the steel available.[113] It was this kind of machine, its technology improved, that was established on the mines in 1911, concomitant with the introduction of a large, centralized power station, the Victoria Falls Power Supply Company.[114] In December 1913 there were fifteen thousand machine drills of the Leyner hammer type on the Witwatersrand. In each of the 372,000 daily machine shifts one white miner supervised ten machines operated by Africans.[115]

The cost of the rock drills was offset by the reduced daily wages of white miners, most of whom by now were South-African born.[116] In the absence of anti-dust preventive measures on the mines, their predecessors, the overseas professional miners, had died from silicosis, the result of their exposure to excessive dust produced by rock drills operated under conditions of mass production.[117] Yet even with the extensive use of the light-hammer type drill in 1912, the industry continued to be both labour and capital intensive. Daily the Witwatersrand mines saw even more hammer shifts, 823,000, with one white miner supervising twenty Africans wielding hand-held hammers.[118] This despite the sudden burst of labour-saving rock drills in the stopes of the entire Witwatersrand gold mining industry.

When it acquired John George Leyner's business in 1911, Ingersoll-Rand became the major supplier of jack-hammer rock drills on the Witwatersrand,[119] a dominance purely based on the superiority of its product, not because one of the mining houses or an American mining engineer had established special connections with it. This was unlike many other enterprises, Fraser & Chalmers being a case in point.

As early as 1887, before the arrival of American mining engineers, American manufacturers and suppliers, in competition with the British, began to furnish the infant Witwatersrand mines with plant and equipment. Fraser & Chalmers in Chicago was one of the first to provide stamp batteries,[120] and through Jennings, Eckstein's became one of its biggest customers. Jennings was familiar with the company's equipment and knew he could rely on it.

In 1892, when large-scale equipment of the deeps was anticipated, Wernher-Beit negotiated the establishment in England, at Erith in Kent, of Fraser and Chalmers, Ltd., a subsidiary company in which the mining house had a large interest. Important was the new company's access to the consultants of the London Exploration Company, who had a hand in appointing its first manager, Louis Seymour, formerly mechanical engineer of De Beers and an associate of Hamilton Smith at the El Callao. Through Seymour, Eckstein's and Rand Mines—which controlled between them more than 30 percent of the mines and which accounted for almost 50 percent of the total Witwatersrand gold values produced[121]—bought in bulk and in return paid virtually bottom prices. Above all, the attraction of a firm in England at that particular time was its "first rate quality and workmanship."[122]

While Anglo-Farrar, Barnato's, and J. B. Robinson tended to favour British plant and equipment, other users of machinery became their own merchants, notably the German groups, A. Goerz and Albu's.[123] The machinery purchases of Consolidated Gold Fields straddled Britain and America. American mining engineers probably favoured American goods to start,[124] but to what extent this attitude persisted is impossible to tell. What is clear is that imports classified by customs as British did not mean that they were necessarily British-made.[125]

For British manufacturers of mining equipment, the American experience in South Africa was a good lesson. They learned to what extent they had fallen behind in many classes of machines, the boiler excepted. This was especially so in their inability to create and adapt technology to suit conditions other than their own.[126] In this the American mining engineers had excelled.

In 1928, John Hays Hammond reflected on his experiences on the Witwatersrand:

> I do not wish to detract from the credit of the American engineers who were in South Africa in my time. They were a fine body of engineers but we all obtained more credit than really was due us for the problems were of the simplest kind, and not comparable in complexity to those involved in the development of the great lead, zinc, silver, and copper mines of our own country.

The industry, with the assistance of predominantly American mining engineers, achieved an enormous gold output, notwithstanding the high costs of both capital and labour. In spite of the availability of international investment capital, capital costs were high.[127] Quite apart from heavy expenditure on development, these capital costs included the high risk premium (amortization) demanded for investing on the Witwatersrand, and the inflated cost of machinery because of the distance from its sources and high transport costs.[128]

Labour costs were also high, both in terms of white and African labour. The white workforce comprised expensive imported workmen, and external political pressures militated against skilled wage reductions.[129] The African unskilled workforce, at least eight to ten times larger than its white counterpart, was "cheap," but only in terms of low wages. Additional indirect costs were those of recruitment, housing, and feeding. More importantly, the short periods under which the African migrants were contracted greatly reduced labour productivity.[130] In short, this was expensive labour.

Thus it was the relative capital and labour costs that determined the extent to which American mining engineers were able to mechanize the Witwatersrand gold mines. To mine them profitably was all the more challenging because of the low-grade nature of their ores. The most significant achievement of the American mining engineers was to organize an industry that was the biggest employer of labour in South Africa, the largest contributor to the Gross Domestic Product (GDP), the largest exporter, and the greatest spur to South Africa's economic growth.

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Notes:

1 *Transvaal Chamber of Mines, Annual Report*, 1902, xxiv. (Hereafter *TCMAR*).

2 *TCMAR*, 1902, xxiv.

3 *TCMAR*, 1902, exhibit 1. Coal mines were the holdings of one of the mining houses. The interests of the remainder consisted almost exclusively of gold mines.

4 *TCMAR*, 1902, "Annexure," *passim.*

5 T. A. Rickard, *Interviews with Mining Engineers* (San Francisco: Mining and Scientific Press, 1922), 246. Rickard originally interviewed Hennen Jennings in 1915 (see "Hennen Jennings, and Mining on a Big Scale: An Interview by T. A. Rickard," *Mining and Scientific Press*, 25 Dec. 1915), but I always use the 1922 source.

6 Rickard, *Interviews*, 246-7. James Hennen Jennings was always known as Hennen Jennings.

7 *TCMAR*, 1916, 320-5.

8 Thomas F. Noer, *Britain, Boer and Yankee: The United States and South Africa 1870-1914* (Kent, OH: Kent State University Press, 1978), 31. My researches confirm those of Noer.

9 Rickard, *Interviews*, 244.

10 *Mining and Scientific Press*, 7 Sep. 1895, 150; 5 Oct. 1895, 219; 2 Nov. 1895, 282, 287.

11 *Mining and Scientific Press*, 28 Sep. 1895, 203.

12 *Mining and Scientific Press*, 2 Nov. 1895, 282. At that time one U.S. dollar equalled approximately 4s. 1.9d. Witwatersrand Chamber of Mines (comp.), *The Mining Industry: Evidence and Report of the Industrial Commission of Enquiry* (Johannesburg: Witwatersrand Chamber of Mines, 1897), 216, table. (Hereafter *MIC*.)

13 Elaine Katz, *The White Death: Silicosis on the Witwatersrand Gold Mines, 1886-1910* (Johannesburg: Witwatersrand University Press, 1994), 64-5. *TCMAR*, 1895, 180, "Labour Returns." See also *Mining and Scientific Press*, 4 Nov. 1893, 293.

14 Clark C. Spence, *Mining Engineers and the American West: The Lace-Boot Brigade* (New Haven: Yale University Press, 1970), 22-3. This is the best study concerning the migration of American mining engineers to the Witwatersrand.

15 Spence, *Mining Engineers*, 5-12.

16 ZAR, *Wetten*, 1896, No. 12, section (148); 1898, No. 12, section (146).

17 P. Cazalet, speech in compilation "Fortieth Anniversary," *Journal of the Chemical, Metallurgical and Mining Society of South Africa* 34, no. 9 (Mar. 1934): 132. (Hereafter *JCMMS*.)

18 Rickard, *Interviews*, 244-6; emphasis his. Cf. Enid de Waal ('The Part Played by the Americans on the Witwatersrand during the Period 1886-1889," unpub. MA thesis, University of South Africa, 1971, 206), who claims that British engineers made no contribution.

19 *JCMMS* 9, no. 2 (Aug. 1908): 40-1.

20 See the following works by A. P. Cartwright: *The Corner House: The Early History of Johannesburg*, Cape Town and Johannesburg: Purnell and Sons, Ltd., 1965; *Golden Age: The Story of the Industrialisation of South Africa and the Part Played in it by the Corner House Group of Companies, 1910-1967*, Cape Town: Purnell and Sons, Ltd., 1968; *The Gold Miners*, Cape Town: Purnell and Sons, Ltd., 1962; *Gold Paved the Way: The Story of the Gold Fields Group of Companies*, London: Macmillan, 1967; *Valley of Gold*, Cape Town: Howard Timmins, 1973. Cartwright's books are the best popular ones. But, as his books are public relations exercises, he could not often be sufficiently critical.

21 A notable exception is the following fine study: Robert V. Kubicek, *Economic Imperialism in Theory and Practice: The Case of South African Gold Mining Finances, 1886-1914* (Durham, NC: Duke University Press), 1979.

[22] I was guilty of such an assumption in my earlier studies, which would have been immeasurably enriched by drawing on such connections. These, however, have been crucial to my more recent article "Revisiting the Origins of the Industrial Colour Bar in the Witwatersrand Gold Mining Industry, 1891 to 1899," *Journal of Southern African Studies* 25, no. 1 (Mar. 1999): 71-95.

[23] For a useful bibliography see Richard W. Hull, *American Enterprise in South Africa: Historical Dimensions of Engagement and Disengagement* (New York: New York University Press, 1990), xvii.

[24] Eric Rosenthal, *Stars and Stripes in Africa*, 1938; rev. ed. (Cape Town: National Books, Ltd., 1968). Enid de Waal, "American Technology in South African Gold Mining before 1899," *Optima* 32, no. 2 (1985): 88-96. Enid de Waal, "The Part Played by the Americans," 6-12. Clarence Clendenen, Robert Collins, and Peter Duignan, *Americans in Africa, 1865-1900*, Stanford University, CA: Hoover Institution Studies 17, 1966. Patrick Manning, "A Draft: Notes toward a History of American Technical Assistance in Southern Africa, from 1870-1950," unpub., Californian Institute of Technology, 1963, 4-8. Hull, *American Enterprise*, 62-5. J. Campbell, "The Americanization of South Africa," seminar paper, Institute for Advanced Social Research, University of the Witwatersrand, Johannesburg, 19 Oct. 1998, 4-7.

[25] I have omitted some of the embellishments.

[26] Rosenthal, *Stars and Stripes*, 133.

[27] Clendenen, *Americans in Africa*, 91.

[28] Campbell, "Americanization of South Africa," 6.

[29] *South African Mining Journal*, 18 Nov. 1893, 353. (Hereafter *SAMJ*.) *Notulen der Verrichtingen van den Hoog-Edel Achtbaren Eersten Volksraad der Zuid-Afrikaansche Republiek, gedurende zijne Gewone Jaarlikjksche Zitting*, 1891, 219-20, Art. 652.

[30] Katz, "Revisiting the Origins," 76-7.

[31] Charles Struben, *Vein of Gold*, (Cape Town, 1957), 21. H. W. Struben, *Recollections of Adventures: Pioneering and Development in South Africa 1850-1911* (Cape Town, 1920), 195, 197, 204. Neither of the Struben works are entirely accurate. See also Transvaal Government, Parliamentary Papers, [Unnumbered], *Report of the Gold Law Commission, 1901-1902, with Minority Report, Minutes of Proceedings, Minutes of Evidence, and Annexures, June 1902*, 203-5, annexure IX. (Hereafter TGPP, *Report of the Gold Law*.)

[32] TGPP, *Report of the Gold Law*, ix, par. 17. Manfred Nathan (ed.), *Transvaal Gold and Base Law: Being Act No. 35, 1908, with Amending Statutes Down to and Including Act No. 36, 1934*, (Johannesburg, 1934), 13.

[33] See, for instance, Clendenen, *Americans in Africa*, 96.

[34] Hull, *American Enterprise*, 67. de Waal, "American Technology," 83. Hull makes this claim following de Waal. This is dealt with in more detail later, but for a corrective, see Cartwright, *Gold Paved the Way*, 74.

[35] Jean Van der Poel, *The Jameson Raid* (Oxford: Oxford University Press, 1951), 59-61, 78, 88, 113, 165-7.

[36] J. H. Hammond, *The Autobiography of John Hays Hammond* (2 vols.), (New York, 1937), v. 1, 293-8, 303-4. Hull, *American Enterprise*, 62, 64-5. Campbell, "Americanization of South Africa," 6. Campbell follows Hull and both follow Hammond. Both Cartwright (*Gold Paved the Way*, 74) and Kubicek (*Economic Imperialism*, 103) provide a corrective.

[37] De Waal, "American Technology," 85. Spence, *Mining Engineers*, 315. Hull, *American Enterprise*, 92, 117. Nor did Milner's legislation prevent them from re-establishing themselves on the Rand, as argued. See Campbell, "Americanization of South Africa," 8.

[38] Charles Butters was the exception.

[39] Sidney Jennings succeeded his brother, Hennen; Henry (Harry) Howard Webb succeeded Hammond; George Edward Webber (sometimes wrongly spelled Weber) succeeded C. Perkins; Thomas Haight Leggett had a fairly long stint at the S. Neumann group and was succeeded by Samuel C. Thomson; Pope Yeatman switched firms after the war, and when he left he was succeeded by the Colorado-trained James Stubbs. See *Mining and Metallurgy*, 4 May 1923, 259; Dec. 1928, 560; 16 Nov. 1935, 484-5; Aug. 1939, 398. Anthony Hocking, *Randfontein Estates: The First Hundred Years* (Bethulie, South Africa: Hollard South Africa, 1986), 72. *Mining Engineering*, Mar. 1954, 338.

[40] Rickard, *Interviews*, 246.

[41] Cazalet, "Fortieth Anniversary," 132. For details of the new company, see Maryna Fraser and Alan Jeeves (eds.), *All That Glittered: Selected Correspondence of Lionel Phillips, 1890-1924* (Cape Town: Oxford University Press, 1977), 11-2.

[42] Rickard, *Interviews*, 245-6.

[43] Cazalet, "Fortieth Anniversary," 132. Kubicek, *Economic imperialism*, 79.

[44] Fraser and Jeeves, *All That Glittered*, 202, L. Phillips to F. Eckstein, 8 Mar. 1909.

[45] Bruce Murray, *Wits: The Early Years; A History of the University of the Witwatersrand Johannesburg and its Precursor, 1869-1939* (Johannesburg: Witwatersrand University Press, 1982), 3-5, 12-22. It was renamed the Transvaal University College in 1906. See also G. R. Bozzoli, *Forging Ahead: South Africa's Pioneering Engineers* (Johannesburg: Witwatersrand University Press, 1997), 71, 74-5; and Rickard, *Interviews*, 243, 245. Spence (*Mining Engineers*, 316) has perceptive comments on the institute.

[46] Rickard, *Interviews*, 246.

[47] *Mining and Metallurgy*, Jan 1934, 75. Rickard, *Interviews*, 226.

[48] Harry S. Denny, "Observations on the Metallurgical Practice of the Witwatersrand," *Journal of the Chemical, Metallurgical and Mining Society of South Africa* 4, no. 4 (July 1903-June 1904): 116-72. Harry S. Denny, "Some Economic Problems in Metallurgy on the Witwatersrand," *South African Mines, Commerce and Industries* (newspaper), 4, 11, 18, and 25 June 1904. G. A. and H. S. Denny, "Rand Metallurgical Practice and Recent Innovations," *Proceedings of the South African Association of Engineers, 1905-1906* 9 (9 June 1906): 239-350.

[49] Cf. Carl R. Davis, J. L. Willey, and S. E. T. Ewing ("Recent Developments in the Fine Grinding and Treatment of Witwatersrand Ores," *Mining and Metallurgy*, May 1925: 244), who claimed that the first tube-mill was installed on the Glen Deep, a Corner House company. This version was repeated by Dr. A. H. White. See Cazalet, "Fortieth Anniversary," 302.

[50] Owen Letcher, *The Gold Mines of Southern Africa: The History, Technology and Statistics of the Gold Industry* (London: Owen Letcher, 1936), 155. *Proceedings of the South African Association of Engineers* 7 (4 May 1907): 347, 1 June 1907. (Hereafter *SAAE*.)

[51] *SAAE* 7 (July 1906): 91.

[52] Rickard, *Interviews*, 237-8. James Gray and J. A. McLachlan, "A History of the Introduction of the MacArthur-Forrest Cyanide Process to the Witwatersrand Goldfields," *Journal of the Chemical, Metallurgical and Mining Society of South Africa* 33, no. 1 (July 1932-June 1933): 381.

[53] Kubicek, *Economic Imperialism*, 198-199. S. Herbert Frankel, *Gold and International Equity Investment* (London: Institute of Economic Affairs, 1969), 102.

[54] Unless otherwise stated, see Katz, Elaine N., "Outcrop and Deep Level Mining Before the Anglo-Boer War: Re-examining the Blainey Thesis," *Economic History Review* 48, no. 2 (May 1995): 304-28.

[55] S. J. Truscott, *The Witwatersrand Goldfields' Banket and Mining Practice: With an Appendix on the Banket of the Tarkwa Goldfield, West Africa* (2nd rev. ed., London: Macmillan, 1907), 1. Frederick H. Hatch and J. A. Chalmers, *The Gold Mines of the Rand: Being a Description of the Mining Industry of Witwatersrand South African Republic* (London: Macmillan, 1895), 9-87, *passim*.

[56] Sydney Charles Goldmann, *South African Mines; Their Position, Results, and Developments; Together with an Account of Diamonds, Land, Finance and Kindred Concerns* (3 vols.), v. 1, *Rand Mining Companies* (London: Effingham Wilson and Co., 1895-1896), xiv. Letcher, *Gold Mines*, 109. D. C. Davies, *A Treatise on Metalliferous Minerals and Mining* (6th rev. ed., London: Crosby Lockwood and Son, 1901), 32-90, *passim*.

[57] John Hays Hammond, "Gold-Mining in the Transvaal, South Africa," *Transactions of the American Institute of Mining Engineers* 30 (Feb. 1901): 852-3.

[58] G. A. Denny, *The Deep-level Mines of the Rand and their Future Development Considered from the Commercial Point of View* (London: Crosby Lockwood and Son, 1902), 28-9. Truscott, *Witwatersrand Goldfields*, 3, and diagram facing p. 100.

[59] Arthur Webb, "Witwatersrand Genesis: A Comparative Study of Some Early Gold Mining Companies, 1886-1894," Ph.D. diss., Rhodes University, 1981, 27-9, *passim*.

[60] Rickard, *Interviews*, 244-5. Robert Vicat Turrell and Jean-Jaques Van-Helten, "The Rothschilds, the Exploration Company and Mining Finance," *Business History* 28, no. 2 (Apr. 1986), 181-7. The firm that employed Jennings was not yet named Wernher-Beit, but was called Jules Porges and Company. When Porges retired in 1889, his two partners reorganised the firm, naming it after themselves. See Fraser and Jeeves, *All That Glittered*, 110; and Rickard, *Interviews*, 244.

[61] S. Katzenellenbogen, "Cyanide and Bubbles: Aspects of Technological Change in Gold and Nonferrous Metals Treatment," in K. Tenfelde (ed.), *Towards a Social History of Mining in the 19th and 20th Centuries* (Munich: C. H. Beck, 1992), 522-4. D. Gilmour, "President's Valedictory Address," *Proceedings of the South Africa Association of Engineers*, June 1904: 347-9. Gray and McLachlan, "History of the Introduction," *passim*.

[62] H. H. Webb, "Discovery and History of the Witwatersrand Gold Fields," *Proceedings of the South African Association of Engineers* 8, pt. ii (1902-1903): 28.

[63] That Smith was right was established only in 1895 by the assay returns of the Bezuidenville borehole. See Barlow Rand Archives (hereafter BRA), Hermann Eckstein (hereafter HE), v. 58, Wernher, Beit and Co. to H. Eckstein and Co., 18 Nov. 1892; and v. 171, G. Rouliot to Wernher, Beit and Company, 7 Dec. 1895.

[64] *Times* (London), 17 Jan. 1893.

[65] H. H. Webb, "Discovery and history," 28-30.

[66] HE, v. 56, Wernher, Beit and Co. to H. Eckstein and Co., 27 Nov. 1890, BRA.

[67] Parliamentary Papers, Great Britain (hereafter PPGB), Cd. 1844, 1903, *Commercial Mission to South Africa: Report Received from Mr Henry Birchenough...Upon the Present Position and Future Prospects of British Trade in South Africa*, 149-50.

[68] *South African Mines, Commerce and Industries*, 4 July 1903, 365. (Hereafter *SAMCI*.)

[69] PPGB, Cd. 1844, 1903, 149-50.

[70] Rickard, *Interviews*, 244.

[71] HE, v. 57, Wernher, Beit and Co. to H. Eckstein and Co., 27 Nov. 1891, 268, BRA.

[72] Gilmour, "President's Valedictory Address," *passim.*

[73] *CMAR*, 1902, "Annexure," exhibit 1.

[74] Kubicek, *Economic Imperialism*, 130.

[75] Hammond, *Autobiography*, 208.

[76] Elaine N. Katz, "White Workers' Grievances and the Industrial Colour Bar, 1902-1913," *South African Journal of Economics* 42, no. 2 (1974): 140.

[77] *MIC*, p. 216, table. See also Francis Wilson, *Labour in the South African gold mines, 1911-1969* (Cambridge: Cambridge University Press, 1972), 36.

[78] Alan Jeeves, *Migrant Labour in South Africa's Mining Economy: The Struggle for the Gold Mines' Labour Supply 1890-1920* (Johannesburg: Witwatersrand University Press, 1985), *passim.*

[79] Katz, *White death*, 7.

[80] Gilmour, "President's Valedictory Address," 358-9.

[81] Elaine N. Katz, "The Underground Route to Mining: Afrikaners and the Witwatersrand Gold Mining Industry from 1902 up to the 1907 Miners' Strike," *Journal of African History* 36 (1995): 468.

[82] Elaine N. Katz, *A Trade Union Aristocracy: A History of White Workers in the Transvaal and the General Strike of 1913* (Johannesburg, African Studies Institute, University of the Witwatersrand, 1976), 46.

[83] Hatch and Chalmers, *Gold Mines*, 2, 12, 25, 245-7.

[84] Kubicek, *Economic imperialism*, 51-2.

[85] Kubicek, *Economic imperialism, passim.* The amount of French capital has probably been underestimated.

[86] Norman Levy, *The Foundations of the Cheap Labour System* (London: Routledge and Kegan Paul, 1982), 19-33.

[87] For the layouts of deep-level and outcrop mines, see Katz, "Revisiting the Origins," 312-7.

[88] Unless otherwise stated, this description is based on the following sources: Hatch and Chalmers, *Gold Mines*, 184; H. Denny, "Observations," *passim.*

[89] Webb, "Discovery and History," 30-2.

[90] Hammond, "Gold-Mining," 846.

[91] Ransome, *Engineer in South Africa*, 284-6.

[92] Hammond, "Gold-Mining," 846.

[93] Katzenellenbogen, "Cyanide and Bubbles," 529. Gilmour, "President's Valedictory Address," 348.

[94] M. Eissler, *The Metallurgy of Gold: A Practical Treatise on the Metallurgical Treatment of Gold-Bearing Ores Including the Assaying, Melting and Refining of Gold*, (5th ed., London: Crosby, Lockwood and Son, 1900), 466-70. Rickard, *Interviews*, 238, H. Jennings.

[95] Eissler, *Metallurgy of Gold*, 7, 67-8, 462-5. Stafford Ransome, *The Engineer in South Africa: A Review of the Industrial Situation in South Africa after the War and a Forecast of the Possibilities of the Country* (London: Archibald Constable and Co., Ltd., 1903), 291.

[96] Ross E. Browne, "Working Costs of the Mines of the Witwatersrand," *Proceedings of the South African Association of Engineers* 12 (May 1907): 343.

[97] *SAMJ*, 8 July 1899: 726.

[98] *SAMJ*, 8 July 1899, 726. Katz, "Outcrop and Deep-Level Mining," 317. *Mining and Scientific Press*, 11 May 1895, 293.

[99] *Report of the Council of the AMM*, 1902, 4. Transvaal Government, Parliamentary Papers, TG 2, 1908, *Mining Industry Commission. Minutes of Evidence with Appendices and Index*, 43, Annexure 11, Table A, H. Weldon.

[100] Unless otherwise stated, the following section on underground methods and the underground workforce is based on Katz, *White Death*, 47-53.

[101] See, for instance, Hammond, "Gold-Mining," 845; and Robert Hunt, *British Mining: A Treatise on the History, Discovery, Practical Development and Future Prospect of Metalliferous Mines in the United Kingdom* (London: Crosby Lockwood and Co., 1884), 568-606.

[102] On silicosis, see Katz, *White Death, passim.*

[103] Katz, "Revisiting the Origins," 79-81.

[104] Browne, "Working costs," 343.

[105] Cartwright, *Gold Paved the Way*, 75. See also Truscott, *Witwatersrand Goldfields*, 195-6.

[106] Truscott, *Witwatersrand Goldfields*, 186, 193-4, 196.

[107] Herbert C. Hoover, *Principles of Mining: Valuation, Organization and Administration; Copper, Gold, Lead, Silver, Tin and Zinc* (New York: McGraw-Hill Book Company, 1909), 149-51.

[108] Truscott, *Witwatersrand Goldfields*, 195.

[109] "Minutes of the Monthly Meeting of the Council of the Association of Mine Managers [of the Witwatersrand], 9 Apr. 1908.

[110] HE v. 152, R. Schumacher to H. F. Marriott, 29 Nov. 1907, BRA.

[111] Great Britain, Public Record Office, Transvaal, Correspondence, 1907, 291/115, Selborne to Lord Elgin, 19 Jan. 1907, telegram. *South African Mining Review*, Feb. 1910: 251.

[112] Jeffery L. Rodengen, *The Legend of Ingersoll-Rand* (Ft. Lauderdale, FL: Write Stuff Syndicate, 1995), 48.

[113] Katz, *White Death*, 163-6.

[114] *South African Mining Review*, Feb. 1910: 251.

[115] PPGB, Cd. 7707, 1914, *Dominions Royal Commission. Minutes of Evidence*, Part II, 85, qq. 2304, 2307, R. Schumacher.

[116] Katz, "Underground Route," 667-89, *passim.* See also PPGB, Cd. 7707, 1914, 50, 63, 85, qq. 1556, 2304-2307, E. J. Way, R. Shanks, R. W. Schumacher; John X. Merriman, private papers, South African Library, Cape Town, correspondence, 1915, R. Barry to J. X. Merriman, 20 Nov. 1915; and Transvaal Chamber of Mines Archives, file M23, circular letters, 59/15, 14/16,

23 Dec. 1915, 2 Mar. 1916.

[117] Katz, *White Death*, especially p. 213.

[118] PPGB, Cd. 7707 1914, 85, qq. 2304, 2307, R. Schumacher.

[119] Barbara Stack, *Handbook of Mining and Tunnelling Machinery* (New York: John Wiley and Sons, 1982), 36.

[120] Hatch and Chalmers, *Gold Mines*, 2.

[121] Fraser and Jeeves, *All That Glittered*, 9.

[122] HE v. 57, Wernher, Beit and Co. to H. Eckstein and Co., 5 Dec. 1891, 5 Feb. 1892, 19 May 1892, vol. 59, Wernher, Beit and Co. to J. B. Taylor, 29 Sep. 1893, Wernher, Beit and Co. to L. Phillips, 25 Jan. 1894, BRA.

[123] Kubicek, *Economic Imperialism*, 148. Ransome, *Engineer in South Africa*, 120-4. PPGB, Cd. 1844, 1903, 58.

[124] PPGB, Cd. 1844, 1903, 58.

[125] PPGB, Cd. 1844, 1903, 41-2.

[126] PPGB, Cd. 1844, 1903, 44-6, 51.

[127] Unless otherwise stated, this section is based on the following studies by S. Herbert Frankel: *Capital Investment in Africa: Its Course and Effect* (London: Oxford University Press, 1938), 88-98; and *Gold and International Equity Investment*, 18-9.

[128] PPGB, Cd. 7707, 1914, 154-5, q. 3215, W. J. Laite. PPGB, Cd. 1844, 1903, 39.

[129] Katz, *Trade Union Aristocracy*, *passim*.

[130] Wilson, *Labour*, 40-47, 56-67, 86-100. Jeeves, *Migrant Labour*, 10-13.